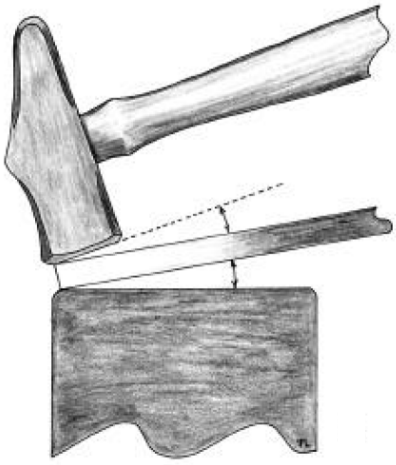
ABANA

Controlled Hand Forging Lessons



Before the introduction of the National Curriculum, ABANA developed a series of articles teaching the fundamentals of hand forging. Published in *Hammer's Blow* magazine between 2000-2010, the Controlled Hand Forging Series is a valuable resource for anyone who wants to learn blacksmithing. It does not have the rigidity of the National Curriculum program which is focused on learning towards certification. Nevertheless, every student, learning for the Curriculum or just for fun, can certainly gain a lot of insight and hone his or her skills by working through these articles.

Get the fire going and have fun!

Warning: Blacksmithing carries an element of risk. It is recommended that you use personal protective gear such as eye and hearing protection and follow all manufacturer safety guidelines for equipment. Your safety is your responsibility.

Controlled Hand Forging Lessons
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Safety, Ergonomics, and Shop Layout

By Dan Nauman and the Educational Programs Committee

Please note: The Educational Programs Committee wishes readers to utilize the *Hammer's Blow* as an open dialogue to share your experiences, ideas and results from these lessons and suggestions. We need your input, positive and otherwise, for the program to progress and excel. We have already received several favorable comments, and wish to thank those people who have contacted us. On another note, we have changed the name of the program from "Forging Fundamentals" to "Controlled Hand Forging," as the latter more accurately defines the nature of these lessons. This change was made in part from observations from the membership.

Before one ventures into hot forging, it is important to consider safety, shop layout, and use of tools. We offer these thoughts as suggestions, and do not claim that all rules pertain to all people, as people come in all shapes, sizes, and with varying opinions. We are offering these ideas from experiences, as well as common sense. They are a place to begin.

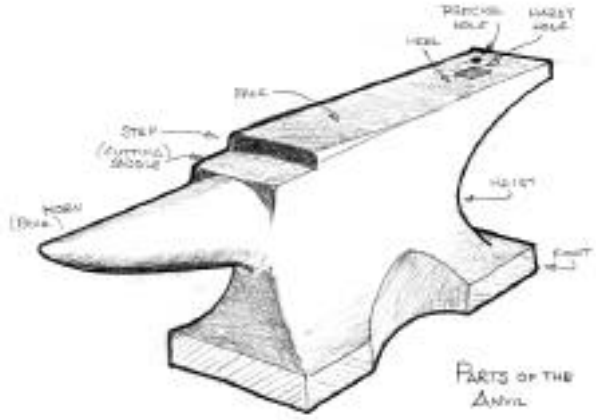
We begin with safety. Protective measures should be taken to prevent burns. Your clothing should not be synthetic, and this includes your shoes. Most synthetics catch fire easily, and often melt right on the skin causing an even worse burn. Preferably, wear heavy-weave cotton or wool clothing, and leather work boots. Do not have cuffs in your pants, as they can catch hot coals. Your pants should cover the top of your boots to prevent coals or molten flux from entering. Some smiths prefer to wear a leather apron to prevent sparks and molten flux from burning their clothes.

Burns will occur. Be knowledgeable as to what first-aid remedies are best for first, second and third degree burns. Have a fire extinguisher, and an OSHA-approved burn kit readily accessible in the work area.

Eye protection is highly recommended. Choose impact resistant lenses with side shields. Many smiths prefer a tinted lens to cut down on glare from the fire. Some safety eye shields cut the ultraviolet rays that are particularly intense from gas and propane forges. Use shields when doing both hot and cold work. You are blessed with only two eyes. Protect both of them.

Ear protection will cut the noise of the anvil's ring to tolerable levels. If you own a power hammer, or any motorized power tool, ear protection will help avoid hearing loss when using these tools as well. Ear plugs and ear muffs are both acceptable.

Preventative measures can also be taken to avoid wear and tear on the body. If you want to be forging well into your later years, work smart. Think about forging as athletic activity. It is wise to stretch and warm up before work, keep loose during work, and cool down after a long forging session. Working smart includes how your shop is set up. *Editor's note: See "Preventing Wrist Injuries,"* The Hammer's Blow, *Vol 9 #2, Spring 2001 for some good wrist stretches and warm-up exercises.*



The parts of the anvil

We will begin the lessons with the five basic tools: the anvil, forge, vise, hammer, and slack tub. Some words of caution to the beginner when collecting tools for your shop: The number of tools for forging can be overwhelming. Do not be overzealous when acquiring or making your tools. Make sure you understand the function and facets of any tool beforehand. Acquire the tools as you need them rather than purchasing and making tools at random. Also, understanding what makes a tool efficient and effective is important before acquisition. Good tools used for the right application make the job easier, and will be reflected in the end product. This may sound obvious; however, far too many individuals use inferior or simply the wrong tool for the job. This is not only unwise, but can be dangerous.

We will be discussing the English pattern anvil in this section. If possible, before you acquire an anvil, it would be wise to learn how to inspect an anvil from an experienced smith. You should be particular about its condition as it is one of your main tools. Consider the following aspects when acquiring an anvil.

The size and weight of an anvil is largely a personal choice. Ideally, the anvil face (main working surface) should be flat, with few nicks, dents and chips. Put a straight edge over the entire length of the anvil to check for a "belly" (depression) in both axes of the face. Forging a bar on a face with a belly will cause the bar to bend radically. Any nicks, cracks, chips, or other imperfections on the working surfaces will be mirrored in the metal worked on those surfaces. The edges of the face should be uniform, and again, with few dents, nicks or chips. The edges of the face should have a radius of about 3/8" from the horn end and decrease to approximately a 1/64" radius at the opposing end, on both sides of the face. Although it is ideal to own an anvil as explained here, an anvil which has obvious wear can still be used and work well in many instances.

The horn (also known as a bick) should be free of dents, nicks,

and chips. The horn, unlike the face, is of a soft material. Check the entire anvil for hairline cracks. Usually, a good anvil will have a resilient "ring" when hit by a hammer. The hammer should seem to leap off the anvil when bounced on the face. The anvil face should have a round hole (pritchel hole) and a square hole (hardy hole) and both should be free of chips, dents and other obvious wear.

The "table" of the anvil (the surface between the horn and the face) should not have any blemishes. The use of this surface is widely debated. It is to some smiths a cutting surface. This is not a good use for this or any surface of the anvil, as once it is blemished by cuts from the cutting tools, it is worthless, as it will mirror these blemishes in the work piece. If you wish to cut a bar on the anvil, use a small piece of copper, brass, or even mild steel to protect the face of the anvil. The table is most often slightly crowned (convex). For this reason, many smiths believe it was intended as a surface to straighten bars.

Many smiths will tell you that the correct height for your anvil is knuckle high when standing erect. An anvil that is too low can tire you out and may cause back problems. Many smiths work at an anvil which is about at thumb knuckle height, or about two inches above knuckle height. The point is to work at a height that is comfortable after hours of work, but still allows a full stroke of the hammer. Some advanced smiths have several anvils at differing heights for more specific work.

The anvil should be placed on a solid and secure base. Some anvil bases are buried as much as three feet into the ground. If the anvil base is not buried or anchored to the floor, make sure the anvil does not rock, slide or pitch. The horn is most often faced to the left, but that is more personal preference. Some right-handed smiths prefer the horn on the right, keeping the hardy to their left.

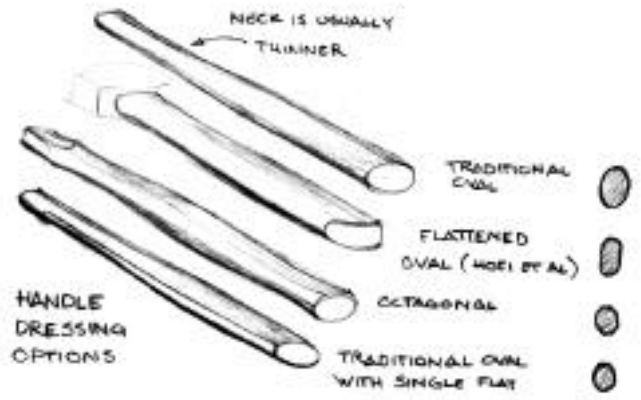
One word about the hardy, which is a tool used for cutting and fits in the square hole on the anvil face. When you are finished using the hardy, remove it at once. A smith can cut or sever fingers from accidentally bringing the hammer hand down upon the hardy while performing another forging operation on the anvil.

We will be discussing the cross peen hammer for these lessons, which has a peen perpendicular to the hammer handle. The act of forging can lead to many ailments, but an overly heavy hammer will do more damage sooner. Force = mass x velocity. A light hammer with a long handle can provide all the needed force one needs to forge. The added bonus is continued accuracy. A hammer that is too heavy can tire one out rapidly, thus making blows erratic. Ultimately, the weight is a matter of preference. A hammer which can comfortably be used all day is best for you. Likely, this will be 1.8 pounds to 2.25 pounds. Advanced smiths have a range of hammers with various weights for various work. Not all work requires the same weight hammer. Ailments from too heavy a hammer include carpal tunnel syndrome, tendonitus in the wrist, elbow and shoulder, damaged cartilage, and torn ligaments.

Gripping the hammer properly is also important. Although there are several ways to grip a hammer, it is widely accepted that placing one's thumb on top, or in line with the hammer handle, can lead to injury of the thumb and wrist joints. Wrapping the thumb around the handle is considered to be a better method of holding the hammer. Some smiths prefer to hold the thumb at a slight angle (about 10:00 to 11:00), with a somewhat relaxed grip. This is still better than straight up at 12:00. The proper grip can help avoid the above-mentioned ailments.

Some smiths prefer a short handle on their hammer. While we do not condemn this practice, we must note that to achieve a heavier blow, either a heavier hammer head or heavier blows must be used with this shorter handle. Plus, when working larger bars, the hand is more susceptible to the intense heat radiating from the bar. A longer handle when held at the end will provide more velocity, thus more impact. One rule of thumb suggests that a proper handle length for you is to outstretch your hand with the elbow at 90 degrees. Balance the hammer head at the end of your fingers. The handle length should equal the distance from the bottom of the hammer head to the inside of your elbow.

The handle can be customized to fit your hand by rasping. Many smiths like a handle pared down so that when gripped, their two middle fingers just touch the fat part of their thumb. Some smiths trim down the first 3"-4" beneath the hammer head to provide some flex to the handle, which absorbs some shock from the impact.



Different handle shapes and dressing options

The shape of the cross peen hammer head is most often square or octagonal and has a flat face with all edges radiused. The peen should be flat at least 3/8" to 1/2" wide with its edges radiused. A sharp peen does not spread metal as well, and produces deep impressions which can be difficult to remove. New hammers almost always have sharp cross peens and sharp edges around the face, and consequently require dressing (reshaping). *See Dressing a Hammer,* The Hammer's Blow, *Vol 8#3, Summer 2000 for more information about hammer dressing- Editor*

The forge used by many advanced smiths is a coal forge, with a

fire pot at least three to four inches deep. A deep firepot produces a better fire for most applications. The fire pot should have a device to break the clinker (the hard mass that collects at the bottom of the coal fire) as well as an ash dump. That being said, fine work can come from forges that many advanced smiths find inferior. The forge, after all, is simply the way the metal gets hot as efficiently as possible. It does not shape the material. Thus, do not be stymied if your forge does not meet the above specifics. You will come to understand why certain tools are better for specific work. As often is the case when starting out, the best tools may not be readily available. As you grow as a smith, you will make or purchase the best tools for your applications.

The height of the forge should be what is comfortable for you. Adjust the height of the forge to avoid stooping. Simply modifying the legs of the forge will create the perfect forge height for you.

The air blast provided to the forge may be a double-lung bellows (single-lung bellows can suck hot coals inside and cause a fire), a hand crank blower or an electric blower. All devices should be made for the job of blowing air into the firepot. The blast may be regulated by an adjustable air gate or by a rheostat for electric blowers. Whatever the device, the blast should be controllable while tending the fire.

There should be enough space on the forge hearth to conveniently hold a few tools for the task at hand. Do not clutter the forge hearth with tools. Another surface to hold additional tools should be near the anvil.

The forge should be outfitted with a chimney to properly vent smoke, fumes and ash. Improper ventilation of carbon monoxide, smoke, ash and soot can cause chronic health problems, even death. Exhaust must be removed from the room completely.

Fluxes of any kind can be a health hazard when used incorrectly. Many fluxes contain materials like borax, and silica, which when inhaled repeatedly can cause chronic health problems. Use fluxes in well-ventilated areas. To prevent inhaling the flux, wear a suitable protective breathing mask. The fumes of flux can also be noxious, so make sure your ventilation system is functioning properly. A breathing mask by itself may not be enough to eliminate harmful fumes.

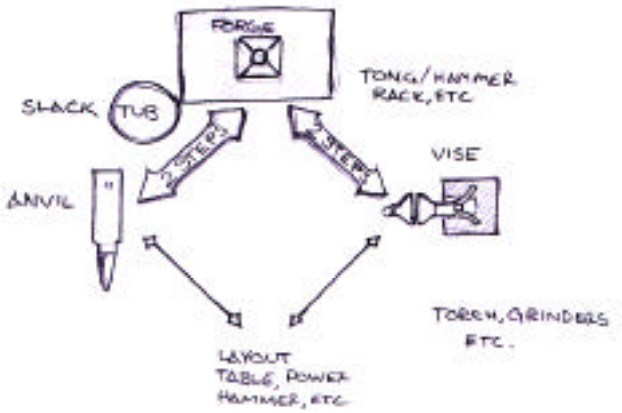
The vise should be a leg vise, otherwise known as a post vise. These vises are made to withstand the impact of the smith's blows. Machinist's vises are often cast iron, and will crack or even shatter upon impact. The vise should be mounted on a solid, well-anchored post of wood or steel. The height of the vise is often the same height as a workbench (about 35" to 38"), but a second vise at a higher height is better suited for filing. Another rule of thumb used by some for bench work is placing the jaw at elbow height. Recommended vise jaw width is five inches and larger.

Leg vises were made for many various trades in many sizes. Vises with jaws under 5" in width were not made for forging. These smaller vises can be damaged from heavy pounding or overtightening. These smaller leg vises may be used for filing, repoussé, and other light work.

The position of the anvil to the forge is generally at a 90 to 180 degree angle from the forge, and about 1 to 2 steps away from the forge. The vise can be at 90 to 180 degrees from the forge, and also 1 to 2 steps away from the forge. The slack tub should be in close proximity to the station, and convenient to quenching hot bars of iron. It should be large enough to quench a bar for safe handling. It should be of non-flammable material (wet wood included). Old whiskey barrels or 30 to 55 gallon drums work well. Clean water quenches better than dirty water.

A glove can be helpful when performing close work, such as chiseling or chasing, on hot bars. However, a glove can be a hindrance when manipulating tongs or the hammer. A glove can be a false sense of security as well. A more severe burn can occur from a burning glove, or from picking up a hot bar with a wet glove.

Stand almost erect when forging at the anvil. If your hat falls off you're stooping too far over the anvil. This might mean that your anvil is too low. Stooping will also lead to a bad back. It also puts your head in the way of a rebounding hammer from the anvil after a missed blow. Keep a comfortable close distance from the anvil. Swing your hammer down, not out. A full hammer swing begins at or above the head and involves the hand, elbow and shoulder uncoiling as a whip. Heavy forging may involve the waist, hips, knees and ankles. Lighter blows start out lower, and require less of the anatomy. Avoid unnatural stances, grips, and approaches. If it feels uncomfortable, rethink what it is you are doing. Most of all, relax.



A possible shop layout

Other tools can be stored outside of the work area, but have them in close proximity so you are not continuously walking across the shop to retrieve them. A cluttered shop is a dangerous shop. Keep unused tools in their place. Place hot bars in a protected place to cool; under or on top of the forge hearth, but not in the open work space. Bar cut-offs should be picked up, especially round bars which can cause an easy fall to the floor. The

anvil is not a table, and should only hold tools used for the work at hand.

Light levels in the shop should be bright enough to perform all facets of the trade whether it be hot forging or cold work. Eye strain from too much or not enough light can cause drowsiness and headaches. It can be unsafe to have a poorly lit shop. Bear in mind that too much light can inhibit one from seeing the color of the metal, which is the smith's way of judging the metal's temperature. Having a vise or workbench at a window can make use of natural light. Brighter light can be switched on at the workbench for close work such as filing, chasing or repoussé.

Although we may not cover the use of gas or propane forges and acetylene torches in the immediate text, they deserve mention in shop safety. These devices can be the most dangerous pieces of equipment in the shop. All fittings should be tested for gas leaks with soapy water. Check valves should be on torch fittings to prevent back-flashes. All gauges should be in proper working order. Check hoses and joints for leaks often, and replace worn hoses. When closing your shop for the night, get in the habit of checking to make sure these devices are shut down whether you used them or not. Similarly, spread the coal fire and make sure it is out before leaving the shop for the night.

Heeding these suggestions can make your forging efficient, less dangerous, and more enjoyable. In the long run, they may provide you with less wear and tear on your body. It is our intent to continually provide you with more suggestions as the lessons progress. With this information, you are ready for lesson #1, which will appear in the next issue.

Lesson One: Drawing Out

By Peter Ross and Doug Wilson

Illustrations by Tom Latané

Lesson Number One–

Draw a sharp point on a 1/2" square bar..

The taper should be straight, three inches long and in line with the axis of the parent bar. The cross section of the taper should be square. The surfaces of the bar should be smooth with no discernable hammer marks.The beginning of the taper should be a crisp line.

Intent:

Students will learn to draw out tapers of specified length and check their results for accuracy.

Tools Needed:

Forge, anvil, hammer, ruler, square.

Materials:

24" of 1/2" square mild steel bar (this is enough material to practice the exercise several times).

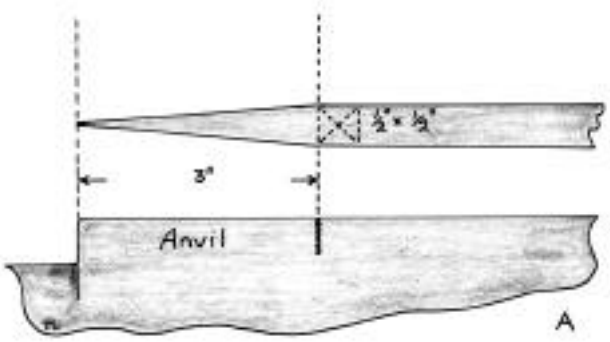
Method:

When working to a specified length, establish the point first, then extend the taper to the desired length.

Step One:

Mark the anvil with soapstone or marker three inches from the anvil step. This is the finished length of the taper you will forge.

Take a yellow-white heat on the end of the bar. Place the bar on

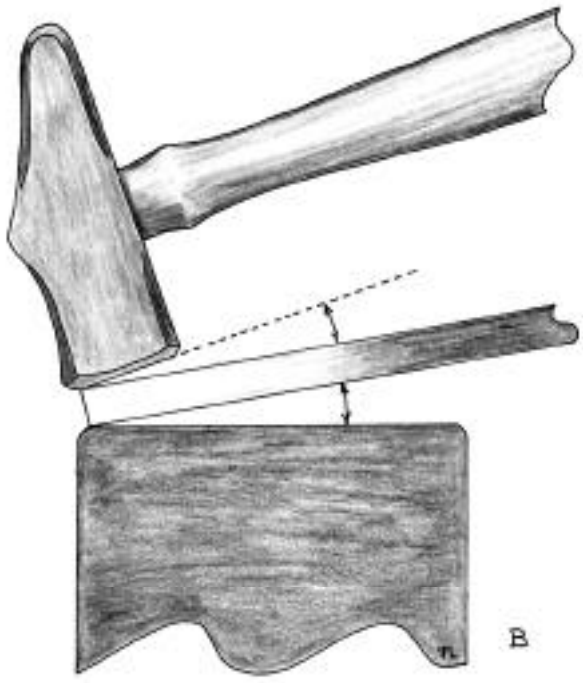


The measured piece held over the anvil.

the anvil so that the end of the bar is at the far edge of the anvil and only the end of the bar is touching the anvil face. This way, the hammer won't strike the anvil surface if it overhangs the hot bar. Strike a blow on the end of the bar with your hammer. The hammer should strike at an angle. There will be a wedge-shaped daylight space between the hammer face and the anvil face which corresponds to the angle of the taper you want to forge.

As you work, adjust the height of the bar as you hold it on the anvil and the angle of your hammer blows. If you hold the bar too high it will bend down in the middle; too low and the bar tip bends down. The bar will remain straight if you are gauging the angles just right.

Rotate the bar 90 degrees after every one or two blows to keep the bar from getting too wide as the forging progresses. Hit, turn



Placement of steel and position of the hammer blow.

90 degrees, hit and turn 90 degrees back again. You need only turn the bar back and forth as the underside of the bar is worked against the anvil. Continue this sequence of forging until you have made a sharp point.

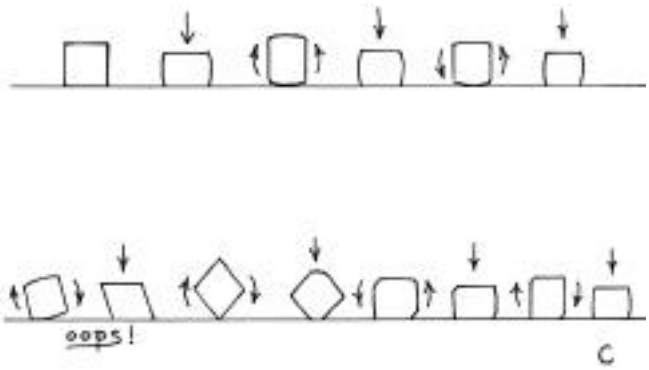
Hint:

It is very important to rotate the bar exactly 90 degrees each time. Use the original flats of the bar as a reference. If the turn is either more or less, the bar will become a parallelogram in cross section and that makes it difficult to attain the desired result.

If the bar does become a parallelogram, hit the corner of the long diagonal; then return to forging the flats of the bar. The sooner you catch and correct this error, the better. Keep a square cross section

Step Two:

Once the point is established, start working back from the point

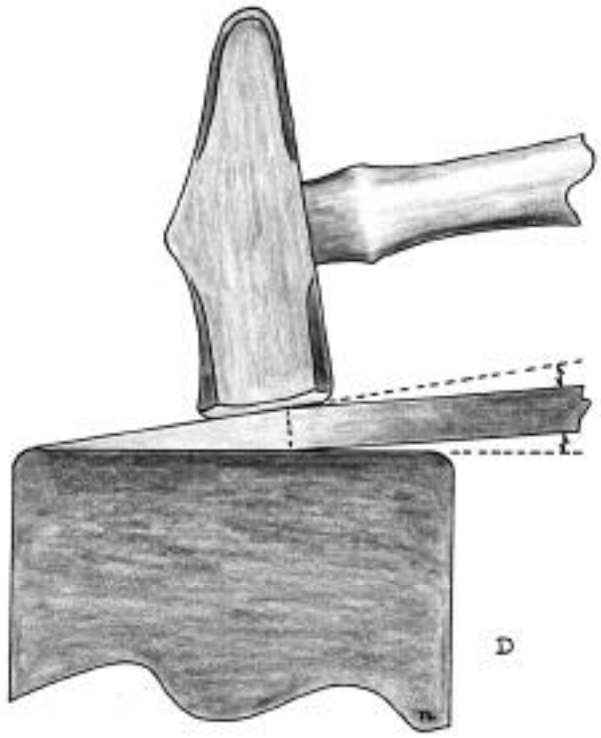


Rotation and deformation of the bar by the hammer, and correcting a parralellogram.

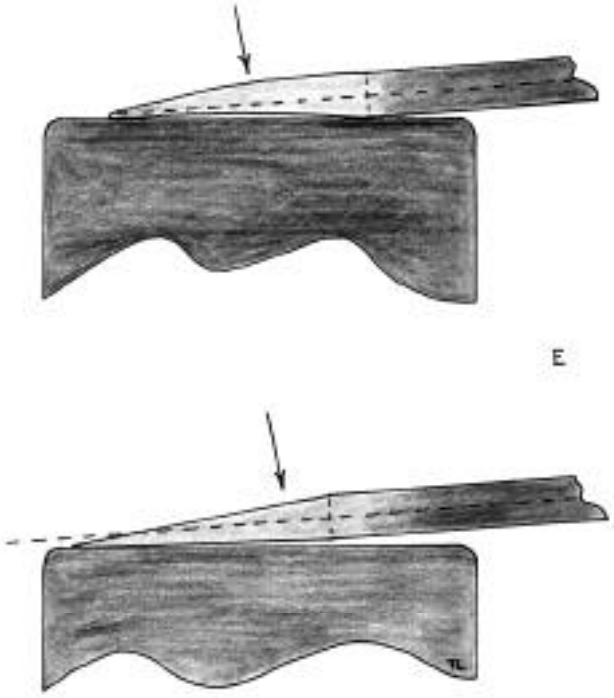
until the taper is 1/4 " short of the desired length . Work with heavy hammer blows at a bright heat while you are reducing the cross section. Lighter hammer blows at lower heats will help you refine the shape of your taper and smooth the surface. Establish a clear and well-defined beginning of your taper.

Step Three:

Now focus on smoothing the surfaces and straightening the taper at the same time. Make the taper straight and true. Refine the shape of the taper with light overlapping hammer blows. Do this as the bar cools to dark orange and red color. The bar scales less at this lower heat and you will get a smoother surface. Sight down the length of the bar for straightness. Straighten with light blows at low heat. Another way to tell if the taper is straight is to



Angle of the bar and hammer when dressing the final taper.



Straightening a bent point (above) and centering an off-center point (below).

stand the bar up with the point on the anvil face and spin it in . If it is straight there will be no wobble.

The four flat sides of the taper should be in line with the original flat sides of the bar and the taper should align with the original centerline of the bar. Any deviation should be corrected with your hammer at the anvil.

Targets:

Try to draw out and finish the taper in two heats. Beginners may take several extra heats.

Maintain a square cross-section in the taper. Check this with a square.

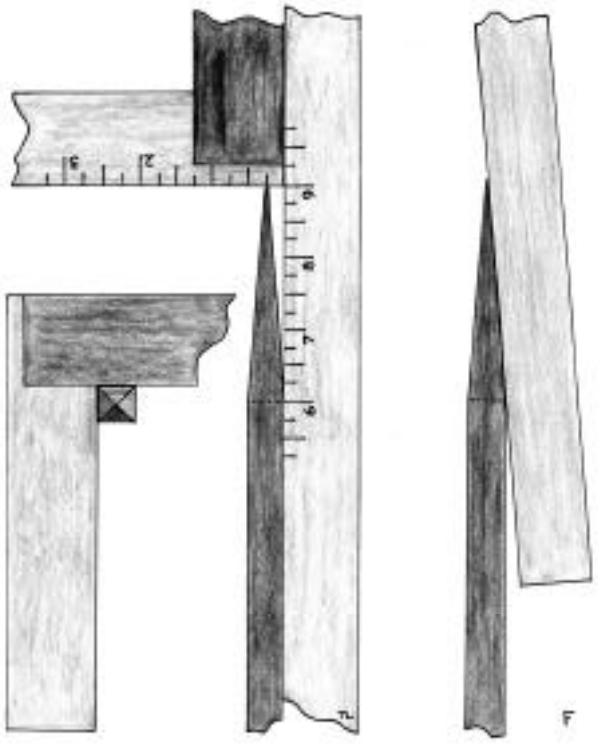
Hammer-finish with smooth surfaces and without discernable hammer marks.

Maintain a perfectly straight axis in the bar and in the 3" long taper. Check this with a rule and also practice sighting down the length of the bar until you can attain the same results by eye.

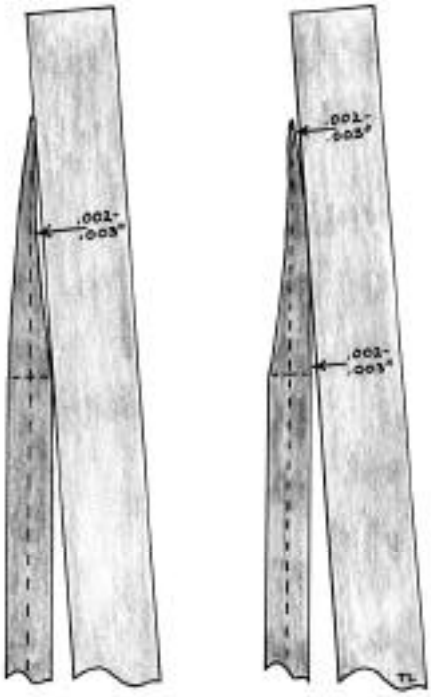
Measure your results using a square and a rule. The four flats of your taper should be straight within two or three thousandths of an inch, length within 1/16" and square in cross section. With practice you should be able to forge to this accuracy by eye. Repeating this exercise with care and attention will enable you to achieve these results quickly and consistently.

Forging Dynamics :

In this exercise, when the square bar is struck, it gets thinner top



Methods of measuring the dimensions.



Exaggerated deviations show how to measure goal tolerance.

to bottom but wider side to side. When you turn the bar 90 degrees and hit again, (you are restricting the spread of the bar, but allowing lengthwise stretch. Repeating this hit, turn, hit, turn sequence results in creating a taper. You are redistributing the mass of the bar with your hammer. As the bar become thinner it becomes longer. Notice that the thinner steel heats faster. It also chills faster. This is because there is less mass. Also note how much the bar you tapered has stretched in length.

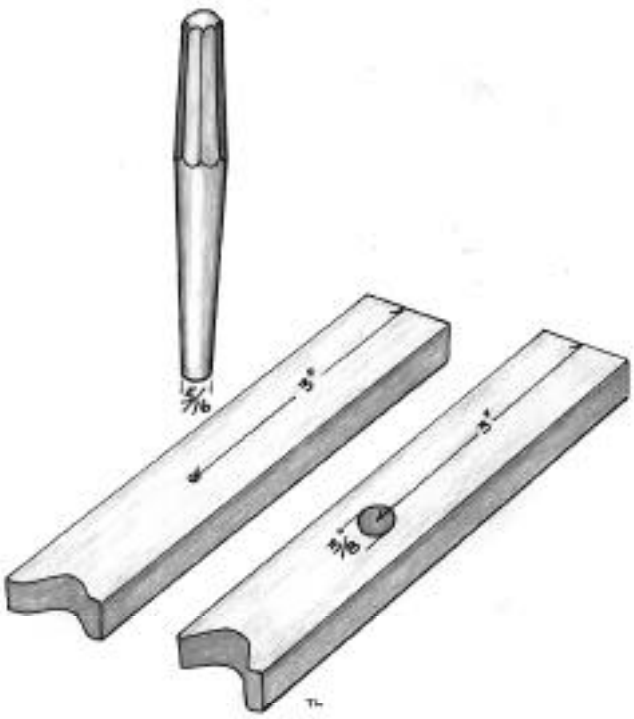
Lesson Two: Hot Punching

By Doug Wilson

Illustrations by Tom Latané

Lesson Number Two–

Create holes or recesses in bars or plate by driving punches into or through hot material.



Punching- layout and specifications

(Holes or impressions can be made any shape you can make a punch.)

Punch a 3/8" round hole through the center of a 3/8" x 1" bar with the hole's center 3" from the end of the bar. Drift (stretch) the hole to finished size.

The finished hole should be 3/8" round, with clean sharp edges.

The hole should pass through the bar at 90 degrees.

The wide surfaces of the bar should be flat with no discernible hammer marks.

The bar should remain 3/8" thick.

The bar will bulge out slightly on either side of the hole.

The original edges of the bar should be straight in line on each side of the hole and without any twisting.

Intent:

Students will learn to hot punch clean accurate holes and to check their results for accuracy.

Tools Needed:

Forge, anvil, hammer, round punch, center punch, square and ruler.

Materials:

24" of 3/8" x 1" hot rolled mild steel.

24" of 3/8" hot rolled round bar(to check final size of punched hole).

Method:

When working to a specific hole size, start with a punch slightly smaller than the finished hole size. After the hole is made it can be enlarged to final size by drifting (stretching) with the punch.

The Punch

The punch may be made of plain carbon tool steel at least 5/8" in cross section, forged to shape and normalized (air cooled until room temperature from a red heat). W1 or O1 drill rod, available at industrial supply shops, would be a good steel for this punch.

The business end of the punch should be a tapered round cross section 2 1/2" long, 9/32" to 5/16" round at its end and filed or ground flat with sharp edges after normalizing.

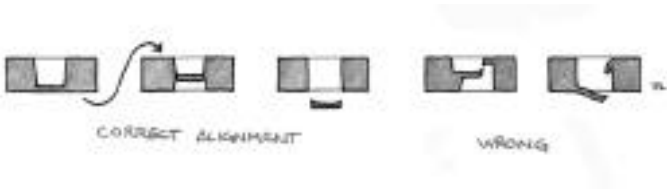
The top end should be tapered slightly to reduce mushrooming in use.

A hand held punch should be 10" to 11" long. A punch held in tongs should be 3 1/2" to 4" long.

Step One:

Make a center punch mark in the center of the bar 3" from its end. Take a bright yellow heat where the bar is center punched. Place the bar flat across the face of the anvil, center punch mark up. Carefully place the punch over the center punch mark. Strike a single solid blow to sink the punch into the hot bar. Make sure the end of the punch is still where it is supposed to be. Continue striking solid blows until the punch is nearly through; another

Some different styles of punches



Correct and incorrect alignment of the punch

two or three blows. The punch will feel solid against the face of the anvil. If you have done this quickly the bar will still be at a bright orange heat.

Hints:

Wear a glove on the hand that is holding the punch.

Quench your punch after every four or five blows. This will help to prevent the punch from deforming.

A few soapstone X-marks on the center punched side of the bar will help you get the punched side of the bar facing up when you first put it on the anvil.

Scraping the surface of the bar with your hammer will help you locate the punch mark. (Scale will fall into the punch mark leaving a small black spot.)

Learn to hit the punch directly and hard on the first blow. Avoid aiming blows.

The cold end of the bar can be supported on your thigh or on an adjustable stand set anvil high.

Step Two:

Immediately turn the bar over on the anvil. Look for slight bulges on either side of the hole and a dark spot where the punch was driven into the first side of the bar. Position the end of the punch exactly over the dark spot. Strike several heavy blows. You will feel the punch solid against the anvil face again. Move the bar, with the punch in the hole, over the pritchell hole (the round hole in the heel of the anvil). Strike one or two more blows over the pritchell hole and a small slug will be driven out of the hole. Now, straighten and flatten the bar with light hammer blows on the anvil face. (The bar should still show color during this part of the process.)

At this point you will have a hole. It should be a bit smaller than the desired size.

Notes:

If the punch doesn't clear the slug from the hole it is likely because the punch was misaligned when the bar was turned over or because the punch didn't have sharp edges on the business end.

The slug should be driven out from the second side of the bar. Avoid the temptation to turn the bar back over to the first side and try to drive the slug out.

Illustration of misaligned punch with slug hanging from one side of the hole.

Step Three:

Now you need to drift (stretch) the hole to the desired size. Heat the bar to an orange heat again if necessary. Place the hole over the pritchell hole , insert the punch and drive it in a bit further. Remove the punch, turn the bar over and drive the punch from the second side. Continue this sequence until the hole is just large enough for the 3/8" round bar to fit through easily. The drifted hole should be just a bit larger than the 3/8" round bar so that when it is cool the 3/8" round will still fit through the hole.

Hints:

When drifting, work a bit from one side of the bar and then from the other. This will make the hole more uniform in size. If you only drift from one side the hole would be wider on the top than on the bottom.

Finally, straighten and flatten the bar with light blows and a low heat.

Targets:

Try to punch and drift the hole and straighten the bar in one heat.

(Beginners may need a second heat to accomplish this.)

Check you results using the 3/8" round bar, a square and a straight-edged rule. The 3/8" round bar should just fit through the hole you punched. The hole should pass through the bar at 90 degrees. The bar should be flat and uniform in thickness. The bar should be straight and without twist. The surfaces of the bar should be smooth with no discernable hammer marks.

Forging Dynamics:

The flat bottom of the punch pushes the steel beneath it outward as it is driven into the hot bar. The sides of the bar bulge outward slightly.

When the bar is turned over and punched from the second side the sharp edges of the punch end shear out a small slug.

Driving the punch further into the hot bar stretches the hole larger, increasing the bulges on either side of the bar.

Steel expands when it is hot and shrinks as it cools. When hot, the drifted hole should be just a bit larger than the 3/8" round bar so that when it is cool the 3/8" round will still fit through the hole.

Drawing a Round Taper

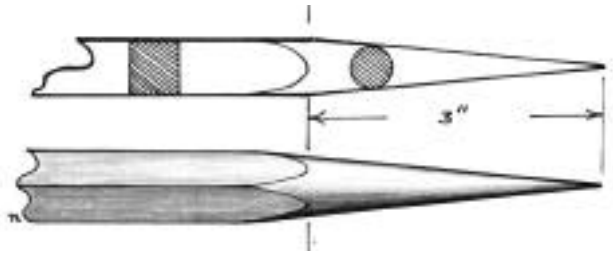
By Jay Close
Illustrations by Tom Latané

Lesson Number Three– Drawing a Round Taper

Definition: “Drawing”, “drawing out” or “drawing down” means to reduce the cross sectional area of a bar.

[Pictures of three or four examples should be inserted here.]

Drawing a round straight taper to a point 3 inches long on the end of a square sectioned bar.



1. The final forged shape.

Intent:

The student will learn to forge a round taper of a specified length on the end of a square bar and to control for the material stretch that results from converting square to round sections.

Tools Needed:

Basic tools only, these to include a rule, straightedge, dividers and outside calipers.

Materials:

24 inches of 1/2 inch square mild steel.

Method:

When forging a round sectioned taper, first create an accurate square sectioned taper. The square taper is hammered to an accurate octagonal taper and sometimes to a 16 sided or 32 sided taper before final rounding.

As the square taper is forged progressively toward round, the length of the taper will grow about 20%.

Knowing this, the square taper you begin with should be 5/6 the desired length of the round taper you need.

Step One:

Review the previous lesson on drawing a straight square sectioned taper on the end of a square bar.

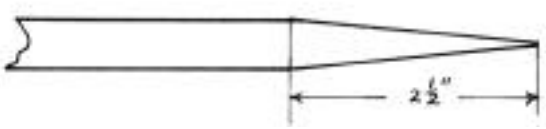
Starting at a yellow or light welding heat , forge a square taper on the end of the 1/2 inch square bar. This taper should be 2 and 1/2 inches long and hammered to a sharp point.

Review also the Targets section of the previous lesson on drawing out a straight taper.

Make sure the sides of your taper are straight and the point on center. It is hard to make a round taper significantly better than the straight taper you start with.

Step Two:

Place a chalk or soap stone mark 3 inches in from the front edge of the anvil. This will be a reference for drawing your taper to finished length. Alternatively, set the points of dividers 3 inches



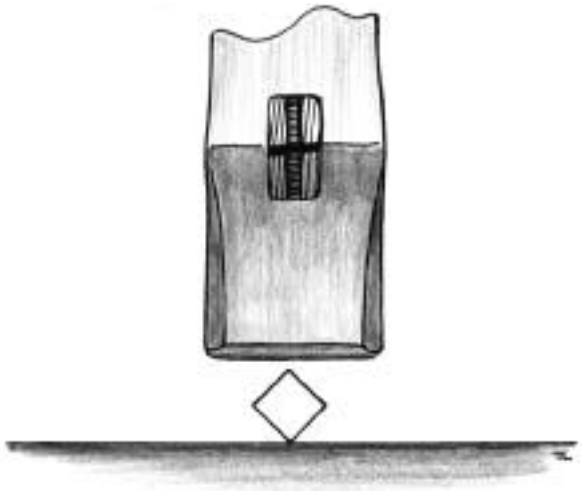
2. Needed straight taper and dimensions.

apart and keep them handy for comparison to your work.

Note in the technical sketch shown above the “fingernail” transition between the square and round, and where on the bar we measure to judge the needed length.

Carefully reheat the bar with the point pushed through to the far side of the fire so that it does not burn before heavier sections of the bar are at a working temperature.

At a yellow or light welding heat, bring the bar to the anvil and place it “corner up.”



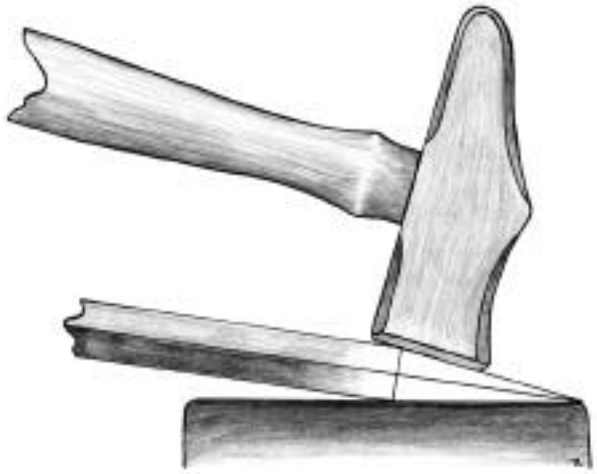
3. Corner up position.

Raise the hand holding the workpiece until you can feel good contact along the downside corner of the square taper.

Starting where the bar is thickest, match your hammer blows to the slope of the upper corner and forge a neat flat or facet all the way down the corner.

As the taper narrows, so too must the facet. Lighten your hammer blows progressively as you approach the point. You want to create a clean facet. This facet will end up with an elongated, asymmetrical diamond shape.

The diamond will be widest at the base of the original square taper. It will taper gradually toward the point. Above the base of the square taper, the diamond will come to a quicker point centered on the corner of the bar. This is where the hammer overlaps on the corner into the parent bar — the diagonal dimension of the bar is greater than the diameter of the needed round taper.



4. Forge a neat flat all the way down to the point.

Roll the bar 90 degrees left or right (remember which) and work another flat on the next corner.

Roll the bar 90 degrees in the same direction and now the bottom flat of the first forged facet will come on top.

The anvil has already begun the facet for you. It is not as broad as the hammered facet, but the smooth anvil face has probably made a neater flat than you could hammer.

Forge this facet to match the one originally hammered. Roll the bar another 90 degrees in the same rotation and refine the other facet started by the anvil face.

At this point you should have four long diamond shaped facets centered on the corners down the length of the taper. On the original flats of the square taper you will see long triangular facets. Your goal is to create an equal sided octagonal section down the entire point length.

5. The forging should look like this.

Step Three:

At another light orange to yellow heat, work down each of the corners of the taper to create a 16 sided taper. This is especially important where the taper is heaviest and the most material needs to be reshaped.

Step Four:

This can often be done at the end of the heat of Step Three. Keeping the taper evenly on the anvil surface, slowly roll the bar beneath the hammer to create an an even texture of hammer marks approximating a smooth, round, even taper.

Trouble Shooting and Corrections

Shape And Dimension Problems:

Check that the sides of the taper are straight and that the point is centered. Review the lesson on making a straight taper with a square section for hints on correcting these problems. If you have

6. The goal is to create an even-sided octagon

approached the work in the organized fashion described, and if you have managed to keep the taper well supported on the anvil as you work, there should be little correction needed .

If the taper is too short, and you began with a proper square section taper, the material must be “hiding” somewhere. Are the sides of the taper straight? Check against a straightedge. Any bulge is material that could be forged into length.

Perhaps, you did not forge an accurate or complete even sided octagonal taper before rounding. The result is a taper that is still “squarish” in section with rounded corners.

[Insert picture here -- sketch # 7]

Go back and hammer down these rounded corners as facets once more. Then forge down the new corners before rolling and rounding.

Sometimes the taper will be a bit short simply because the hammered texture isn’t refined enough. Make sure there are no obvious flats or facets left on the work that are more than about a 1/16 inch wide.

If your taper is too long, determine why. For example, you may have worked into the square sectioned bar beyond the start of the initial square taper. You must do this on the corners but not on the flats of the square. Using your hot cut hardie, trim the tip back to prepare for drawing and rounding the taper once more.

Important: you must trim back more than the needed shape change. If the taper is 1/2 inch too long, trim off 1/2 plus a bit more. You still must draw out the now blunt tip. How much to trim is a matter of experiment and experience, but you’ve lost the element of control that working from a specific square taper gave you. As a “guesstimate” to get you started, try trimming back an extra 50% of your original error. For example, if the taper is 1/2 inch too long, cut back 3/4 inch.

Having trimmed the tip, re-draw the point starting again with facets down the length of the taper that are then blended into a

7. Cross sections of a "sqarish octagonal" bar and desired round bar.

smooth round. When changing the dimensions of a round, always work from facets first.

If the taper is too long, maybe you have over forged some portion of the round creating concave sides. On a thin point like, this do not attempt to upset the bar to shorten it and fill out the concavity. Rather, trim as recommended above and redraw the point, square first, then round.

Surface Texture Problems:

Small concavities or dimples are a common problem with the surface, especially near the thicker part of the taper where the corners of the bar are first forged . These dimples result from not having the bar hot enough or from not hitting hard enough or a combination. If not severe, they can be forged out and blended into the surrounding surface.

Remember to keep your anvil surface clean and work the bar down to a black red finishing heat. Hit hard to make the shape change, but lighten up with finish work. Hit light, sharp, smoothing blows. Keep the taper well supported on the anvil. Create an even textured surface with no individual hammer mark predominate.

Targets

Time Targets: See the earlier lesson on drawing a square sectioned taper for goals for the first step of this lesson.

Once the square section taper is established, try to convert it into an even sided octagonal taper in one heat.

Take a second heat to make the upper part of the taper 16 sided and round the whole length. (A larger diameter taper may require the whole length worked 16 sided or even 32 side. A smaller diameter taper may be able to skip the 16 sided step.)

A third heat working down to a dull red may be used to refine and smooth the surface.

Dimension Targets: Strive to create a taper that is 3 inches long plus or minus 1/16 inch.

Draw the point as fine as you can, but no more than 1/16 flat on the end.

No section of the taper is to be greater than 1/2 inch diameter.

Except on the corners above the taper the original 1/2 square bar should remain unchanged.

Shape Targets: The point must be on center.

The sides of the taper must be straight. (The previous lesson on the square section taper will give guidance on judging this.)

The section of the taper must be round not "rounded squarish".

Except for the corners, the dimensions of the parent bar must remain unchanged above the taper.

Strive for a clearly defined "fingernail" transition between the square and round sections.

Forging Dynamics

(1) There are three reasons to work the round sectioned taper as a square, then a series of progressively smaller facet before achieving a round:

a. When using wrought iron, the traditional and historical material of the blacksmith, this was the way to retain the fibrous integrity of the material. Premature rounding causes the individual iron strands to shear past one another and create internal cracks and other flaws in the bar.

b. With any material, this method allows the greatest control of dimension and repeatability of results.

c. A hammer blow that travels across a surface in motion or a hammer blow that makes a sweeping motion itself is less effective.

Working the bar as opposed stationary facets for as long as possible makes most effective use of the hammer blow.

(2) Comparing the cross sectional area of bars helps predict material requirements for different forging operations. For example, a one inch square bar has a cross sectional area of one square inch. On the other hand, the cross sectional area of a round bar one inch in diameter is only about 80% of the square:

area of a circle equals pi times the radius squared, OR

area of a 1 inch circle equals 3.14 times (.5 X .5), OR

.785 inches

When the square becomes round, the material in the corners of the square gets forged in, causing the bar to stretch.

It is actually quite easy to make a round greater than one inch in diameter from a one-inch square bar. Do this by not retaining the one inch dimension as the corners are first forged to create an octagon. The bar will swell to greater than one inch across the flats.

If you want a one-inch diameter round from a one-inch square, first hammer the square slightly undersize, then octagon and then round. This anticipates the swelling that results from forging in the corners of the square.

3) When you forge the first facet on the top corner of the square taper, the anvil is beginning a facet directly underneath on the bottom corner. The hotter (softer) the bar and the harder you hit, the more closely will the bottom facet made by the anvil approximate the dimensions of the top one made by the hammer. However, even with the hardest blow on the hottest metal, the iron itself absorbs some of the impact of the hammer so the bottom shape change will never exactly equal that of the top. This is why we work all surfaces of a bar if a uniform product is desired.

(4) If the hammer blows are light and/or the bar is cool, the shape change brought about by the hammer is increasingly concentrated on the surface directly beneath the hammer. If you don't forge the corners of your taper forcefully enough or hot enough the corner alone will spread. As the adjacent corners spread you create a small pocket or concavity in the surface. Look for these as they are an indication of working the bar too cold or not hitting hard enough to force the shape change into the middle of the bar.

Bending

By Jay Close
Illustrations by Tom Latané

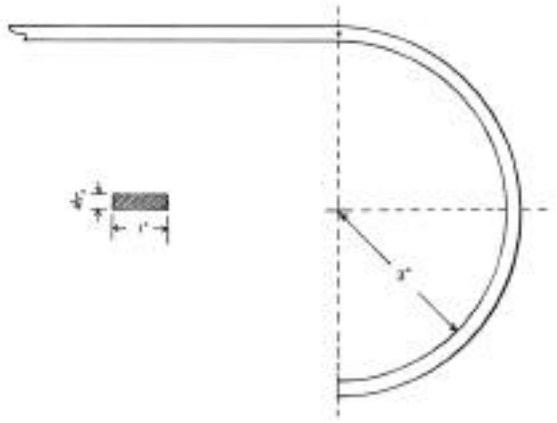
Lesson Number Four– Bending

Definition: For bar stock, bending creates a change in the longitudinal axis of the bar. This change can occur in a single plane as in bending a classic scroll, or the change can occur in multiple planes as in a corkscrew.

Straightening is a special form of bending, as are sinking and raising when dealing with sheet stock.

Bending a semicircular curve with a three inch inside radius on the end of a flat bar.

Intent: The student will practice calculating the bar stock needed



1. Dimensions of the finished forging.

to produce a bend of specified radius and learn to use the horn of the anvil to create a controlled semicircular bend of required dimensions.

Tools Needed: Basic tools only, these to include a rule and a square.

Material: 24 to 30 inches as convenient of 1/4 inch by 1 inch mild steel bar.

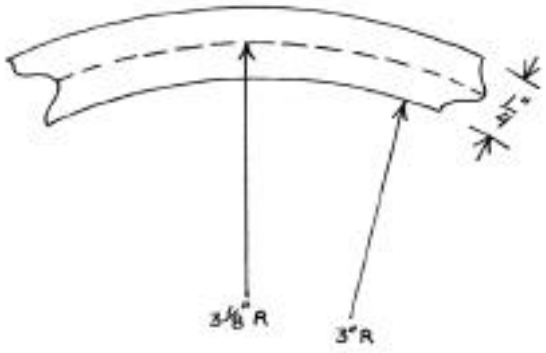
Method: After calculating the needed material to make the bend, the curve is produced by using the horn as a bending point or fulcrum. Shifting the location of the bar on the horn and changing where and how hard the bar is struck controls the needed curve.

Step One:

In the technical sketch, above, the radius of the bend is constant, i.e. you are asked to make a semicircle or a half circle with a radius of 3 inches measured to the inside of the bend.

However, the actual needed bar stock is determine by an imaginary line down the middle of the bar thickness. Therefore, as the bar is 1/4 inch thick, calculate the material needed for a 3 and 1/8 inch radius bend.

There are many ways to determine the needed material. These methods vary in accuracy and convenience. If you lack a full sized drawing and are working from a scaled drawing or just a set



2. Material needed.

of dimensions, simple geometry yields an accurate result.

In the same way that pi times the diameter of a circle equals its circumference, pi times the radius will give the linear dimension of a semicircle or half circle.

bar length needed = pi times radius

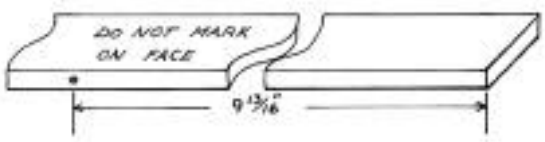
bar length needed = 3.14 times 3.125 inches or 3 and 1/8 inches

bar length needed = 9.8125 inches or 9 and 13/16 inches

Measure 9 and 13/16 inches from the end of the bar and center punch a distinct mark on the edge of the bar (not on the face).

This arithmetical method of determining the needed length of bar will only work with curves that have an even, unchanging radius, but it is very accurate.

Many smiths feel it necessary to work from a full sized drawing.



3. Material layout.

If this is available, other methods for determining the needed bar stock are possible. Some smiths lay a piece of string or wire on the drawing along the needed curve and then straighten the string or wire to take a measurement. Others will step off the needed material using a set of dividers or a compass. A useful tool called a "traveler" can also be employed and yield a very accurate result. These methods, while of varying degrees of accuracy, have the advantage of being useful for scrolls and irregular curves as well as semicircles and full circles. Where appropriate, we will cover these other methods in subsequent lessons.

Whatever method you choose, remember to take your measurement down the middle of the bar thickness.

You may feel it useful to make a full sized sketch of the needed shape, not just to determine stock requirements, but as a guide to the desired final form. If so, use the above dimensioned drawing as a guide. For such simple shapes as this, ultimately you will come to find this drawing unnecessary and you will learn to hold an image in your mind of the completed form to guide you.

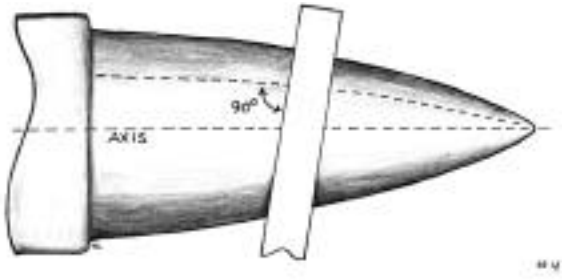
Step Two:

Take an even, light orange to yellow heat on the end of the bar. Try to heat at least 4 or 5 inches, but evenness of the heat is important.

When hot, place the bar across the horn of the anvil at a slight angle to the axis of the horn, approaching perpendicular to the taper of the horn. This helps avoid the curve taking on a corkscrew spiral as it is forged. The exact angle to hold the bar depends on the geometry of the horn and is a matter of experimentation, observation and correction as you work.

With the bar held horizontally, the point of contact with the horn is directly on top. Extend the end of the bar no more than a half an inch beyond that point of support so that the end is unsupported and free to bend.

Hit the end of the bar straight down and the work will deflect. Most of the deflection will be on the end of the bar you hit , but the metal will "kick up" a little on the near side of the point of



4. Holding the bar at an angle.

support too. The hotter the bar and the harder the blow the less it kicks up.

The amount the bar moves depends on (1) how hot/soft it is, (2) how hard you hit it , (3) where you hit it, (4) how much of the the bar is unsupported by the anvil. These are also areas for experimentation.

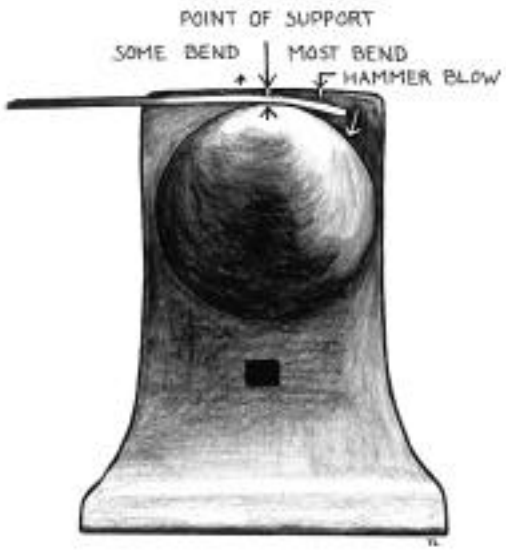
Get this first part of the curve well bent. It is often easier to straighten it later than introduce more curve.

After the first hit, advance the bar another half inch or so and hit again.

Do this a third time and check progress. If you have made a sketch, compare the beginning curve to that. Otherwise, look at your curve and imagine it continuing at the same rate. Does it look like it will create the desired curve?

If you need a tighter bend, return to the approximate location of your first hammer blow and hit the bar again.

If you have clearly bent too much, place the end of the bar on the horn and hit on the near side of the point of support.



5. Forging dynamics of bending on the horn.

Drawing #8 in the "Trouble Shooting and Corrections" section farther on show the idea.

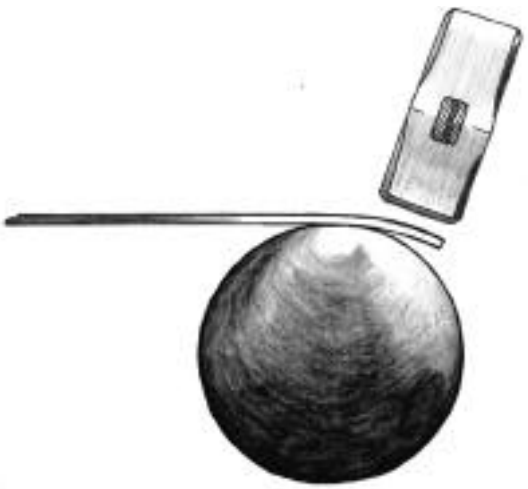
HINTS:

Hitting on the near side of the point of support will open a bend. Hitting on the far side of the point of support will close a bend.

As much as possible, try to hit vertical blows straight down on the work. This is just good ergonomic practice.

In all cases, try to have the hammer face contact the bar squarely, even if the point of impact is at an angle. You can accomplish this by (1) swinging into the bar (that is, not hitting vertically) , or (2) angling the hammer face and continuing to hit straight down. The drawing gives the idea.

As the bar bends and you need to rework an already bent section, feel free to lower the bar holding hand in order to keep hit-



6. The hammer face should strike the face of the bar squarely whether the blow is straight down or swung at the angle necessary to match the surface of the bar.

ting straight down. Do not bend at the waist, but flexing the knees can help. At a certain point this becomes awkward, so angle your hammer blow as necessary. Raising and lowering the bar holding hand will also alter the point of contact of the bar on the anvil and the nature of the bend.

In no case bend the bar against the curve of the angle. The horn is not a forming jig. It is only a variable fulcrum point for bending.

Much of the ease of bending a smooth curve comes from even and anticipated resistance to the hammer blow.

Any blow that pinches the bar between the hammer and the anvil is a drawing blow that thins the work and makes controlling the bend more difficult.

Likewise hot and cold spots in the bar present the same challenges.

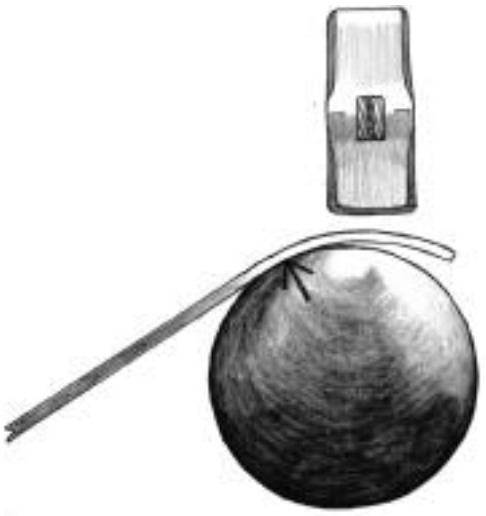
A hard blow at a high heat close to the anvil horn with a small amount of the bar unsupported will result in the tightest bend.

Hit lighter and bend less.

Work colder and bend less.

Push more of the bar across the horn, hit farther away and the curve will be gentler.

Work the curve never hitting twice in a row on the same spot. Keep the hammer blows moving and the bar advancing across



7. Lowering the bar to alter the point of contact.

the horn.

Bending will develop its own cadence: Hit. Advance the work. Hit. Advance the work. Hit. Advance the work…etc.

Check your work.

Make corrections.

Check your work again.

Do not mindlessly hit the work. Observe the shape. Decide on a course of action. Then hit with confidence.

Step Three:

When satisfied with the first part of the bend, put the bar back in the fire to heat the next section.

At a light orange to yellow heat repeat the sequence of Step Two to continue the bend. Keep track of your punch mark and visualize the complete curve as you work.

Step Four:

After you are satisfied with the curve allow the bar to cool slowly in the air and then check the needed dimensions (see the Targets section below). A cold bar will allow a more accurate assessment of the required specifications. At this point small corrections in the curve and dimensions can be made cold employing the same approaches you used while the iron was hot.

Trouble Shooting and Corrections:

Identifying and correcting problems are the keys to this lesson. It will take much experience before a semicircular curve can be made with no fuss.

8. Bending sequentially by moving the bar across the horn.

Basically, problems are of two types: over bending and under bending. Both present their own challenges.

To correct a bend, you can vary (1) where the bar is supported on the horn, (2) the deviation from horizontal of the straight section of the bar , (3) whether the bar is held with the bend up or down, and (4) whether you hit on the far side or the near side of the point of bar support . How you manipulate these options to correct a problem often depends on how far along the bend is before the problem is addressed.

The earlier a problem is corrected the easier will be the correction and the less the effect of the correction on the subsequent work.

Here are some problems and potential solutions:

a) An over bent end of the the bar that is caught early is corrected by setting the tip of the bar on the horn and hitting on the near side of the point of support. Remember the prior hint: Hitting on the near side of the point of support will tend to open or straighten a curve; hitting on the far side of the point of support will tend to close or tighten a curve.

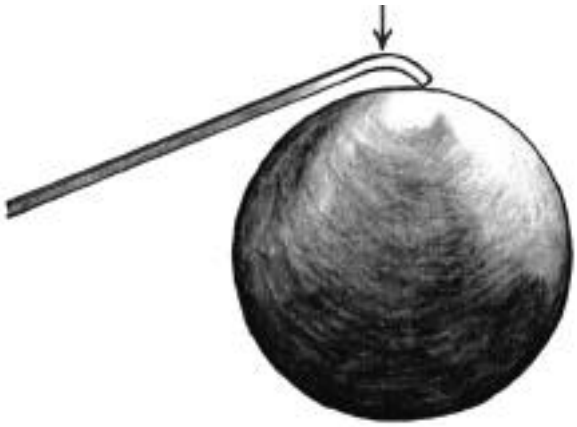
If, on the other hand, the over bend is not noticed until most of the curve is already completed, then the bar is best flipped so the curve reaches under the horn and the end comes on top. Support the end and hit to the far side of the point of support.

b) An under bent end of the bar, if caught soon, can be corrected by placing the end of the bar on top of the horn, lowering the holding hand down and hitting down to tighten the bend.(See drawing #7)

If not caught soon enough, an under bent end of the bar can be corrected by flipping the curve to run under the anvil. Support the end on the horn and hit as needed on the near side of the point of support to tighten the bend.

c) Sometimes the bend will begin to twist like a corkscrew. This results from holding the bar perpendicular to the axis of the anvil not the curvature of the horn. Try to flatten this corkscrew on the anvil face as you work, but alter the angle of the bar on the horn to keep the twist from developing in the first place.

Using the horn, you can also bring the twist into alignment by tilting the bar with one edge off the horn and striking down on that unsupported edge to swing the bar back into a single plane. You may have to do this sequentially along a broad section of the bend depending on how extensive the spiral has become. Remember, avoid thinning the bar against the anvil. You want to hit only the unsupported edge of the bar.



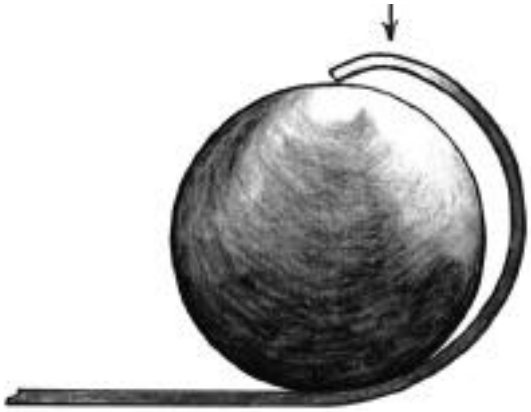
9. Straightening an overbent bar.

Targets:

Try to get the bend done in two or three heats.

The distance between the end of the bar and the beginning of the straight section should be 6 inches plus or minus a 1/16.

If you slide a square along the straight section, where is meets the punched layout it should also hit the end of the bend.



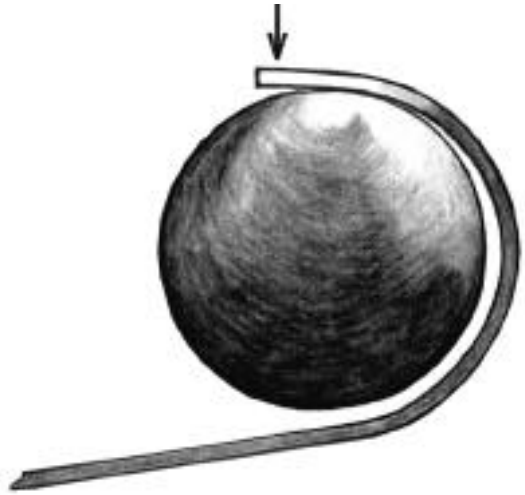
10. Another way to straighten an overbent end.

The straight section should remain straight

The curve should be even— no flat, straight areas or sharper bends than the needed curve.

Forging Dynamics:

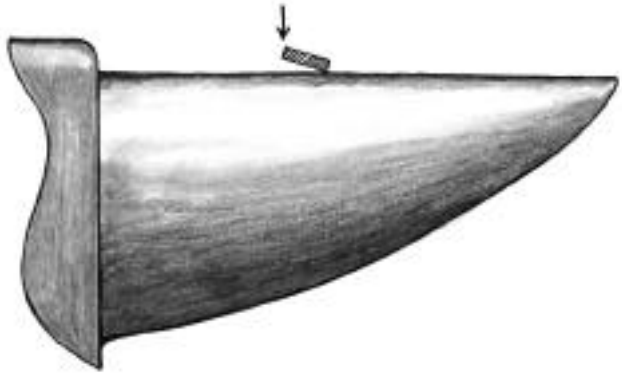
The hotter the bar, the softer it is. Therefore, the more shape change that will result when a given hammer blow is applied. In bending we apply a force to change the axis of a bar. By supporting the bar at a given point on the horn we concentrate the effect of our hammer blow to a certain length of that bar axis. On the far side of the horn where the bar is unsupported and



11. Correcting an underbent end

free to bend, the hammer will have most effect. On the worker's side or near side of the point of support the effect of the blow is "dampened" by the anvil horn and the support given the bar by the worker's arm and body. The effects of a bending blow will to some degree transfer past the point of support on the anvil, but will be less than on the unsupported side. The softer/hotter the bar, the more effective the dampening effect of the horn and worker's body.

Hitting on the end of a long unsupported section, spreads the energy of the hammer blow over a longer area so the effect on any one point is less. Hence, a gentler bend.

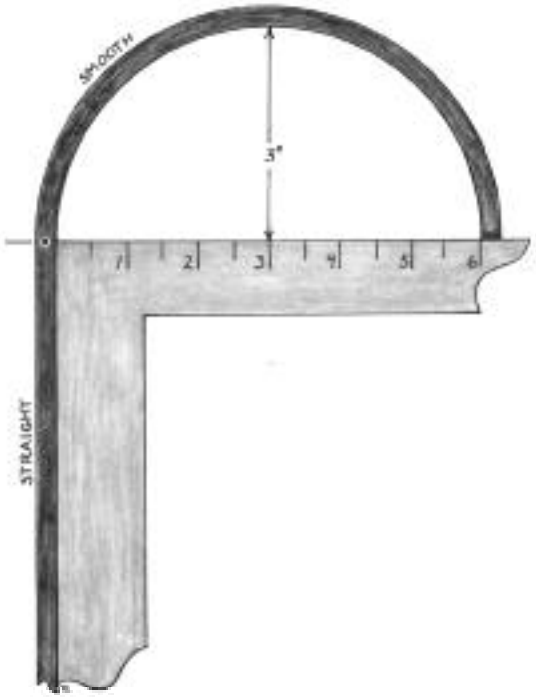


12. Correcting a spiral

Hitting in the middle of a long unsupported section will result in an 'S-curve'. The part supported by the horn won't bend; the free end has its own inertia and resists bending from a force place far from it; the middle bends down and the ends tend to stay where they are.

A hotter section or a thinner section will respond to a hammer blow the same way, by deflecting more than the cooler or thicker areas to either side.

(2) Every bent bar has an inside and an outside radius different by the bar thickness.



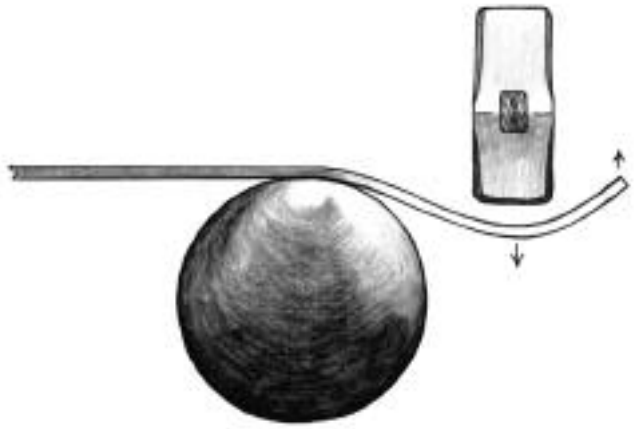
13. Checking your work.

When calculating material needs for a bend of a specified radius, if you figure the lineal requirements using the outside radius, you will have too much material. If you use the inside radius you will end up short. The central axis of the bar will remain unchanged in a bend or twist, therefore, do your calculations from that dimensions whether or not it is specified on the dimensioned drawing.

(3) As you bend a bar of iron, the bar upsets on the inside of the bend and stretches on the out side. The stresses of stretch and upsetting combined with differential resistance to the stress of bending will make a bar cup in cross section as it is bent.

The upset bar inside the bend is offered the least resistance by growing side ways. The bar actually gets wider. The stretched bar on the outside of the bend is forced longer but the material for the stretch must come from somewhere. The bar grows narrow as a result. The combined widening of the inside of the bend with the narrowing of the outside makes the bar cup.

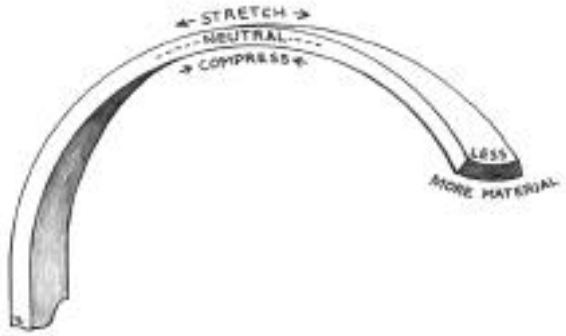
(4) When marking out for a bend, use only a round centerpunch mark, not a chisel cut or something similar. This will minimize the potential for concentration of stress in the bar that could lead to a crack or split. In no case should you mark the face of the bar either inside or outside of a bend. Both situations, by disrupting the unbroken, bar surface will result in the concentration of



14. Forging dynamics– forging an "S" curve.

stresses at that point. These considerations are particularly critical when forging wrought iron and when the bend is acute.

(5) Assessing final dimensions when the bar is cold has two advantages. First, it is more convenient and safer to look closely at the work when the bar is at room temperature. Second, like most materials, iron expands when hot. When working to high



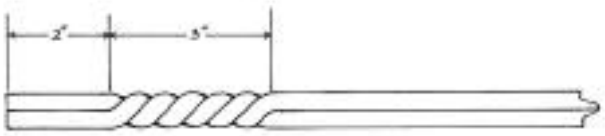
15. Forging dynamics– "cupping" of the metal within the curve.

levels of accuracy, final dimension should only be assessed at room temperature.

(6) Even quenching ferrous materials with low carbon contents can leave them with internal stresses and slightly stiffer. As a general principle, allow your work to cool slowly in the air when finished forging. If there is any slight adjustment need to be done while the bar is cold, the bar will resist less.

Twisting

By Bob Fredell
Illustrations by Tom Latané



1. The completed twist

Lesson Number Five--Twisting

Definition:

Twisting rotates the bar around its axis.

Intent:

The student will twist a 1/2"square bar one and one-half turns.

2. A Twisting Wrench.

The twist is 3" long and starts 2" from the end of the bar. The finished twist is to be straight and along the same axis as the untwisted portions of the bar. The entire length of the twist is even so that it does not easily show variations in the spaces between the turns. The twist is to be made to dimensions and in one heat.

Tools Needed:

You will need basic tools plus a twisting wrench, divider, container to direct water to parts of the twist and two lightweight bars 6" to 10" long.

3. An alternative type of twisting wrench.

Different types of twisting wrenches may be used. By welding a handle on to a smooth jaw plumbers' wrench an adjustable twisting wrench is made. The traditional "S" shaped twisting wrench may also be used. Experienced blacksmiths are able to use flat-lipped blacksmith tongs. However, beginners using this method run a higher risk of making a crooked twist because when applying the rotational force from only one side of the bar there is a tendency to bend the bar up, down or sideways.

Two light bars to test completeness of the twist.

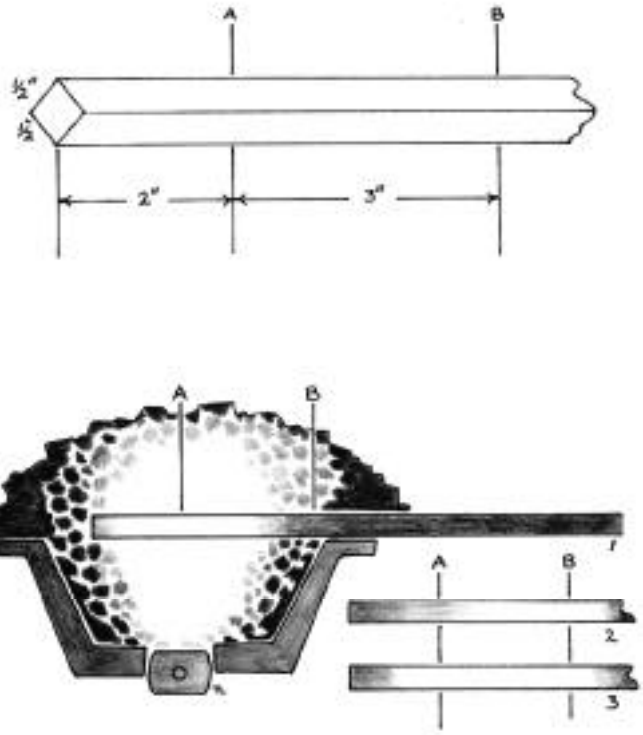
The exact size of these bars is not critical. Bars in the area of 1/4"x 1/2"x10", or slightly shorter, work well. The idea is to use straight, lightweight bars.

Water container

Use a container of your choice. You may use an old soap squeeze bottle, a tin can with a pinched top or anything else that produces a small, well-controlled stream of water.

Materials:

24" of 1/2" square mild steel



4. Measuring and heating the bar.

Step One:

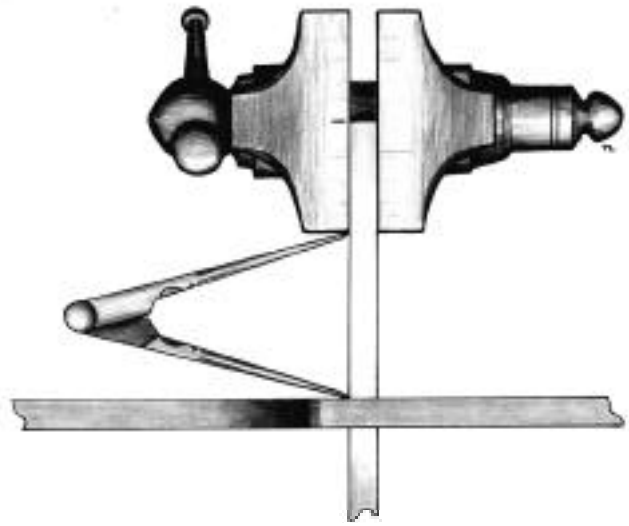
Place the bar in the fire so that 2" from the end of the bar is in the center of the fire and heat to a medium orange heat. Push the bar so that 5" from the end is over the center of the fire and heat to a medium orange heat. This is done to insure that the heat is well beyond the area to be twisted. Withdraw the bar and inspect the temperature. The color of the bar must be exactly the same for at least one inch beyond both directions of the area to

be twisted. Reheat as necessary to achieve a perfectly even heat that is three inches long. The length of this heat will ensure an even twist.

Hints:

An even heat makes for an even twist; an uneven heat makes for an uneven twist… *close* to even doesn't do it!

Do not heat the bar hotter than the recommended temperature because too high of a heat may cause the edges to crack when twisting.



4. Setup for twisting.

Step Two

Place 2" of the bar horizontally in the vise. This may be achieved in several ways. (a) Before heating the bar, center punch 2" from the end. However, this will leave a mark that you may or may not consider unsightly. (b) Place a chalk mark on the vise 2" from the end. This will work only if the twist is to be close to the end of the bar. (c) For twists in the center of a long bar, place a blacksmith's stand or other obstacle on the opposite side of the vise to act as a stop. *Note*—for some applications other than this lesson, the smith may find it useful to place the bar vertically in the vise.

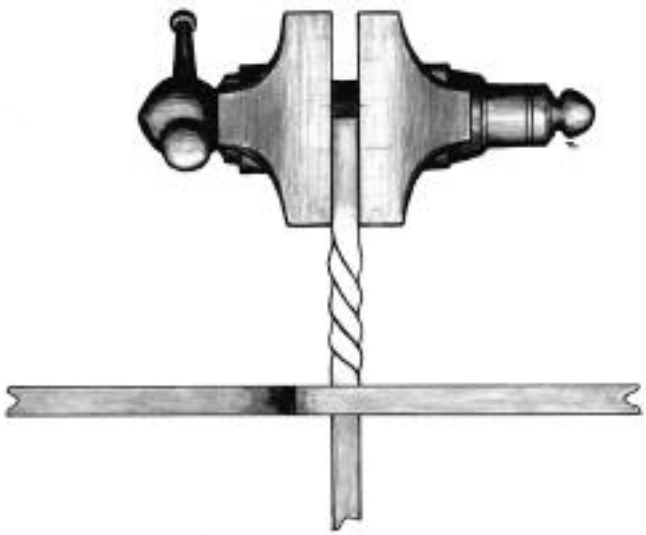
Use the dividers pre-set at 3" to determine the location of the twisting wrench and place the twisting wrench on the bar.

Hints:

When setting down the dividers do not allow the weight of the twisting wrench to rest on the bar as the bar may bend downward.

Step Three:

Twist one turn using even pressure with both hands. The twisting will take place only between the vise and the twisting wrench. Be sure to use gloves to protect your hands from falling scale.



5. Twisting in the vise.

Hints:

Be consciously aware of not bending the bar up, down or sideways, as this will put a bend in the bar.

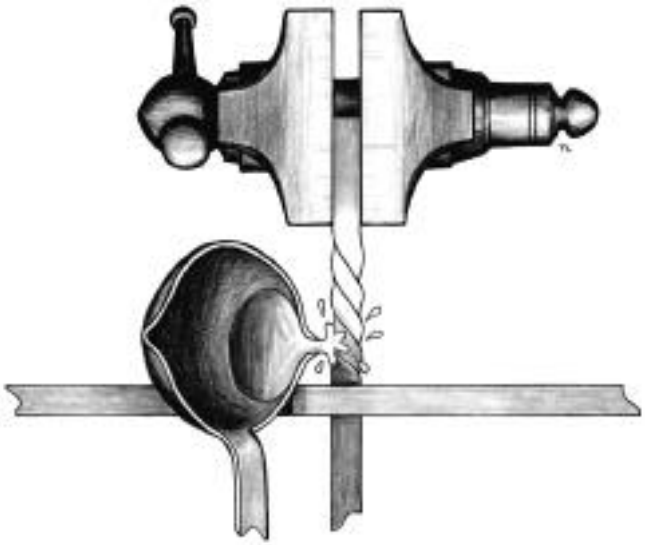
Some twists call for multiple twists in the opposite direction. Always make the first twist in the same direction to avoid forgetting which way to twist. (This may be either clockwise or counter clockwise.) It is well to develop the habit of always twisting in the same direction, except when the design calls for doing otherwise.

Step Four:

Quickly brush off the scale and inspect the twist. If part of the twist is tighter that the rest, cool it with water. Continue twisting to finish with exactly one and one-half turns.

Hints:

You will need some practice to learn how much water to use.



6. Cool tight sections with water.

7. Check the twist to make sure it's straight.

Step Five:

Sight lengthways down the bar; rotate 90 degrees and sight again. The bar, including the twisted and untwisted portions, is to be straight. The bar needs correction if you can detect a bend. Learn to train your eye to see deviations.

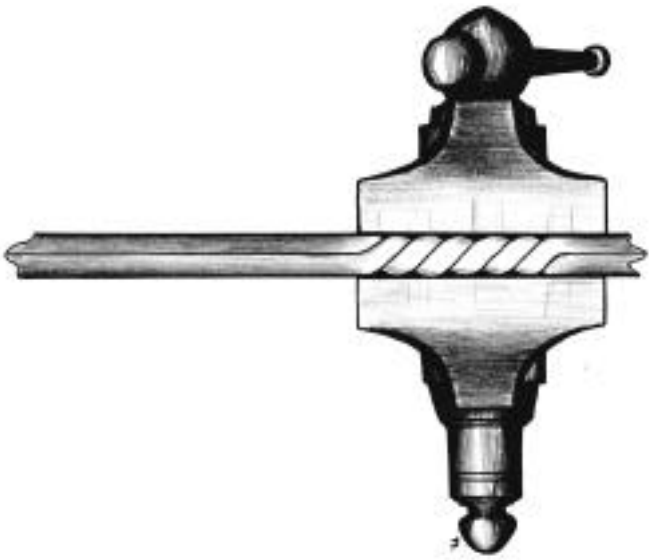
Beginners may need to use the following procedure to check for straightness: Place a straightedge lengthwise along the bar on a corner covering the twist and both untwisted parts. Do this on all four corners. The straightedge is to make contact with the untwisted corners and the corners of the twist.

If the bar is not straight and requires correction, proceed to step #6. If it is straight go to step #7.

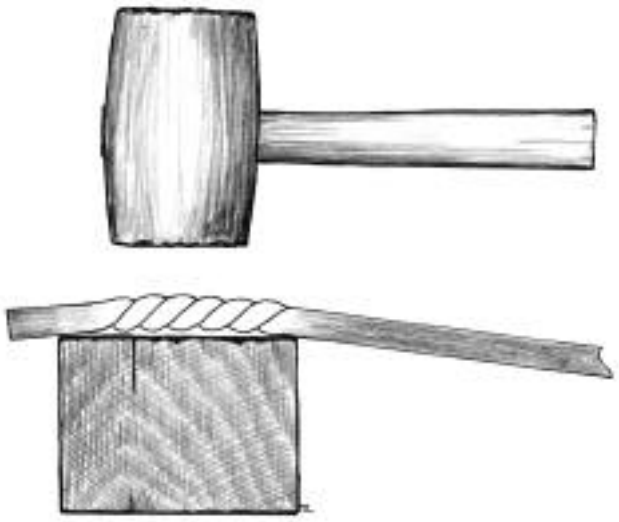
Step Six:

If the bar is simply bent, this may be quickly corrected by placing the twist in the vise on the diamond and gently tighten, rotate to the other diamond and tighten, then repeat this procedure on the flat of the bar. A second method is to place the bar on a block of wood and strike it with a wooden or rawhide mallet. Be sure to use wood to avoid deforming the edges of the twist. Wet the wood to reduce the amount of smoke in your eyes.

Correction may be more difficult if the bar is offset at the junction of the twist and untwisted portion. The block of wood method described above may correct the offset. Or, reheat to an orange heat, quench the twist to protect it and place the twist in the vise at the point of the offset. Strike the bar to move it back



8. Correcting a simple bend.

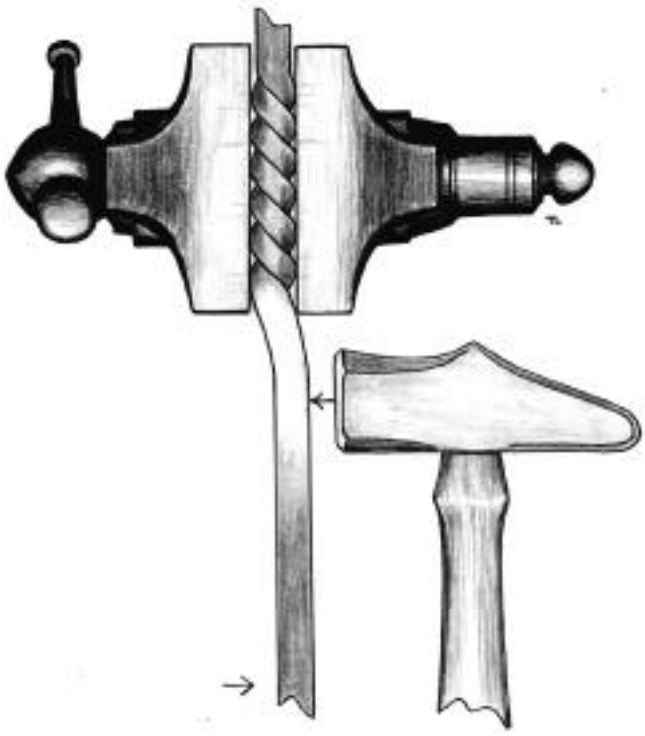


9. Another method for correcting a simple bend.

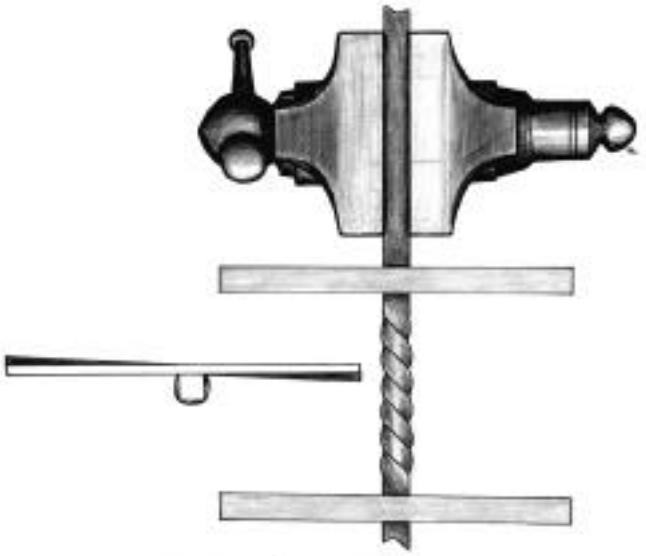
into alignment. At the same time apply pressure in the opposite direction at the end of the bar to avoid bending the bar.

Hints:

Bends and offsets are most often caused by moving the twisting wrench up, down or sideways or allowing gravity to sag the bar downward when twisting. Be consciously aware of applying even pressure on both handles of the twisting wrench.



10. Correcting an offset bend.



10. Another way to straighten an overbent end.

Step Seven:

To check for exactly one and one half turns, place the twisted bar horizontally in the vise. Lay one of the light bars on the flat, untwisted portion at one end of the twist and at a right angle to the twisted bar. Likewise, lay the other light bar on the other side of the twist. Sight lengthwise down the twisted bar. If the light bars are exactly parallel you have completed this lesson. If they are not exactly parallel the bar is either twisted too much or not enough. Place the twisted bar back in the original position in the vise and adjust. This process may require the twist to be heated.

Targets:

The twist is to be:

1. 3" long and 2" from the end with a deviation no more than 1/16 of an inch.

2. 1 1/2 turns with the leveling bars as described in step #7.

3. No cracked edges.

4. Equal size increments of the turns. The spaces between each corner of the twist are to vary no more than 1/16" as measured lengthwise along the bar. *Note*—the vise and the twisting wrench are heat sinks causing slightly wider turns at the ends.

5. The entire bar is straight. A good test for straightness of the twist is to place a straightedge along the twist and check for contact with each of the corners of the twist. Also, sight lengthwise along the bar—there is to be no detectable crookedness for the entire length of the bar.

6. Complete the twist in one heat.

Forging Dynamics:

The length of the bar remains the same because the axis of the bar does not change. Twisting makes the edges stretch; the flat surfaces remain straight, although they have the appearance of being concave. A cross section of the twist will show the flat surfaces as straight.

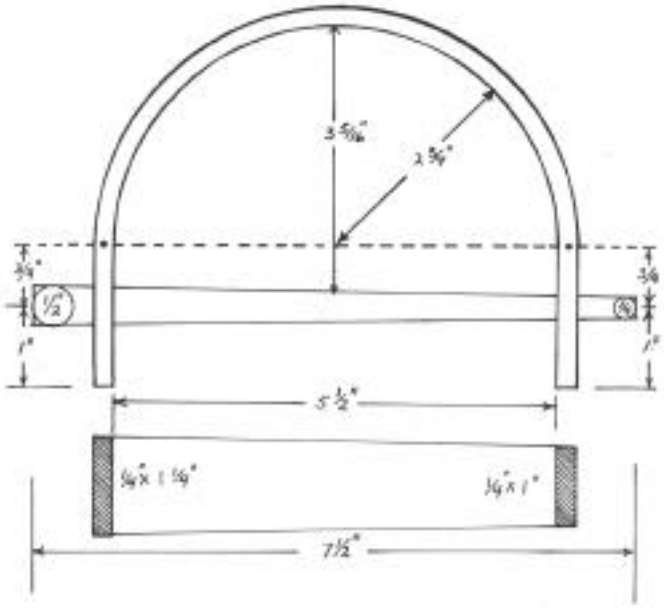
The corner-to-corner diameter of a square is greater than the face-to-face diameter. Before twisting the bar, the corners and the faces are parallel to the axis. When twisted, the corners and faces revolve around the axis at an angle to the axis. The corners, having a greater radius than the faces, will protrude farther out from the axis of the twist than will the faces. The radii of the face gradually becomes less moving from the corner to the center of the face; a concave shape is then created between the corners while the faces remain straight.

11. Forging dynamics of twisting.

Drawing, Punching, and Bending

By Peter Ross
Illustrations by Tom Latané

Lesson Number Six- Drawing Punching, and Bending



1. The final forged shape.

Definition: This lesson uses skills developed by previously published lessons.

Intent:

The student will learn to incorporate several basic skills into a single project while maintaining dimensional control.

Tools needed:

Basic tools plus tongs to hold 1/4" thick flat bar, tongs to hold 5/8" or 3/4" diameter on end, and punching tongs to hold punch (if using a short punch), center punch, rule, compasses.

Materials:

24" (or as convenient) of 1/4" x 1 1/4"

24" (or as convenient) of 1/2" square mild steel

5/8" or 3/4" tool steel to make two punches

Method:

It will take planning to achieve target dimensions. Let's start by thinking of the bent rectangular bar.

First, the bar must be the right length and the two holes correctly placed. If the bar is forged to proper length, the bending will be simple. We can accurately compute the overall length and the distance between holes from the plan (see lesson Four, Bending, *Hammer's Blow*, Volume 11, #2, Spring 2003). This will give us the "straightened" layout of the bar. With this layout established, the choice of steps can begin.

In planning a project, it is wise to do the less-predictable operations early and do the more predictable ones later. By "predictable" I mean in the dimensional sense- not the skills of the workman.

For example, forging a taper of precise length can be done with certainty (using the method learned in lesson one, *Hammer's Blow*, Volume 11, #1, Winter 2003), but it is difficult to predict how much stretching will occur while punching holes. If we punch early in the sequence, the uncertain effects on dimensions are resolved before drawing to final length. Maintaining correct dimensions will be simpler and more direct. Making the round tapered pin will not affect the dimensions or fit of the flat bar, and can be done independently.

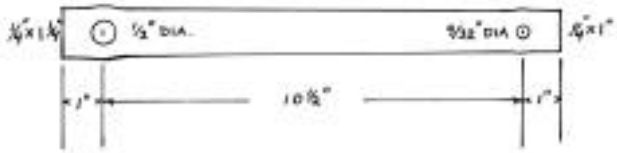
Step One:

Make two punches, each with a 4"-long round taper. One should end in 3/16" diameter and the other end in 3/8" diameter. Be certain that the entire taper is carefully forged and truly round. Any irregularities in the tool will transfer to the work.

Review Lesson #3 (drawing a round taper) if necessary.

Previous lessons have involved only mild steel, but for this exercise, we will need something tougher for the punch. If the punch is made of mild steel it will likely bend in use. Using a harder steel, even if it is not hardened and tempered, will make a more durable tool. At this beginning stage, I recommend avoiding more exotic and expensive tool steels. A very serviceable punch can be made from the simplest tools steels (such as W-1) and they will be much more forgiving for the beginner to use. The drawback of simple steels is that they are softer and will deform more easily during use, especially if they get hot. Good technique will enable you to use them with very little problem.

If you would rather not buy new steel, you may use a piece of scrap (such as a piece of coil spring) of appropriate thickness.



2. Flat bar in its unbent layout.

Step Two:

We will start with the flat bar.

Refer to the drawing of this project for dimensions and calculate the length of the flat bar before bending. Also determine the distance between holes. Review this procedure in Lesson Four (Bending) if necessary.

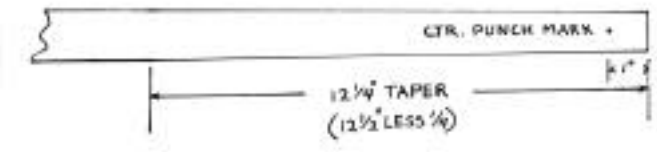
It is often a good idea to make a simple sketch of the piece as it should look before bending with these dimensions noted. At this stage, it is nothing more than a tapered flat bar with two holes.

Begin by forging a taper on the end of the flat bar. This taper does not end in a point, so draw the end of the bar only until

you reach the target dimension- in this case, 1/4" x 1". Square the end by upsetting if necessary. Once you have forged the end to dimension, work your way back up the bar until you have a straight, even taper 1/4" shorter than the desired length. This will allow for some stretching during punching and final corrections.

Hints:

Do not draw the bar too thin, as this is the hardest fault to correct. Any areas that are too thin must be upset to proper thickness. Refer to the lesson on upsetting if necessary.



3. The marked bar.

Targets:

Make sure the bar is an even 1/4 " thick the entire length of the taper. Variation should be 1/64" or less.

Hold length tolerance within 1/16"

Make the taper as smooth and straight as if it were the end of the project.

Step Three:

Measure from the small end to find the location of the small hole. Using the center punch, mark the location. Make a deep mark so that it will be clearly visible when the bar is hot.

Take a heat and punch the small hole.

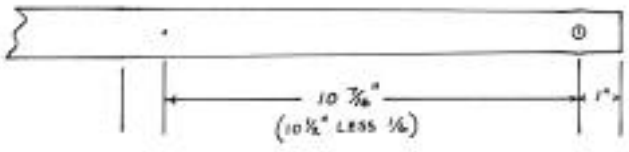
Drift the hole to 9/32" diameter using the punch.

Refer to lesson 2 (Hot Punching) if necessary.

Hints:

It is a good idea to mark the bar when cold (or mostly). This will avoid errors caused by measuring a hot, expanded bar: after the bar cools and shrinks, the marks can be off by as much as 1/8". Also, using the center punch on hot material may draw the temper from the small tip.

Targets:



4. The layout of the second hole.

Punch and drift the hole in the same heat. Since the punch is close to the final hole size, this should not be difficult. After drifting, the bar should be at a low heat and ready for smoothing. For this project, it will be acceptable to leave the bulge around the hole.

With practice you should be able to punch, drift, and smooth the bar in one heat.

Step Four:

Using the center of the first hole as the starting point, measure for the location of the second. Punch and drift the second hole to 1/2" diameter.

Hints:

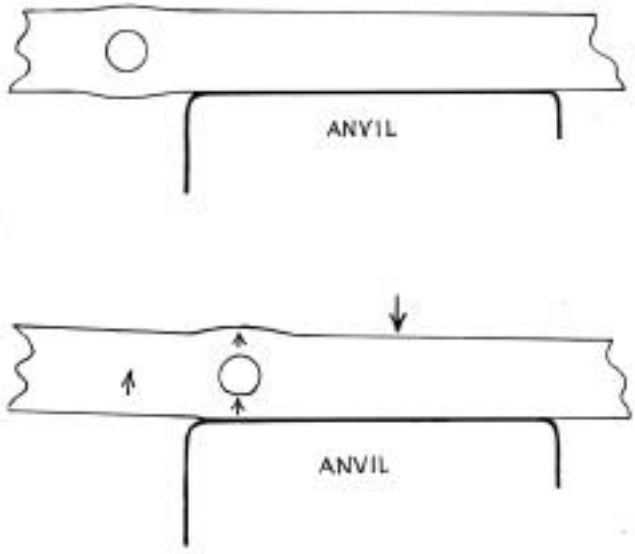
Rather than center punching the exact location, make the mark approximately 1/16" too close to the first hole. This will allow for inevitable stretching, and decrease the chance of the holes being too far apart. If there is any error to correct, it will be much easier to stretch the bar a little than to shorten it.

A more accurate measurement can be made when the bar is cool.

With the second hole finished, measure between the holes and correct the taper length to match the dimensions on your sketch. Final measurement is best done with the bar below a red heat, to minimize errors. This is also the time to make sure the taper is straight and even and the surfaces smooth.

For this project, the bulging of the bar edges around the punched holes may be left as is.

Once the holes have been punched and the bulges created, it is very important not to let the bulge rest on the anvil even when working in the middle of the taper. With a bulge on the anvil, the taper will not rest squarely on the anvil face. A hammer blow



5. Proper placement of the bar.

in this condition will bend the bar and squash the hole. This is an example of an idea presented in lesson one: the bar is squeezed by the hammer and the anvil simultaneously. You must think of what the anvil will do whenever positioning the bar.

Targets:

Hold length tolerances of each section to plus or minus 1/32", and overall length to within 1/16".

Step Five:

Now that final length is established, the piece can be cut from the bar. Make a mark on the face of the bar with the center punch, or on the edge with the hardie. Take a heat, and using the hardie, cut the piece from the bar.

Hints:

It is helpful to cut before bending for two reasons: first, if we are going to dress the end of the bar with the hammer, this is the last convenient time. Once the bar is bent, it will be impossible.

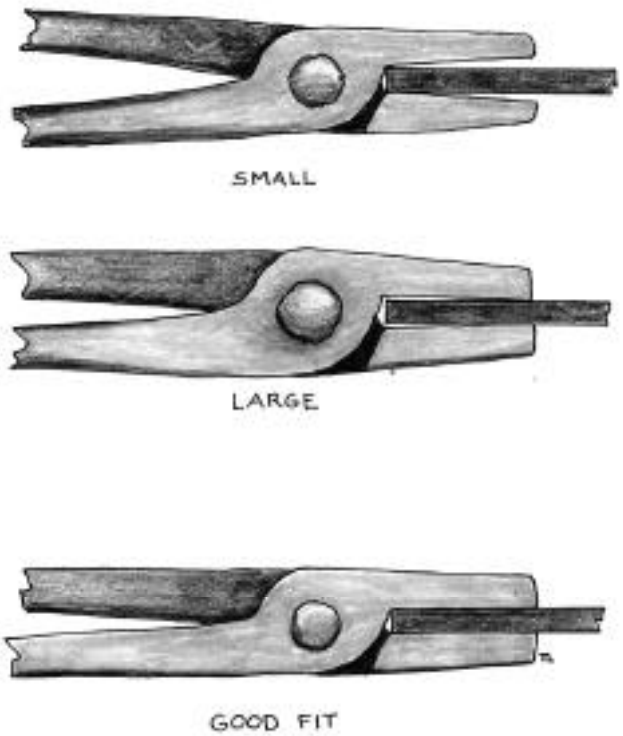
Second, cutting would deform the bend if it were already done. We would have to do the work all over again.

Careful cutting will keep the end of the bar as square as possible and make upsetting easier. Since this is a rectangular bar, it will help to cut part way through from all four sides. The intent is to keep the resulting burr as small as possible and centered on the end. If you cut equally from opposite sides rather than mostly from one side this will happen.

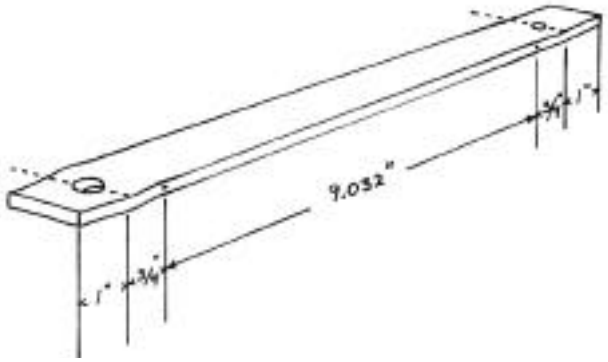
From this point onwards, it will be necessary to hold the piece with tongs. Simple flat jaw tongs will work well for this project. Most tongs are made to fit one size bar, though they sometimes will hold several additional sizes adequately. To check to see if tongs fit properly, the jaws should be parallel at the thickness of the bar. Thus, the jaws will contact the bar for the entire length of the jaw. Conveniently, one pair of tongs sized to hold 1/4" thick flat bar will hold the piece at either end, or anywhere in between.

Hints:

It may be necessary to square the end after cutting. If so, make sure to quench everything except the end itself to prevent undoing the accurate dimensions already achieved.



6. Proper and improper tong fit.



7. The bar with punch marks on edge.

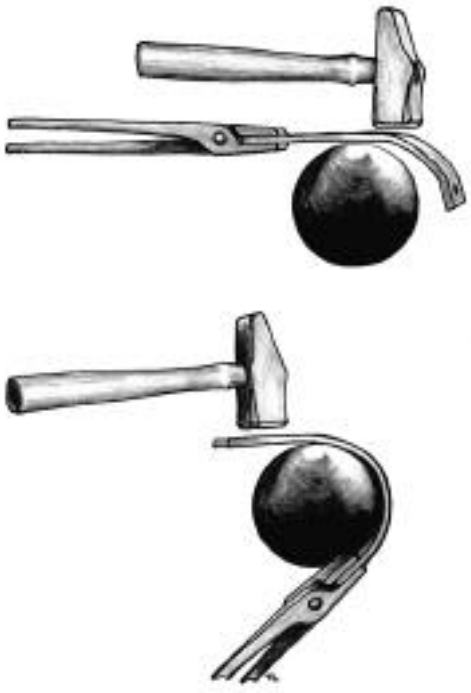
In preparation for the final step, it may be helpful to mark the limits of the bend (see Lesson 4, Bending) on the edge of the bar.

Step Six:

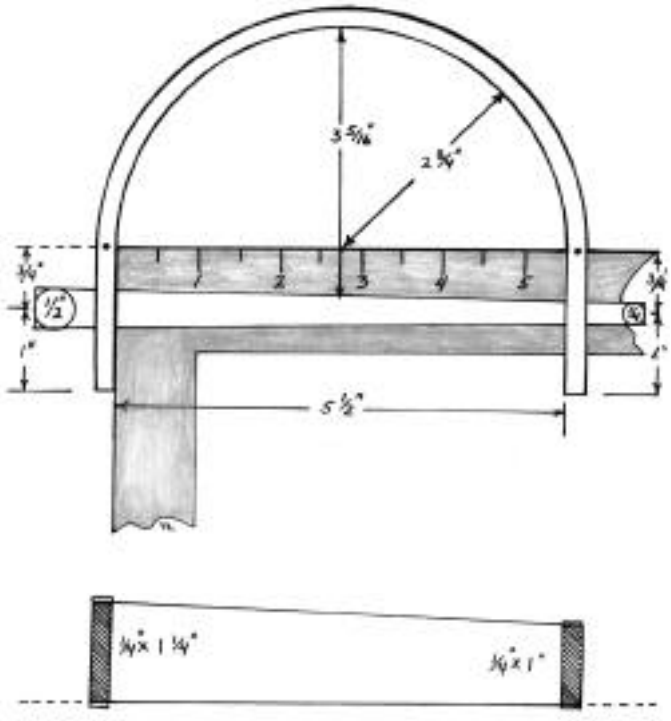
Bend the piece to match the given dimensions. Heat approximately one half the length of the bar and bend while holding the cold end in the tongs. Once done, switch grip to the bent end, heat the second half, and finish the bending. Switch grip as often as necessary to make corrections and adjustments.

Hints:

Since the bar is tapered, care must be used to get an even bend (it will bend more easily where it is smaller). If you have chosen to center punch the edges of the bar for reference it should be easy to determine if the bends start and stop at the correct places.



8. Manipulation of stock for bending on the horn.



9. A square can be used to assure that the curve begins and ends properly, to locate a center to check the curve, and to check that the straight ends are parallel. The sides of the curved bar should lie evenly on a flat surface except for the swelling around the punched holes.

Refer to Lesson Four (Bending) if necessary.

Remember, the two ends including the holes are not bent, but straight.

Targets:

The two straight sections at either end should be parallel in side and end views, and the correct distance apart. They should also be perpendicular to the imaginary "horizon" created by connecting the two dots.

With a straightedge connecting the two reference dots, check the radius of the bend and whether the ends are square.

Match the given dimensions within 1/16" or less.

Step Seven:

With the flat bar completed, it is time to make the tapered round pin.

Starting with 1/2" square bar, draw a round taper to match the given dimensions.

With the proper taper made, cut the piece from the bar and square the cut end if necessary.

Straighten and check for accuracy.

Hints:

Refer to Lesson Three (Drawing a Round Taper, *Hammer's Blow*, Volume 11, #2, Spring 2003) if necessary.

When cutting a round bar that is to have the end squared, cut evenly all the way around the bar. This will leave the resulting burr small and centered on the end.

Since you are using 1/2" square bar as a starting material, it is possible to make a pin which is larger than 1/2 " diameter. Therefore, use care in checking your progress.

Step Eight:

With both parts cool, slide the pin through the holes in the bent bar. The pin should stop close to the desired location, with close to correct amounts projecting from both holes. If the pin is round and straight, the distance between it and the top of the arc will remain constant even if the pin is rotated.

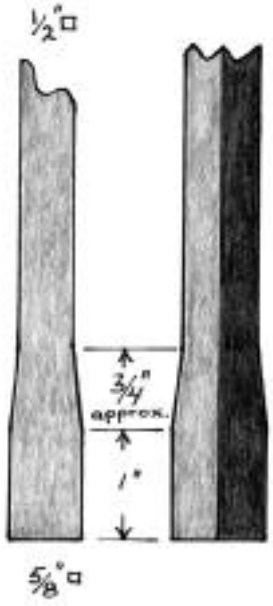
Check all given dimensions.

Hold tolerances to 1/16" or less

If you have made a full-size drawing, you can place the finished piece directly over it to check your results.

If the piece does not match the sketch, you can also figure out where the errors occurred; whether holes are in the right place, bending was accurate enough, or overall length was estimated correctly.

Upsetting



The finished shape

By Peter Ross
Illustrations by Tom Latané

Lesson Number Eight–Upsetting

Definition:

Upsetting increases the cross sectional area by deforming existing material instead of adding material.

Upset 1" of the end of a 1/2" square bar by 25% (drawing of finished shape)

Intent:

The student will learn the basic principles for upsetting the end of a bar efficiently, practice the methods, and be able to produce accurate results.

Tools needed: basic tools only, including a square

Materials:

14" of 1/2 " square mild steel

Method:

The bar is hammered end-on. This shortens the bar and causes it to swell where it is hot.

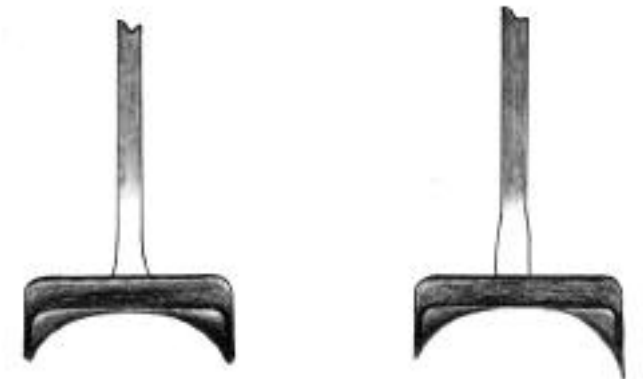
In order to work efficiently, the following conditions must be met:

1. the bar must remain straight.
2. the bar must be at a very high heat
3. the bar must be hit hard

Managing these factors is more difficult than it might appear. This is one process where almost everything works against you. Since hot steel bends so easily, it is very likely for a bend to start even while striking on end. Once even a little bend starts, almost all upsetting ceases and the blows simply cause more bending (If you have ever tried to drive a nail once it has bent even a little bit, you will understand the situation).

Very little is accomplished unless the bar is at its softest. At a medium orange heat or below, results are almost negligible. Therefore, it is crucial to start at the highest heat and work quickly.

As a practical example, try to make a small section of rope swell by pushing from both ends. If you hold too far apart, the rope will bend. It only swells when you keep everything straight and localize the work area. Also, compare the resistance between upsetting and bending the rope. It will bend with much less force. This illustrates the necessity of following the three requirements when working steel.



Upsetting with lighter vs. heavier hammers

Factors to consider when upsetting:

1. The size of the hammer affects the results. A light hammer can be used faster, but since it has less mass, the blows work only the very end of the bar.

A heavier hammer will have a deeper effect.

If too heavy, the hammer cannot be used fast enough; adding extra heats. For this exercise, a hammer between 1 1/2 and 2 pounds will be adequate.

2. The length of the heat is very important. If too long a heat is taken, the bar will bend rather than upset.

3. The end of the bar affects straightness. Even though the end of the bar will deform during upsetting, how it looks at the start is crucial. If the end is not square to the bar length, the first blow will cause bending. Additional blows only exaggerate the condition.

A bar end that is out-of-square causes bending

If this continues, there is no easy way to correct the problem.

The likelihood of any smith holding and striking the bar perfectly plumb every time (or even once, for that matter) while working as quickly as possible is slightly less than winning the lottery. Most experienced smiths count on the bar bending frequently. There is almost no way to prevent this. The object is to notice bending as soon as it occurs and correct it right away. The sooner a problem is noticed, the simpler (and faster!) the correction can be made. This sometimes means only one or two upsetting blows between straightening, so the key to upsetting is to work quickly and make constant corrections.

4. How solidly the bar is supported will determine the effectiveness of each blow. A bar backed against the anvil will upset much faster than one supported in the hand.

A bar can be held in the vise for upsetting. However, there are some serious drawbacks to this method. For one thing, the vise will pinch the bar (especially at very high heat) and leave scars. For another, it is awkward to straighten a bar while it is clamped in the vise. Proper straightening is best done at the anvil, and it is quite slow clamping and unclamping the work every two or three blows. Finally, the vise is an effective heat sink, and cools the work appreciably.

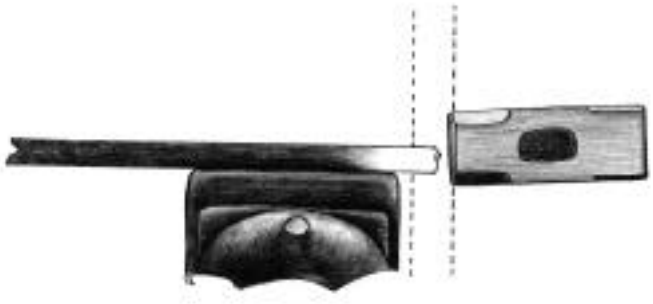
5. You have the choice of holding a short bar with hot end up or down. If down, the length of the bar absorbs some of the blow, so less is accomplished. If the hot end is up, the blows fall directly on the heated end, which is good. However, it's much harder to hold the upper end steady if you grip at the bottom and strike at the top. You will also get many scale burns on your wrist. Holding the cold end up with the heated end down on the anvil face is the best compromise.

Note: it may be tempting to use tongs to hold the bar, enabling you to hold the hot end up after all. This sounds like it solves all the problems, but in fact it can slow down the quick changes from upright to straightening to upright so much that extra heats will be necessary. It is better to learn the proper hand grip method.

Step One:

If you are starting with a bar with an uneven end, you must square it first. To do this you will upset the very tip of the bar. Since only a small area is to be worked, you can usually do this easily in one heat. Hold the bar so that the hot end projects beyond the far edge of the anvil an inch or two and strike the end of the bar. You will be hammering almost directly towards yourself and bracing the cold end of the bar against your thigh. Remember to keep straightening as necessary until the end of the bar is square to its long axis and the original dimension (in this case, 1/2" square). Check with your square if necessary.

Note: it is possible to start with a bar that has been cut hot on the hardie, but only if it has been cut evenly from all sides; leaving the resulting burr centered on the cut end. After the first one or two upsetting blows the burr will be gone. An uneven cut will leave an off-center burr and this will guarantee bending.



Bar and hammer in position.

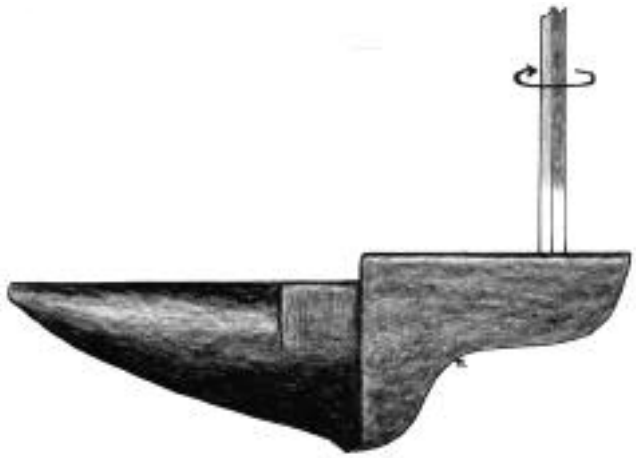
Now for the real work. Take a near welding heat on the end of the bar. It is important to heat only 1 –2 inches. Even with the best of intentions, the heat is sometimes too long. In this case, quickly quench all but the area to be upset. The fastest method is to submerge the long end of the bar (along with your arm) in the slack tub. This works well with a short bar such as the one in this lesson. If you move the bar around in the water it will cool even faster than holding it still. Remember, wasting time at the tub means the bar will be much cooler by the time you are ready to strike. Best results come from heating the bar correctly so you can go directly to the anvil.

Target:

If you have taken a good heat, you should be at the anvil and ready to strike within 1 or 2 seconds. If quenching is necessary, try to take no more than 3 or 4 seconds from fire to striking the first blow (beginning of step 2) .

Step Two:

Hold the bar upright on the anvil and strike the upper end two or three quick, hard blows.



Holding the bar on the anvil top

Look frequently at the hot end as you are working. As soon as you see the bar bending, stop upsetting and straighten, using as few blows as possible. Overzealous straightening can lead to drawing out the bar… negating your progress. You do not need to get the bar perfectly straight, but close.

As soon as possible, return the bar to upright and strike two or three more upsetting blows. Continue in this manner until you have slightly exceeded the target dimension, taking additional heats if the bar cools below a medium orange.

Note:

While checking for straightness, remember also to keep watching the end. If you see the end of the bar going out of square, you must stop upsetting and correct as illustrated in step 1.

What can be done to minimize the time used in straightening? Many smiths will rotate the bar 1/4 or 1/2 turn between blows to keep minor mistakes from compounding.

Occasionally, a correction can be done without much interruption. If the bar end goes out of square and causes a bend, bending the bar in the opposite direction will address both corrections (straightening the bar, and squaring the end) at once. Remember, reducing the interruptions to actual upsetting means fewer heats to accomplish the goal. Every second saved counts.

Correcting an end that is out-of-square

Step Three:

Smooth and straighten the upset area, being careful to draw the bar just to size. A lower heat (dark orange to bright red) is best for this step.

Check the bar dimensions to confirm it is square in cross section, straight, and proper size (5/8"). Correct as necessary (see lessons on drawing, straightening, bending)

Target:

With practice this exercise may be accomplished in one heat, though a beginner may take two or three at first. The finished upset section should be within 1/32" of the intended 5/8 thickness and the bar should be straight and square.

Splitting

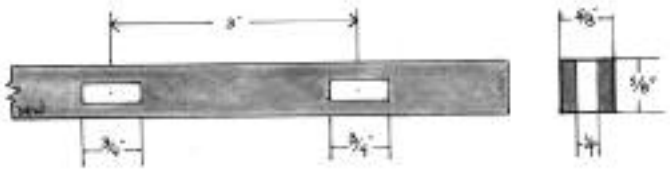
A coffee table by Doug Wilson using the techniques described

By Jay Close
Illustrations by Doug Wilson, photos by Jay Close

Lesson Number Eight–Splitting

Definition:

Cutting a bar by driving a sharp-edged chisel usually parallel to the length of the bar.



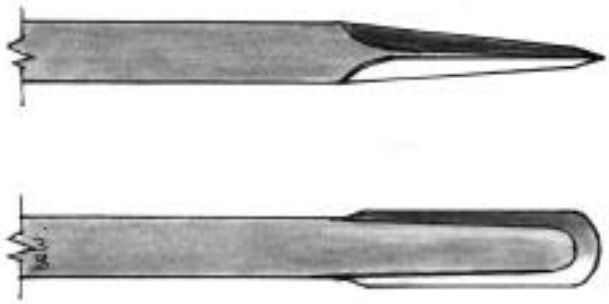
The finished practice piece with dimensions

Lesson: slitting and drifting two mortises or slots in a square sectioned bar.

Intent:

The smith will learn the technique of slitting and drifting a narrow mortise to specified dimensions and how to anticipate the stretching of the bar to position mortises accurately.

Jay's tooling for this lesson



A slitting chisel

Materials:

24 inches of 5/8 inch square mild steel.

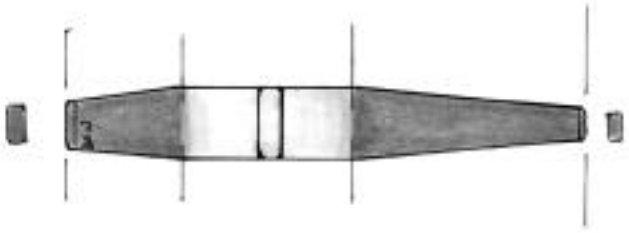
Tools:

In addition to the basic tools you will need a slitting chisel about 5/8-inch wide forged from W-1 or some other appropriate steel, and a drift 3/4-inch wide and 1/4-inch thick.

Make the drift of the same sort of steel as the chisel, although a drift of mild steel, carefully used, will work for a few repetitions of the lesson.

If the chisel is short, you will need chisel tongs to hold it. A pair of pick up tongs will be useful dealing with the drift.

Make the cutting edge of the chisel to approximate the drawing above. The edge is curved and thin. Keep it symmetrical—an off-center edge will be hard to drive straight. The length of the chisel edge should be about 75% of the length of the finished opening—in this case about 5/8-inch for an opening 3/4-inch long.



A drift

Make the drift to resemble the drawing. Provide a long, lead taper, a parallel section and a driving taper a bit longer than the bar thickness. To avoid sharp inside corners in the material, file or grind a slight chamfer on the edges of the drift. Round the top where the hammer hits to minimize mushrooming.

Method:

Overview of the Process: When a narrow slot or mortise is needed it is often slit and drifted rather than punched. This is particularly true when it is desirable to retain the full thickness of the bar stock around the opening.

In the process taught here, a slit is cut then a drift inserted into the slit. This drift works like an internal anvil as the sides of the bar are progressively forged thinner on either side of the slit and the ends of the slit squared as the drift is driven in further.

Step One:

Measure the overall length of the bar you are starting with and record that measurement.

One inch from one end of the bar place a center punch mark deep enough that it will be readily observed on the heated bar. Center the punch mark in the middle of the bar.

Roll the bar 180 degrees and place a corresponding center punch mark on the opposite side. These two marks will guide the placement of your chisel as you cut from both sides.

Step Two:

With tools ready at the anvil, heat the end of the bar to a full yellow. Make sure that the area around the center punch marks is hottest.

Place the heated end of the bar in the middle of the anvil with a center punch mark facing up.

Put the chisel edge centered over the punch mark aligned with the length of the bar.

Tip: If you have difficulty seeing the punch mark, rub the side of your hammer across the bar surface. This will scrape the surface free of scale, but scale will collect in the center punch mark and make it visible.

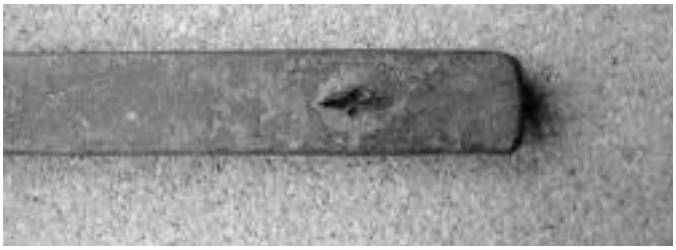
Steady the end of the bar you have been holding against your thigh. Pick up the hammer.

Hit the end of the chisel to leave a distinct but light witness mark to your chisel placement.

If necessary, correct the placement of the chisel and drive it hard into the bar a little more than half way.

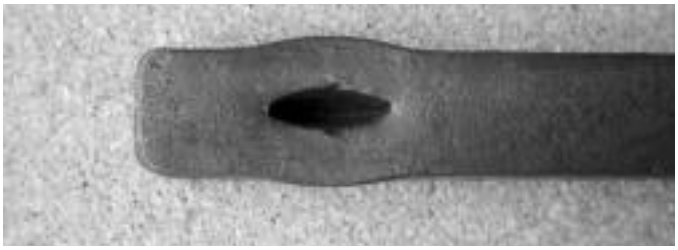
Hold the chisel vertically. Hit the chisel vertically, and you will cut vertically.

Jay Close steadies the bar against his thigh.



A "witness mark" centered on the centerpunch mark

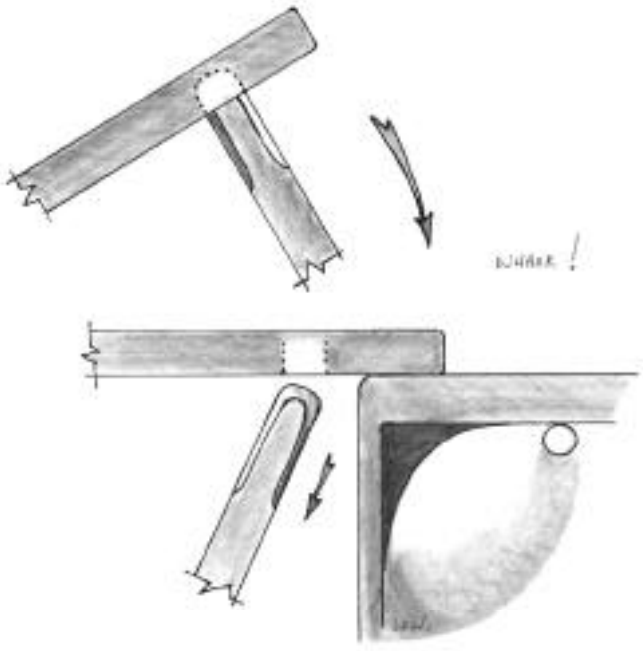
Do not allow the chisel to stay in the cut! If it softens in use, it stops cutting and begins to deform. As a starting point, three quick hammer blows to the chisel and then get it out of the cut.



The cut halfway through

Especially for a W-1 chisel, as soon as you notice it turning red, quench the edge. Residual heat in the rest of the tool will slightly draw the hardness, keeping the tool from becoming brittle.

Tip: If the chisel sticks, twist it to slightly widen the slot and it should pull free. Sometimes tapping the sides of the slot will knock out a reluctant chisel. Or turn the work upside down and swat the end of the bar on the edge of the anvil to use momentum to pull the chisel free.

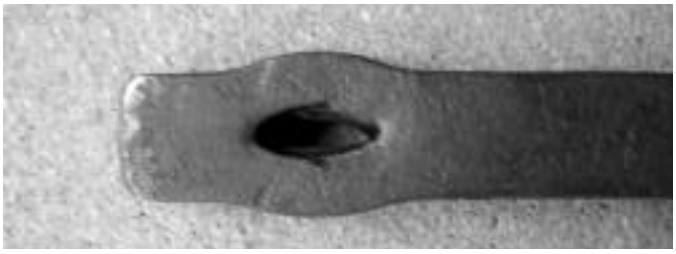


Removing a sticky chisel

With the cut a little more than half way through, put the bar back in the fire.

Tip: Inspect the chisel. If it has deformed on the edge, correct and resharpen before continuing.

Unless you need to resharpen the chisel, resist the temptation to thoroughly cool the chisel. It will cool in the air as you reheat the bar and will have enough remaining heat to not overly cool the bar as you continue cutting.



The completed slit

Step Three:

Repeat step two chiseling through from the opposite side until the two cuts meet halfway through the bar. You should see a clean opening all the way through with the sides of the slit bulged out.

Step Four

Prepare your tools so that the drift and pick-up tongs are handy. Take a good yellow heat on the bar around the slit. Tap the drift into the slit until solid resistance is met, i.e., until you are beginning to reshape the ends of the opening just by driving in the drift.

The lead taper of the drift should extend through to the opposite side of the bar. Make sure you are hitting it in over the hardie hole, the pritchel hole, a bolster block or open vise jaws.

The trick is to support the work as closely around the slit as possible.

Tip: An unsupported bar can collapse into a wide pritchel or hardie hole, so hold the bar along the side of the hole where one edge at least will receive support. If you are hitting the drift a number of successive blows, move the bar left, right, front, back around the square hardie hole or around the circumference of a large pritchel hole.

Supporting the bar with the edges of the pritchel hole

Once you meet resistance, forge the bulge of the sides against the drift working both sides evenly. Knock the drift in further to continue squaring the ends and bulge the sides again.

Remember, you are shaping the sides of the slot with the hammer working against the drift, but the ends of the slot can only be cleaned up by driving the drift in against them.

The exact balance between forging the sides with the drift in place and driving the drift deeper to clean the ends of the slot is a matter of experiment. The variables include the width of your chisel, the taper of your drift and how aggressively you pursue each shaping option.

Repeat the forging of the sides and then remove the drift by tapping on the end of the lead taper or tapping the lead taper on the anvil surface.

The sides will stretch longer and thinner. This is good. But the wall around the slot will also stretch wider. This is bad. The undesirable stretch must be forged out with the drift knocked free of the slot.

Do this now. A couple of hammer blows on each side should suffice.

WARNING: the drift is now VERY HOT and can only be handled with tongs!

If the drift has taken on a red color, quench it quickly to black but not down to hand-holding temperature.

If the bar is still at least orange, put the drift in from the opposite side of the slot and repeat the forging in of the bulge and resetting the drift.

Do not work below a clear orange to bright red heat. Do not allow the drift to get red and soften while in the slit. Get it out and keep it relatively cool. A soft internal anvil is of little use.

Resist the temptation to cool the drift to hand-holding temperature. This will rob heat from the workpiece and slow down the pace of the work. Handle the drift with tongs.

When the bar is red, remove the drift, forge in the unwanted stretch in width and get it back in the fire.

Step Five

Complete the drifting of the hole using the same procedure outlined in Step Four:

Tap in the drift until the drift squares the ends of the slot. Forge in the bulge on both sides evenly. Remove the drift and dress the top and bottom of the slot. Re-set the drift from the opposite direction and work the sides evenly again.

As a final sizing step, as the bar cools to red, drive the drift through all the way from one direction. The sides should not bulge.

The drifted slit

Then, drive the drift through from the opposite direction as the bar loses forging heat. If necessary, do some low heat dressing of the bar surfaces and tap the drift through one final time.

Step Six

Now that you have slit and drifted a mortise, measure its overall length with the bar at room temperature.

Compare that to the overall length of the bar before the mortise. The difference will tell you how much the bar stretched to create a mortise of that size.

Knowing this stretch factor, mark the center point for another mortise that will end up 3 inches from the center of the first one.

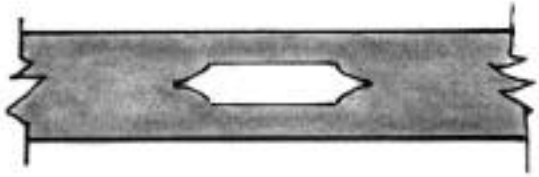
For example, say you started with 10 inches of bar. After you made the first mortise the bar grew to 10 and 1/2 inches. From the mortise center, the mortise pushed the bar 1/4 inch forward and another 1/4 inch back. If you want a second mortise a specified distance from the first, you must anticipate this 1/4 inch stretch center to center.

Mark the center of the second slot half the overall stretch of the material closer to the first slot than the needed final dimension.

Slit and drift the second mortise just as the first.

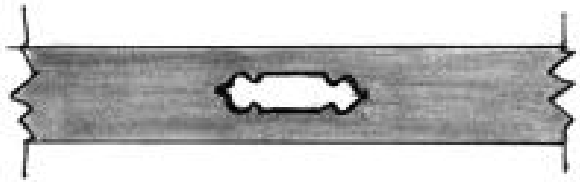
Troubleshooting:

Your mortise should look like a rectangle reflecting the cross-section of your drift. If it looks like the drawing below, the drift never had a chance to square the ends of the slit. This came about because either (1) the length of the chisel cutting edge was too long compared to the width of the drift, or (2) you did not drive the drift in far enough before stretching the sides of the slot.



Results of a chisel too long for the drift

If your mortise looks like this, you have over-stretched the sides of the slot so that on the final forging the drift was not completely filling the mortise.



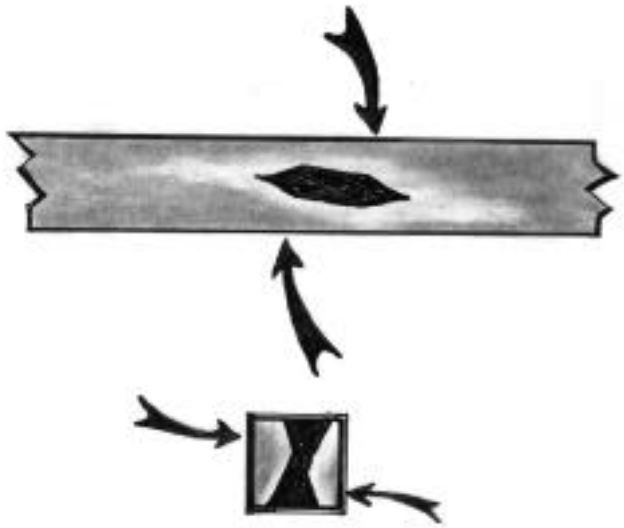
Results of overstretched sides

You can also create a mortise that is fairly rectangular but too long. This comes from over-stretching the sides of the slot. With a careful heat localized around the slot you can upset the slot shorter and then re-forge and drift. Remember to adjust the balance between stretching the sides and driving the drift on the next mortise. If this does not help, you probably need a narrower chisel.

Sometimes the chisel cuts are centered in the bar but misaligned along the bar length. Often this problem will sort itself out in the drifting. You can also put the drift in—it will enter at an angle—and tap it more upright as you forge in the sides. Do a little at a time from both sides taking advantage of the stiffness of the drift "on edge."

Chisel cuts not centered in the bar will leave uneven material in the mortise walls. You can help the problem by concentrating your hammer blows on the thicker sections and avoiding the thinner ones. In the drawing below with two off-center chisel cuts, hit where the arrows point.

A similar correction can assist if the slit is angled away from the axis of the bar. Work the areas shown below more.



Correcting off center chisel cuts

Tip: A poorly shaped chisel edge can cause much frustration. Even if centered on the bar and struck vertically, an asymmetrical edge will lead the chisel at an angle causing poorly centered cuts. Inspect the cutting edge of the chisel often.

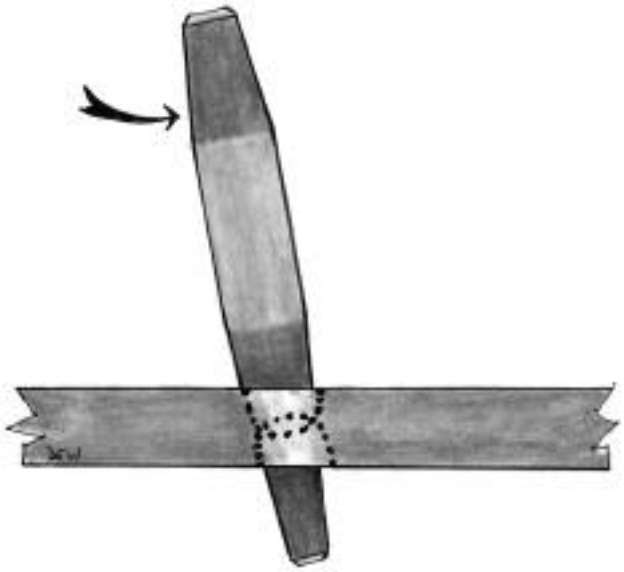
If your mortises are not 3 inches apart, you will need to adjust them—hopefully, just slightly. For greatest accuracy, remember to make your assessment when the bar is at room temperature. For your own interest, record the measurement both while the bar is red and when it is at room temperature and note the difference.

If the holes are a little far apart, take a long heat in the middle. Make certain the two slots are cool and carefully shorten the bar by upsetting. With care this can be done without producing an obvious bloating of the middle of the bar.

If the distance between the slots is short, you'll have to draw out the middle to lengthen the bar. Again, take a long heat and distribute your efforts over a long section of the bar so as not to produce an obvious thinning.

TARGETS

Time Targets: With experience and confidence you will be able



Chisel cuts angled away from the axis of the bar

to cut the slit in one heat and drift it in perhaps two or three more. For your first efforts, cut half way in one heat and take a second heat to complete the slit from the opposite side. Then allow four or even five heats to complete the drifting and a final one for clean up.

Shape and Dimension Targets: The dimensions of the slot will be largely determined by the size and shape of your drift, i.e., 1/4-inch by 3/4-inch. This should be "on the money," no more than a 1/16-inch longer than the drift is wide.

The bar should remain the same dimensions through the slot as the rest of the bar. A straight edge laid along the flats of the bar should show no particular swelling or cavity around the mortise.

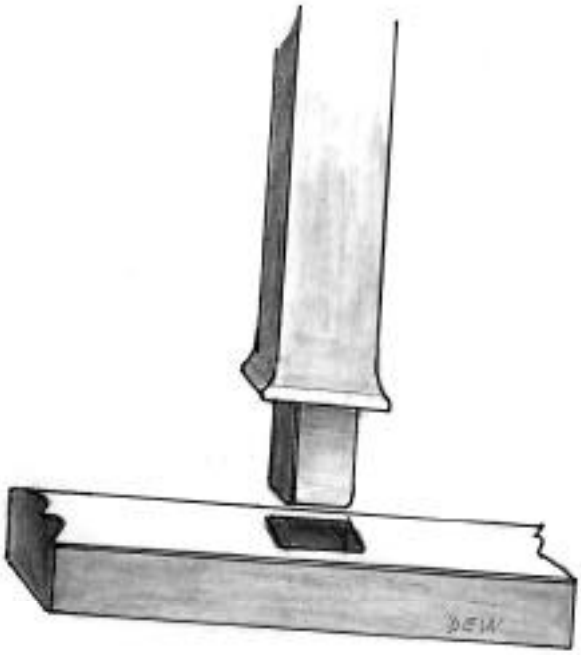
Tip: Hot-rolled bar often has slightly rounded corners. The area around the two mortises has been bulged, stretched and reforged enough that the corners are likely quite square. The contrast of square corner areas and round corner areas can often fool the eye into "seeing" a change of dimension where none exits, so observe carefully when testing the sides for straightness.

The slots should be centered in the bar with even wall thicknesses. The distance between the two slots should be 3 inches plus or minus 1/16-inch.

If you upset or drew out the bar between the slots to achieve the proper dimension, any dimensional change in the bar should be spread over as wide an area as possible and not be immediately obvious. The bar should be straight along its axis.

Mortise and Tenon Joinery

Text and Illustrations by Doug Wilson



#1. Example of technique

#2. A top and bottom side set

Lesson Number Nine–Mortise and tenon joinery

Definition:

Making a mechanical joint with two or more pieces

Intent:

The smith will learn to forge a tenon and assemble a mortise and tenon joint.

Tools

Side set – top and bottom (drawing #2) Note that the cutting edges aren't sharp. The cutting edges are slightly radiused.

Set hammer

Monkey tool or bolster plate with 1/4" x 3/4" hole (drawing #3)

(This is a tool block with a 1/4" x 3/4" hole in center.)

Materials:

1/2" x 1" x 18" mild steel bar.

Method:

Step One:

Upset end of bar and forge to 1 1/8" x 5/8", 3/4" from end. End tapers down to 3/8" x 3/4". (drawing #4) Mark bar on hot cut 3/4" from end.

Step Two:

Take a full yellow heat. Place the bar over the bottom side set. Hit a light blow. The bottom surface of the bar will be cut. Turn the bar up on its corner. Strike another light blow.

Turn bar onto uncut next surface. Strike again. This marks the second side of the bar. (drawing #5)

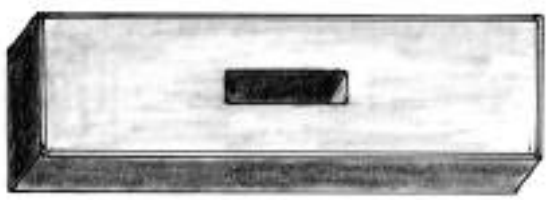
Repeat and cut the remaining two corners and sides with light blows.

Notes: The light blows on the corners help to insure proper tool alignment.

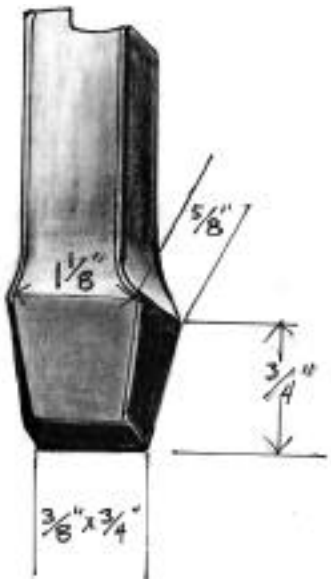
Misaligned cuts or double cuts cause hot shuts, then cracks. Proper tool alignment is critical here. Any mis-cuts should be filed out immediately.

Once marked, the bar can be supported on a stand or your hip. Use top tool to continue. (See previous lesson for bar support.)

Reheat bar if necessary. Continue cutting until the core of the bar is just a bit oversize, in this case about 5/16" x 13/16".



#3. A bolster plate



#4. Upsetting and forging dimensions

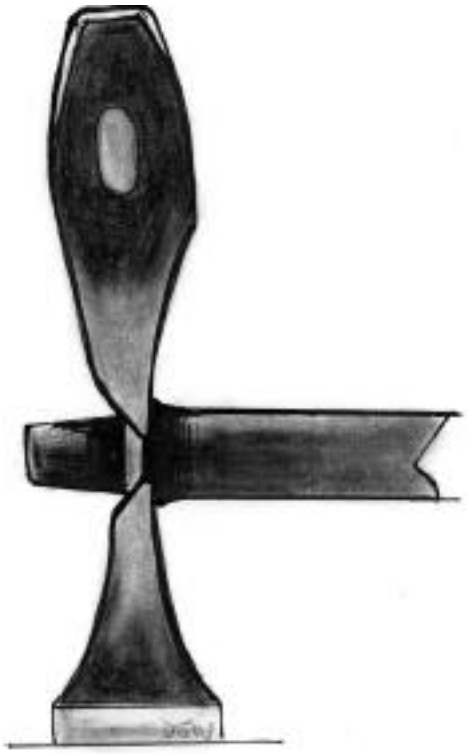
Notes: If the tenon is a bit too fat that's ok. Too thin won't do.

A striker's assistance helps with drawing down the tenon.

Step Three:

Reheat bar to full yellow. Place bar over sharp edge of anvil face. Place set hammer directly over it. (drawing #6)

Strike a heavy blow. Turn the bar 1/4 turn. Strike again. Turn again in the same rotation. Strike again. You are drawing out the tenon.



#5. Marking the second side of the bar

Continue until you have drawn down the tenon to 1/4" x 3/4"; length as far as it goes.

Finally, lightly forge down the corners.

Note: As you forge down the tenon, the set hammer and the anvil must be parallel. Check size of tenon by inserting end of tenon into bolster.

Step Four:

Upset square shoulders. Reheat to full yellow. Heat should extend about an inch up from tenon shoulder.

Note: Quench the tenon to prevent burning if necessary.

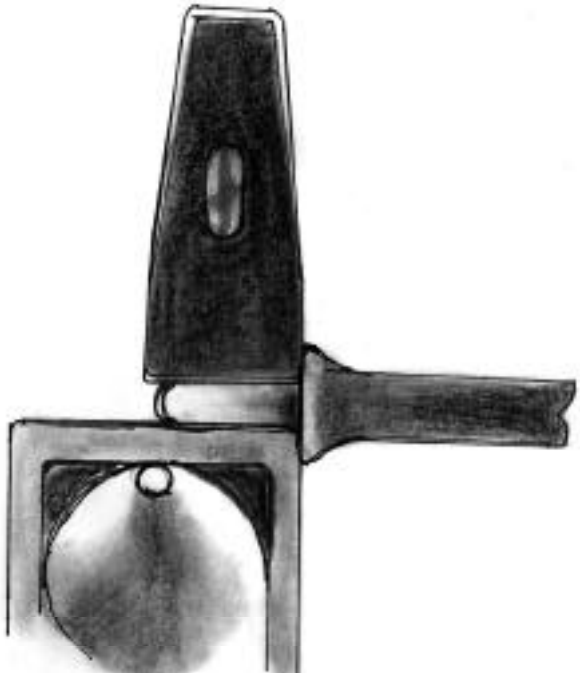
Pull the bar from the fire. Set bolster over the hardie hole. Insert tenon. Upset and square by hitting hard on top end of bar. (drawing #7)

Straighten bar as necessary. Square shoulders to bar with light hits on anvil face.

Note: Tenon should be centered on the bar. Centerlines of bar should be straight. Shoulders should be straight and square.

Step Five:

Cut tenon to length on cutoff hardy. In this case, length should be 1 1/4" from shoulder.



#6. Using the set hammer

Note: Beveled edges on the end of the tenon help prevent thin, sharp or cracked edges on the finished tenon head.

Step Six:

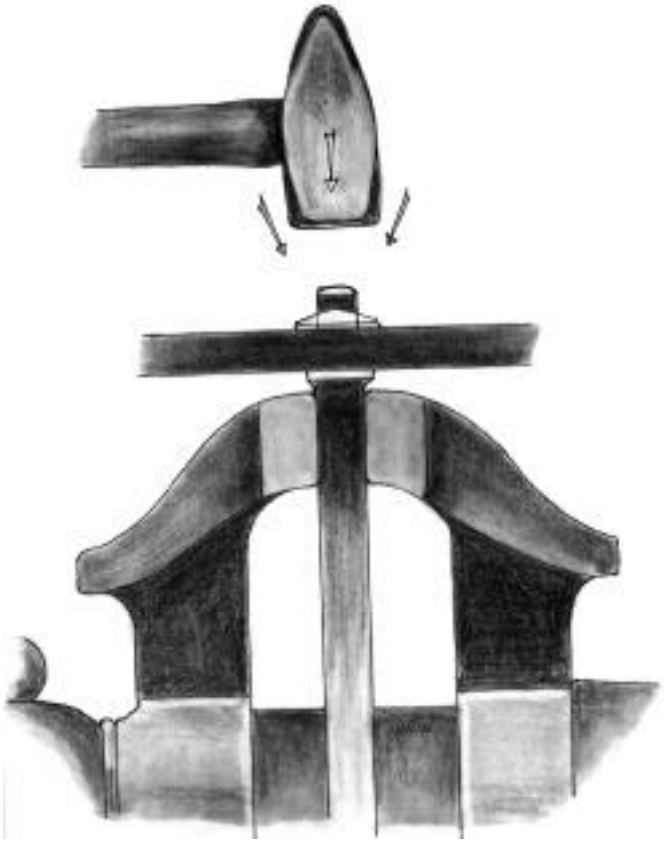
Finishing the joint. Heat tenon and about 1" above shoulder to full yellow.

Quickly set bar in vise. Set mortise onto it. Tap it down so it sits firmly on tenon shoulders. With rapid hammer blows, upset the tenon. (drawing #8) First hammer blows are straight down. Finish with angled blows.

#7. Using the bolster plate

Note: The entire tenon and a bit of the shoulder must be at a bright heat to insure a tight joint.

Forge the head of the tenon into a symmetrical shape with smooth edges. It should be centered on the face of the bar it has joined.



#8. Upsetting the tenon

Note: If you run out of heat, you can use a torch to reheat the tenon head. It is best to finish this operation in one heat. A second heat should only heat the tenon, not the bar with the mortise. (drawing #9)

Troubleshooting:

If the tenon has cracks at the shoulder, this was caused by (1) cutting too deep in step two, (2) misaligned or double cuts, or (3) forging tenon at black heat.

Note: File out hot shuts before and during forging of the tenon.

If the tenon head is not centered on the bar it joins, your upsetting blows may not have been straight down or the mortise was not centered in the bar the tenon joins.

Targets, Time:

Upsetting bar, one heat.

Cutting shoulder and drawing out tenon, two to three heats.

Trimming end of tenon, one heat.

Assembling pieces and heading tenon, one heat.

Targets, Dimensional:

Tenon head should be symmetrical, without sharp edges and centered on the bar it joins.

Tenon shoulder should be the same dimension or slightly smaller than the bar it passes through and joins.

#9. The lesson completed

Forge Welding

By Dan Nauman
Illustrations by Tom Latané
Photos by Dan Nauman

Lesson Number 10– Forge Welding

Definition:

Fusing two or more bars together by bringing them to a high heat in a forge, and applying pressure to the area being fused by hammer blows.

Lesson: Upsetting, scarfing (see *Definitions, below), and forge welding the ends of two bars of equal size together to make one bar.

Intent: The smith will learn the technique of welding two bars of equal size together, accurately maintaining the original stock size and shape after welding.

Materials: Two 15" bars of 1/2" square mild steel.

Tools needed: Basic tools include standard cross peen hammer and anvil. Flux (see *Definitions, below), either borax or EZ Weld. Calipers and a square can be used to evaluate your work.

Method:

Forge welding is used in several circumstances: to produce a smooth transition of adjoining elements; to secure several elements into a bundle (i.e. leaves, grapes, acorns, basket twist); to join a bundle to another element; to close the ends of a single bar shaped in a ring, oval, or rectangular shape (as in a frame); to join mild steel to high carbon steel (as in an ax bit); or to laminate several bars together to form a billet (as in Damascus laminate).

A forge welded sample from Cyril Colnik

Definitions:

1.) Scarf (scarfing): Preparation or preparing a portion, often the end of a bar for welding by tapering to a thin edge which can be blended into the mating material.

2.) Flux: The product applied to the areas to be fused to reduce oxidation, and lower the melting temperature of the scale.(Examples: borax, EZ weld, etc.)

3.) Clinker: The hard, gritty, often glassy mass that congeals in the bottom of the fire-pit.

4.) Coke: Soft coal that has had the bulk of its impurities burned out. Coke's appearance is puffy. As good quality soft coal burns, it expands and congeals to the neighboring coal nugget forming a larger mass. Almost entirely carbon in its makeup.

Note: Just as there are different approaches to other aspects of forging, the same is true for forge welding. It cannot be said that any one way is best, as there are many experienced smiths who produce consistently sound welds in a different manner than explained here. Different scarf forms, different fluxes, and several other aspects of forge welding can be learned and utilized. To introduce these differences in this lesson would prove confusing to the student. Thus, this lesson will concentrate on the method taught to me in the 1970's. Differences aside, the fundamentals usually prove to be similar or identical.

In all cases, a high heat is needed at the point of fusion to successfully weld the bars together. The color of the bars should be yellow to yellow/white when removed from the fire. The only exception to this would be when welding high carbon steel to mild steel. A lower heat of orange/yellow should be the highest heat applied so as not to burn the carbon out of the carbon steel.

The gray scale that forms on a bar when heated is the enemy of the forge weld. The bars will not fuse properly when scale is present. Scale forms on the outside of the bar in the presence of oxygen. Flux forms a barrier around the areas to be fused, protecting it from oxidation. It is applied to the bars at an orange heat. Flux is not glue, or a bonding agent, rather it lowers the melting temperature of this scale, and prevents more scale from forming while heating in the fire. Some smiths theorize that to

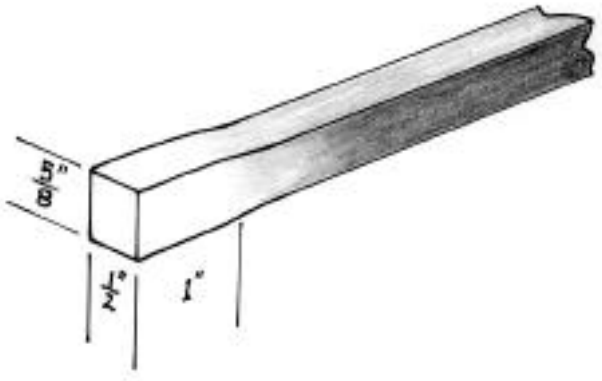


Figure 1: Upset end preparation

some degree flux also raises the burning temperature of the metal.

Another important aspect of welding is to be absolutely sure you have a “clean,” domed fire. A clean fire is free of a clinker in the fire-pit, and has no fresh coal burning in the center of the fire. A good welding fire also has an abundance of coke domed and banked in the fire-pit. Should the fire “hollow out” while heating the bars, only coke should be added to the fire to replenish the fuel. Fresh coal cools the fire, and also introduces impurities naturally found in coal. These impurities are largely burned out as the coal becomes coke.

When taking a welding heat, a good deep fire with the bar in the center of the fire under a good two or so inches of coke will reduce (but not eliminate) the amount of scale which forms on the bar during heating.

Step One–Preparing the scarf:

Taking a short high (yellow) heat on the last 1" of the bar. Then upset about 1" of the end of the bar so that the bar measures at least 9/16" square. (See previous lesson Number 7) Next, forge one dimension back to 1/2" producing a cross section measuring 1/2" x 5/8".

Step Two:

Take another yellow heat on the end of the bar, again on the last 1" of the bar, place the end of the bar (with the 5/8" sides vertical) squarely on the anvil’s face with the end of the bar 1/4" from the inside edge of the anvil. The edge of the anvil should be somewhat sharp for this step. Hitting straight down with the hammer’s face halfway above the anvil face and halfway beyond the anvil face (Figure 2, photo), reduce the cross section to about 1/2 the thickness of the material, in this case to 5/16".

Tip: In order to create a clean shoulder in this operation, put a slight downward pressure on the bar so the bar stays where you put it. Then after the first or second blow add a slight forward pressure to keep the bar from “stepping” off the anvil.

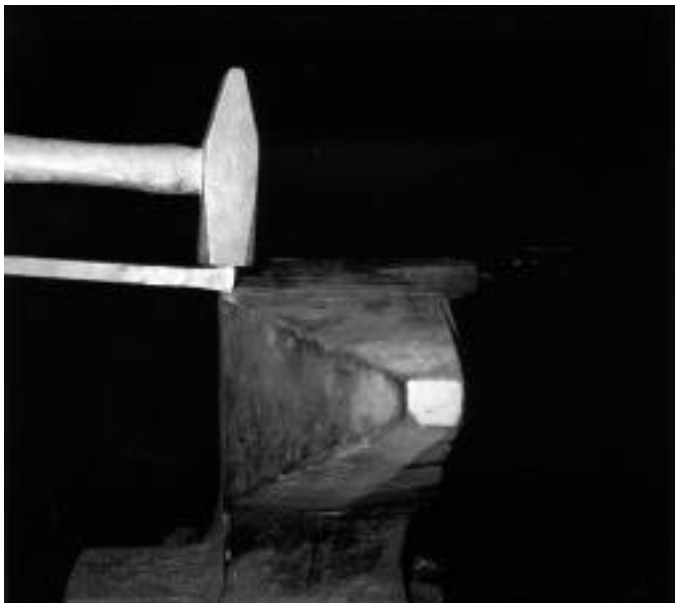


Figure 2: A half-face blow

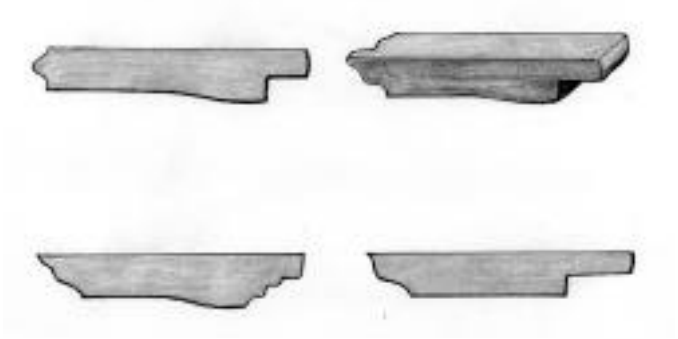


Figure 3:Above, correct. Below, incorrect. Left– initial shoulder backed off anvil too soon. Right– no upset remains for scarf to be laid upon during weld.

Step Three:

The forging dynamics of the material will cause the area of the bar on top of the anvil to slightly spread wider than desired. In the same heat from step two, turn the bar 90 degrees, and forge this area back down to 1/2" in thickness.

Step Four:

Take another yellow heat on the last inch of the bar. Place the shoulder produced on a sharp edge of the anvil, pressing the shoulder squarely against the side of the anvil. The hand the bar is holding should be lowered slightly so the face of the scarf is off the anvil face. (Figure 4, photo). Move the hand holding the bar to the left of square, and take a blow. Moving the bar back and forth at a 90 degree angle (right to left), and using each step produced by the previous blow to brace against the side of the anvil, slowly step the bar off the anvil. (Figure 5, photos). In this same process, the profile of the bar should be drawn out to a flat point. (Figure 6, photo). If done correctly, the face of the scarf should have steps as shown in the figure 7 below. When the scarf

Figure 4

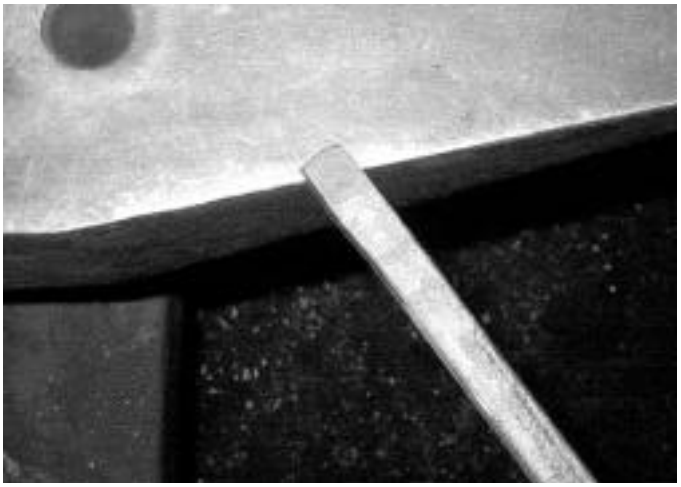


Figure 5

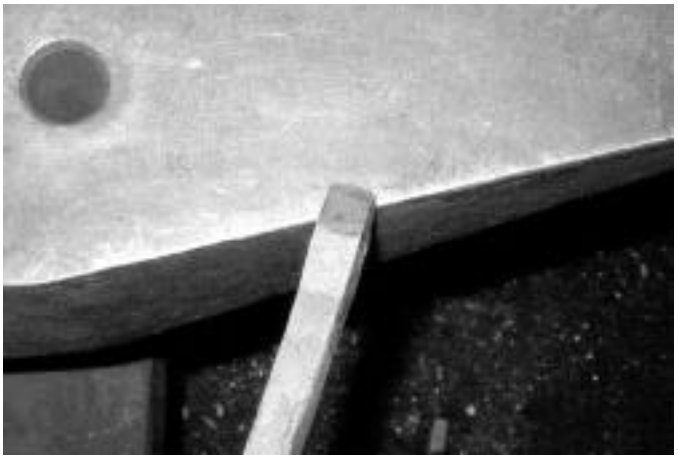


Figure 6

is drawn out, forge a slight curve at the end of the scarf. (Figure 7) You should be able to do all of step four in one heat.

Notes on scarves:

The reason for the curve at the end of the scarf is simple. The anvil acts as a heat sink when hot metal is applied to it. If the end of the scarf is not off the anvil when welding, it might cool too rapidly, and the weld will not be properly fused in this area. The curve keeps the thin edge of the scarf off the anvil before the first blow, retaining the heat longer to produce a sound weld.

The thin tapered edge of the scarf is formed to produce a smooth weld joint. A scarf with a thick edge will produce a weld with a very visible seam (Drawing, figure 8).

Step Five:

Repeat steps One through Four on the second bar.

Step Six: Fluxing the scarves.

SAFETY! - Some fluxes may emit noxious fumes when heated. Make sure your forge and building are vented properly.

Reduce the air blast in the fire if you have an electric blower. If you are manually applying the air blast, reduce the force of the blast to more of a whisper. This will reduce the chances of burning the scarves while fluxing by reducing the available oxygen in the fire.

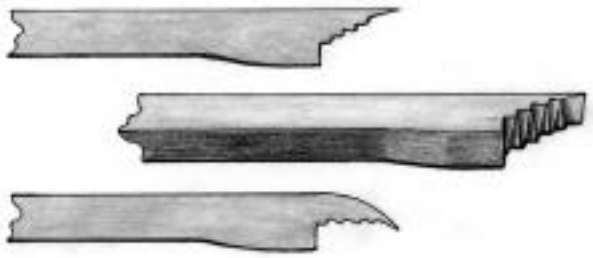


Figure 7:Top– shouldered and stepped scarf. Bottom– Curved tip. Shoulder prevents scarf from overlapping beyond upset area when scarfs are quickly placed together.

Making sure you have a clean and deep fire, place the scarves into the center of the fire, face up. If the bars are not covered with coke, cover them. When the bars reach a bright orange, with the bars remaining in the fire, take your fire rake make a hole in the fire over the scarves so flux may be sprinkled on the face of the scarves. With a small spoon with a long handle (so you do not burn your hand), apply enough flux with to cover the scarf, as well as beyond the scarf where the other scarf will join. (Figure 9, drawing). Cover the bars once again with coke. When you are finished fluxing the scarves, position them so they are facing down in the fire.

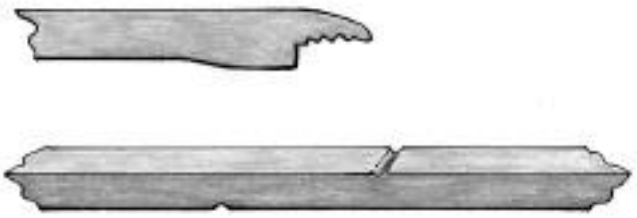


Figure 8: Blunt scarf makes seam difficult to blend

Notes:

One of the biggest mistakes beginners make in welding is not applying the flux back far enough on the bar where the bars will be fused.

Some smiths prefer to flux all sides of the scarves, while others simply apply flux to the scarf faces. The theory behind fluxing all sides of the bar is to insure that all surfaces are free from scale, as well as to increase the burning temperature of the bar. The bar can and will burn if allowed to get to a full sparkling white heat, at which point the flux will also burn off. The bars likely will not weld at this high temperature. Also, the molecular structure of the material will break down, creating a weaker joint, and often an unsightly weld.

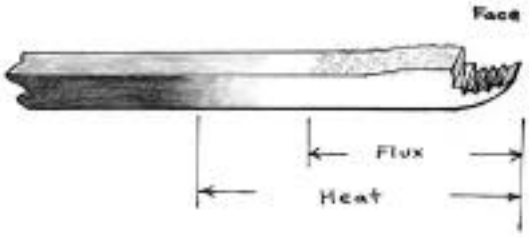


Figure 9:Fluxed face heated from below.

If you choose to flux all sides of the scarves, turn the bar 90 degrees only after you are certain the flux has adhered to the scarf surface. You will know when this happens, as the flux will be the same color as the bar. If one bar gets hotter than the other, move it to the side of the fire where the fire is cooler, or reduce the air blast further.

Fluxing the scarves in the fire keeps them hot, and reduces the amount of scale formed, therefore shortening the time it takes to produce the weld. Removing the bars from the fire to flux the scarves is not necessarily wrong, as many smiths prefer this procedure, and do so successfully. Sometimes, fluxing in the fire is virtually impossible (i.e. welding a wagon wheel tire.) In these cases, removing the bar from the fire is necessary.

Always keep coke on top of the bars when not in the act of fluxing.

Tip: Rub soapstone or chalk on the face side of the bar to indicate direction of the scarf face when pulling the bars from the fire.

Step Seven: Welding the bars

Have your hammer at the anvil in a position to grab it quickly. The scarves are at a welding heat when they are at a yellow-white appearance in color (Often referred to as a "welding heat.") Make sure the scarves are heated well beyond the shoulder where the mating bar will join. Some smiths wait to see just a few sparks coming from the fire, indicating the piece is just starting to burn. This is not necessary, and can lead to burning the tips off of the scarves.

Tip: If you are not sure if the pieces are at a welding heat, gently touch the pieces together in the fire. If they want to stick, almost like a magnet, they are probably ready to weld. With experience, this touching in the fire will not be necessary.

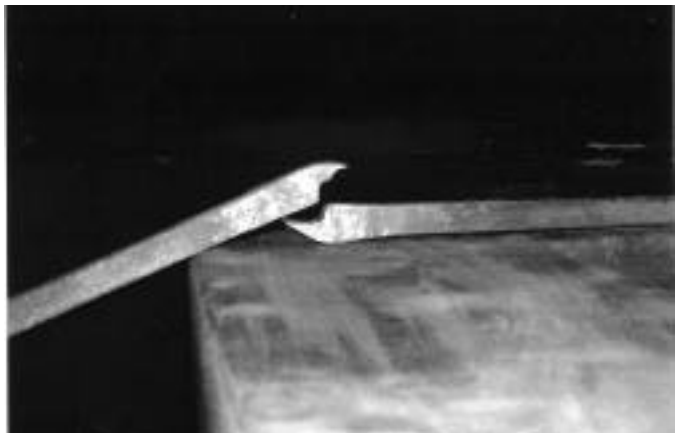
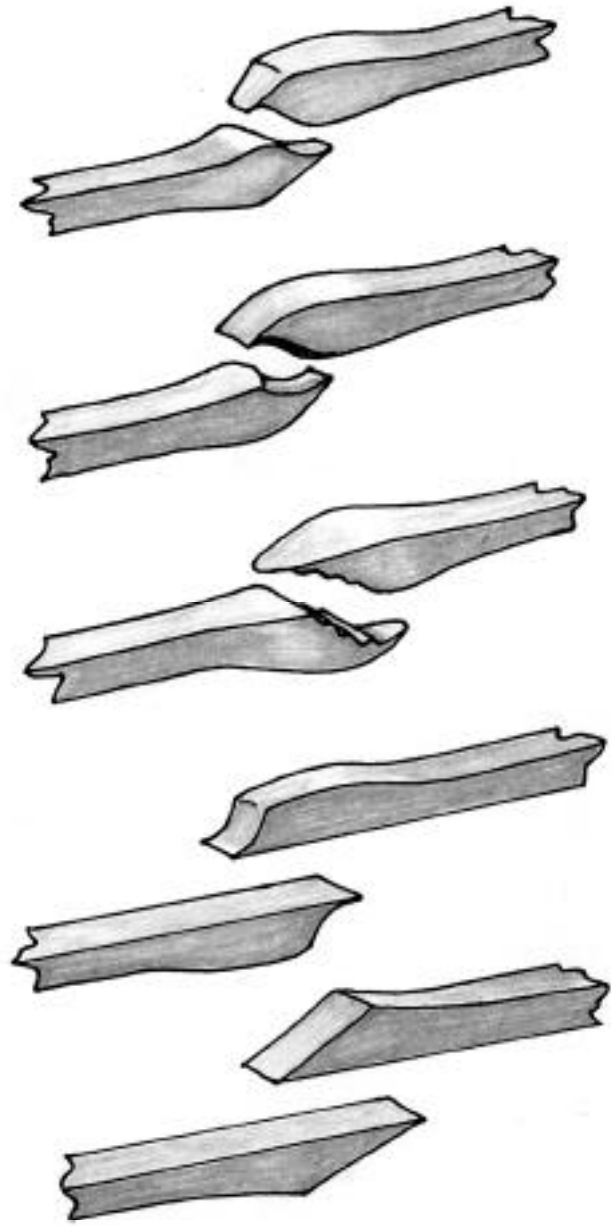


Figure 10



Some other forms of bar end scarfs. The 90º shoulder on the scarf described in the text will aid in quick alignment of bars to be welded, preventing overlap beyond upset material.

SAFETY : When welding, molten sparks fly from the bars which can burn others, as well as you. Alert others in the area when performing a weld, and make sure other items in the shop that are flammable are protected from the sparks. Some smiths wear a protective leather apron when welding to prevent their clothes from burning. You and anyone else present should be wearing eye protection with side shields at all times. After welding, be aware of the possibility of fire caused from stray sparks in the surrounding area i.e. shop rags, charcoal, dry wood, etc. These items and others ignite easily from molten metal

Figure 11

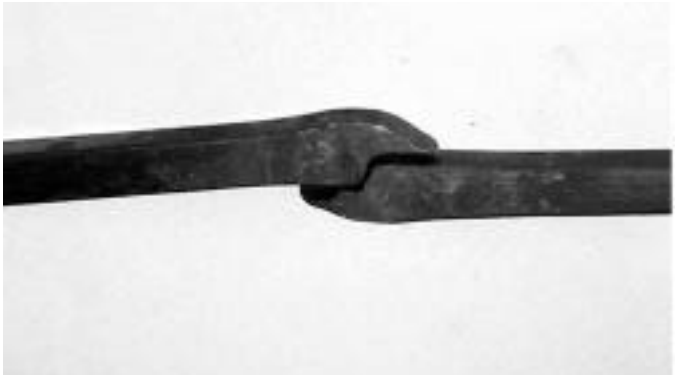


Figure 12

and flux spattered from the forge welding process.

Bring the pieces out of the fire, rotating one piece 180 degrees so that the scarf is facing up. Place the bar with the face up on the center of the face of the anvil, coming in from the far side of the anvil. (This bar should be in your hammer hand.) Place the other bar on the near edge of the anvil, with the scarf off the face, pointing up at about a 45 degree angle. (Figure 10, photo). In a hinging fashion, lower the scarf down onto the opposing scarf, keeping contact with the edge of the anvil to control the accuracy of the placement of the scarf (Figure 11, photo) and press down on the opposing scarf. The heels of the scarves should be placed together as shown. (Figure 12, photo). Press down hard enough so you can release the bar in your hammer hand.

Release the bar in your hammer hand, grab the hammer, and strike firmly in the center of the joint. Forge the entire joint rapidly with six or seven blows. Make sure you forge the thin tip of the scarf as it will cool rapidly. Next, flip the now welded bar 180 degrees to forge the opposite side. Hit six or seven blows on the entire joint and then turn the bar 90 degrees and repeat five or six more blows on the joint. Flip the bar 180 degrees and hit the joint once again five or six blows. Repeat as necessary, never forging colder than a medium orange heat.

Note: Dark spots on the joint indicate cooling of the material and will not weld there. This may be caused by too low of a

Figure 13: Bars for practice weld– no alignment of scarfs.

heat, or inadequate fluxing. These areas must be fluxed again, returned to a welding heat, and forged to fuse the joint.

While welding, keep in mind that you do not want to forge the cross section of the joint down beyond the parent stock size. Also, be careful not to forge beyond the joint as this will reduce the cross section of the bar beyond the parent stock size.

With a properly executed weld there will not be any "dark spots" or evidence of a scarf. If there is evidence that the weld is not complete, flux the open seams of the joint, and take another welding heat. Remove the bar from the fire, and forge down carefully, so as not to greatly reduce the cross section of the bar beyond the parent stock size.

Note: Timing is important. If you take to much time getting the pieces from the fire to the anvil, you may lose too much heat to weld the bars together. To increase your proficiency, you may want to take a few "practice runs" by removing the bars while cold from the fire pit positioning them on the anvil as described in Step Seven. Do this until you are comfortable with the procedure. You will then be able to release the bar from your hammer hand and grasp the hammer without the bar falling to the ground.

Tips:

-Some fluxes, such as EZ Weld brand, are very aggressive and may adhere to the metal after the weld has been completed. To remove it, take another welding heat, remove the bar from the fire, and scrub vigorously with a stiff wire brush. Flux is harder than a file, so do not try to file the flux off, as it can ruin your file.

-A lighter hammer of 1 1/2 to 2 pounds may work better than a larger hammer. With a lighter hammer, the hammer can be swung faster, and more accurately. Also, the chance of forging

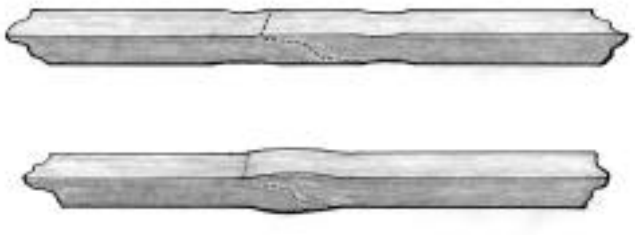


Figure 14: Top– thin areas due to loss of material from burning, too little upset, or over-hammering, must be upset. Bottom– remaining bulge must be drawn down to dimension.

down beyond parent stock size is reduced with a smaller hammer, as you will not have the heavier force of the larger hammer.

-You may want to first practice a more simple weld to get used to the properties of forge welding. The faggot weld is a simple, crude weld which has no end preparation (no scarves.) Try bending a 3/16" x 3/4" piece in half and weld the last 3/4" of the end of the bars together. (Figure 13, drawing). Be extra careful when performing this type of weld, because the larger surface area causes more molten flux and sparks to fly from the joint.

Step Eight: Refining the weld (If necessary)

If the cross section of the joint is still larger than the parent stock size, place the bar back in the fire and bring the joint to a welding heat. Remove the bar from the fire, and carefully forge the joint back down to the parent stock size.

Potential problems and solutions:

If the weld is properly executed, the joint is invisible, the bar has no bulges or "necked in" spots, and has sharp 90 degree corners. (Figure 14, See drawing of bulge and necked in spots). To refine the bulge, proceed as described in Step Eight.

If the bar is necked in it will be more difficult to fix. The portion of the bar where it is necked in is taken to a welding heat, and then upset (refer to Lesson Seven) back to the parent stock size. A poorly executed weld will begin to come apart or fail entirely in the upsetting process.

If a parallelogram was formed at the joint, first upset the joint, then take another heat and forge down the acute angles slightly. (As explained in Lesson One.) Then carefully reduce to the parent stock size.

Targets:

-The scarf is produced in one heat.

-The weld is completed in one to two heats, and the joint returned to the parent stock size.

-The joint is to be square in section with sharp corners, no necked in areas, and no bulges. You can check your accuracy with a pair of calipers. Check for squareness with a steel square.

-The welded bar is to be straight, have no twist, be free of flux residue and the bar should have no visual evidence of a seam.

More examples of forge welding from Cyril Colnik

Drawing Down- Part One

Table bracket by Jay Close. Every bar was resized from larger stock.

by Jay Close

Illustrations by Tom Latané, photos by Jay Close and Jane Gulden

Lesson # 11- Drawing Down- Part One

Definition: Reducing the cross-sectional area of a bar.

Lesson: Resizing a 1/2-inch square bar into a 1/4 by 5/8-inch rectangular bar by hitting the bar "on the flat."

Intent: This lesson is a first practical experience in hand forging.

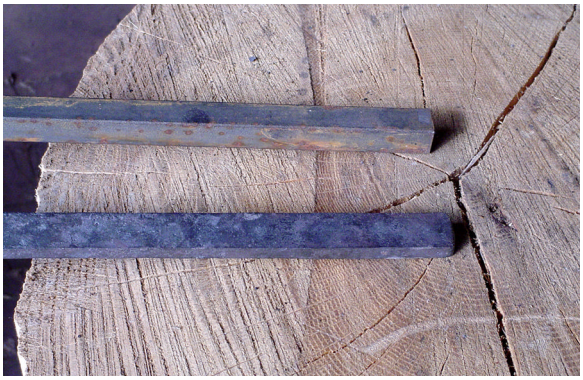
The student's primary mission is to strive for good technique: proper fire maintenance, good heat selection and use, and relaxed and effective hammering.

After familiarity with the process, the student should be comfortable working a bar linearly, from one end to the other, with minimal reheating of finished sections.

The student will also practice correcting twist and crookedness in the bar and gain experience working to given dimensions.

Tools: Basic tools are needed. Include a straight edge and a double caliper. Lacking a double caliper, two outside calipers can be substituted. Set one caliper to 1/4 inch, the other caliper to 5/8 inch.

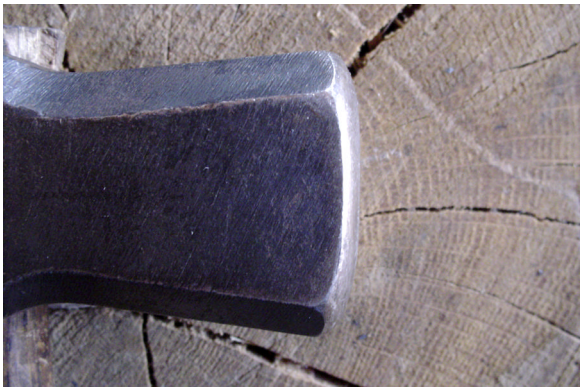
Hint: An easy way to repeatedly set your calipers accurately is to set them to an unworked bar of the target dimension. Collect an array of short bar sections that become your shop's standards for setting caliper dimensions.



1. The starting bar and the resized bar.

Make certain your hammer face is properly ground, without sharp corners.

Prepare two "winding sticks" from 1/4 by 3/4-inch bar as described below. Feeler gauges will be helpful in evaluating the work, as will a dial caliper, if available.



2. Properly ground hammer face

Material: 1/2-inch square mild steel about 24 inches long.

Method: The bar is heated in sections and each section resized by hammering flat on the bar face. Each section is finished before moving to the next. Corrections to the bar are carried out as needed. When half of the bar is resized, it is turned end-for-end and the resizing continued from the middle where the work left off.

Step One

Review the earlier discussions on hammer selection, the ergonomics of forging, fire maintenance and shop safety.

Place the bar horizontally in the neutral part of the fire.

The tip of the bar will heat more quickly. Place it beyond the fire's hot spot and let the heat of the bar radiate to the end.

3. Bar placed in the fire horizontally, with the tip beyond the hottest part of the fire

To speed heating, keep the fire built up on the sides and keep the bar covered with loose coke. You should still be able to monitor the heat of the bar through this coke layer.

Heat no more of the bar than you can work at any given hammering session, perhaps three or four inches of the bar.

At a yellow or light welding heat, get the bar to the anvil where your hammer is waiting. The bar will never be hotter and never be softer than when you first take it from the fire. DO NOT WASTE TIME GETTING TO WORK.

Hint: Set your hammer in the same place on the anvil and in the same orientation, ready for each heat. This minimizes confusion and wasted time.

With the bar held horizontally and flat on the anvil, with the hot part in the middle of the anvil face, hit FLAT, HARD, and RHYTHMICALLY.

Hint:: Regardless of the length of the heated section of the bar, only work on as much of the bar as you are able to completely resize in one or two heats–probably no more than two or three inches.

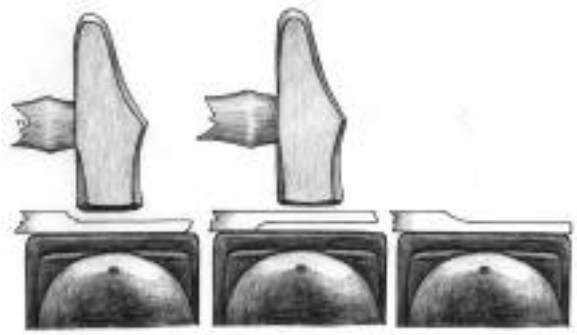
The first blow inevitably creates an offset or step in the bar on one side. Keep the bar horizontal.

Hit HARD four or five times on the top, then roll the bar 180 degrees to work the surface that had been against the anvil.

Try to roll between hammer blows with no interruption of the rhythm. Keep the holding hand relaxed to help you quickly and assuredly manipulate the bar.

When you flip the bar 180 degrees, the offset created by your work on the first face keeps the bar from sitting flat on the anvil. This is unavoidable, but your first blows on the new side will push the metal down to contact the anvil.

Hold the bar horizontally. Resist any tendency to raise or lower the holding hand.



4. Step created by drawing part of the bar down. Bar is rotated 180° and kept horizontal as drawing continues.

As the re-forged section lengthens you can sometimes hang the unworked section of the bar off the anvil face and still be working toward the middle of the anvil. This will help you keep the bar horizontal.

Take four or five blows on the new face, then work the edges of the bar. Smooth them and note the effect of your hammer blows. You may need to adjust the strength of the blow because you are hitting a narrower surface. On the other hand, if these edge blows become too light, you risk the development of an I-beam cross-section to the bar. See the discussion in Part Two of this article under "Forging Dynamics," in the next issue.

Work all sides of the bar. Alternate heavy flattening blows on the faces of the bar with blows needed to refine the edges.

Develop a rhythm. For example:

five hard blows on one face.

roll the bar 180 degrees and hit five hard blows on the opposite face.

roll the bar 90 degrees, work the edge.

roll the bar 180 degrees, work the other edge, and repeat.

Hint: The tip of the bar heats fastest and reshapes easiest. There is danger of over-thinning the end. Forge the tip when the bar is slightly cooler and offers more resistance.

If you reach an orange heat and are far from the target dimensions, put the bar back in the fire. Keep it soft.

Take a second heat on this section and continue forging.

Note: If you have been unable to complete a section of the bar by the end of the second heat, think about why this is the case. Are you not hitting hard enough? Perhaps you are spreading your efforts over too much bar? Did you start at a yellow heat to maximize softness and available time? Are you wasting time through ineffective hammering or taking too long to get to the anvil?

Intelligent analysis and self-correction are the foundations of progress as a blacksmith.

If you near finished dimensions at an orange heat, make a check with the calipers and continue working to a dull red. The bar is much stiffer now and resists shape change. That is fine for lighter, smoothing blows.

5-7. Working the face of the bar in the middle of the anvil, working the edge of the bar, and working the face with the unforged bar off the anvil.

The calipers should just slip onto the bar and glide over the surfaces without rattle or feeling sprung open. With practice you get a sensitive feel for dimension by use of these simple tools. Remember, unless the caliper points are opposite each other on the bar, they will not measure accurately.

As you smooth, pay more attention to the texture your hammer leaves. If you:

a) Maintain a clean, scale-free anvil face

b) Do not overheat the bar

c) Work all sides of the bar, and

d) Work all sides down to a dull red heat,

You can achieve a clean, hammered surface.

Often it is convenient when forging a long area to keep the hammer hitting in one spot on the anvil and work the bar back and forth beneath it. This can be particularly effective when working toward a smoothly hammered surface.

8-9. Top– proper use of the caliper with points opposite each other. Bottom photo shows a false reading.

Hint: You may notice that the side of the work held against the anvil (if the anvil surface is clean) often appears smoother than the flat you are hammering. The broad flat of the anvil naturally creates a smoother finish than the hammer. Use this to your advantage, working each flat equally against the anvil as the bar approaches dull red.

Use the available heat wisely. The first part of the heat when the bar is softest is for the major shape change, the latter part of the heat is to refine the shape, smooth the surface, straighten the bar and get it ready to put back in the fire.

If this is your first experience at the anvil, the actual dimensions you achieve are almost irrelevant. You have been focusing on and learning much else. If on your first try you have resized a section to an even rectangular shape with straight sides, this is a significant achievement, but it is only the beginning.

After one or two repetitions of this lesson, set goals for yourself. Check each section as you complete it with the calipers and hold yourself to their target dimensions before considering a section complete. This is mostly a matter of self-discipline.

Final evaluation will wait until after the bar is cold.

If you have completed the first section, you can now heat the next area. Work in a linear fashion, one section complete before moving to the next. This is a key to efficient forging.

In preparation for another hammering session, before the bar goes back in the fire, straighten it as best as you can. Put your hammer in its “ready position,” put the bar back in the fire and finally wipe the anvil surface clean of scale.

Step Two

When reheating, push the finished bar section through the fire into a cooler part of the coals. Concentrate the heat on the area you will be working.

With another yellow or light welding heat on the bar, continue forging the next heated section. Remember your rhythm:

hit HARD on the bar face four or five times.

roll the bar and hit HARD on the opposite face.

forge the edge, dressing it straight.

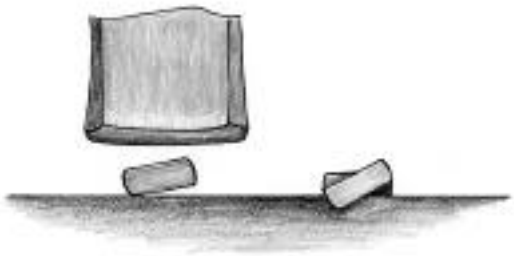
roll the bar and forge the opposite edge, and repeat as needed.

After each session at the anvil, check dimensions. If oversize, keep forging. If undersize the bar can be upset to thicken it, but that is another technique and another lesson. For now, take note of your mistake and resolve to do better on the next section.

Keep the bar straight as you work. It makes manipulating the bar less awkward.

As you feel more comfortable with the reshaping, set some goals as you work. Determine how much of the bar you can complete to final dimensions in one or two heats. Once you can do that consistently, push your limits and see if by hitting harder or faster or using a higher heat you can get more done. Discipline yourself; challenge yourself.

As more of the bar is reshaped, watch for twist.



10. Development of a twist as the result of not keeping entire bar flat to the anvil face.

Note: Twist is the result of not holding the work flat on the anvil. The holding hand (left hand for the right-handed smith) rotates, raising the edge of the bar slightly off the anvil.When this slightly raised edge is struck, the bar twists. If not corrected, multiple, small repetitive errors create a major deviation from flat. Knowing how twist develops allows you to correct it as you forge: compensate with a purposeful cant to the opposite side.

Step Three

When half (or a bit more) of the bar has been resized, the end that you started on will be at a black heat. Further cool that end in the slack tub.

Hint:: If you find that the end you hold gets uncomfortably hot as you work, cool it periodically in the slack tub. If this problem is chronic, you are taking too long to reheat the bar, allowing more time for heat transfer. Remember:

a) Heat in the hottest, neutral part of the fire.

b) Keep the fire built up around the work.

c) Cover the bar with loose pieces of coke; and

d) Do not let the fire grow bigger than necessary.

Flip the bar end-for-end so that you are now holding the resized end in your hand. Continue to work down the length of the bar starting where you left off in the middle, reforging section by section until complete.

Targets

Shape targets

The bar must be straight. Without experience it is difficult to judge this by eye. Use the straightedge as an eye-training tool.

Put the bar in the vise with one flat up. Hold the straightedge on the flat of the bar and peer along the contact edge backlit by a strong light source, like a window. In even the best work you will not notice full, light-blocking contact. What you should see is an even pattern of contact from one end of the bar to the next.

Sometimes the straightedge rocks or pivots on a high spot. If a corresponding low spot exists opposite, then you have identified a bend in the bar.

If the straightedge pivots on one flat and at the same relative place on the opposite flat, you have identified a bulge in the bar. This is more of a dimensional issue than a straightness one.

Take note of the width of any gaps between the straightedge and the bar. The eye can see light through an opening as small as a thousandth of an inch. A gap that is more than 4 or 5 thou-

11. Checking with a straightedge– dramatic deviation on left, close approximation on right.

12. Deviation from straight on left because of bend, on right because of narrow portion in the bar.

13. Wide and narrow portions of a bar averaged along its axis.

14. Testing with the feeler gauge.

sandths can appear huge. We want to keep overall dimensional tolerance to plus or minus 1/64 of an inch. Use the feeler gauge to check the gaps. How small a problem can your eye easily see?

If you have such a large gap, check the area with your calipers. Does the gap exist because of a bend in the bar? Or does the gap exist because the bar is too thin at that spot? The bend can be corrected easily. The thin spot will need to be upset. For now it is best to "split the difference," thinking about straightening the bar along an imaginary axis line so the mass is equally distributed around that axis, regardless of "thicks and thins."

Before doing any corrections, sight down the length of the bar and test your eye judgment. Can you see the problems that the straightedge picked up? If not, keep looking, using the straightedge to guide you. Occasionally turn the bar and look from the other end.

Hint: Changes in thickness, a twist or an uneven edge of the bar can cause the eye to see a bend where none exists. Addressing these problems is rarely a neat, step-by-step process. You will often work back and forth among bends, twists and dimensional problems.

15. Sighting down the bar to locate bends and help keep it straight.

Do not become wedded to the straightedge and feeler gauges. Use them to train your eye so that you do not rely on them any more, but the straightedge, in particular, will never be completely discarded.

Test all four flats of the reshaped bar. The bar must be free of twist.

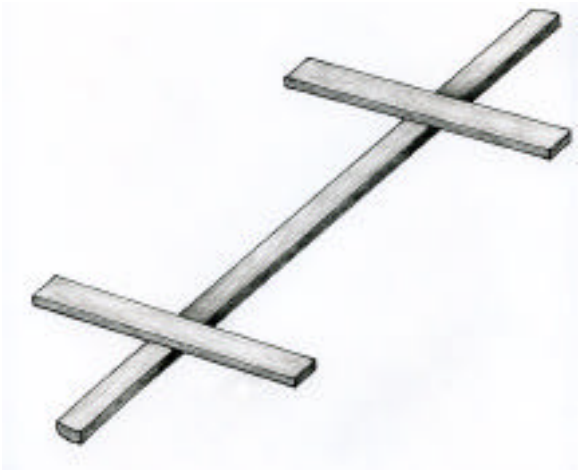
Bends and twists are first cousins. Some bends are localized twists and a twist in the bar can easily deceive the eye into "seeing" a bend. Eliminate twist before doing your final corrections for straightness. The goal is to learn to see twist without aids, but until that time make use of a pair of "winding sticks." A couple of straight sections of bars 1/4" by 3/4" and 8 or 10 inches long will suffice.

Lock the workpiece in the vise, grabbing it on the edges with the face of the bar above the vise jaws. Balance one winding stick on the upper face at one end of the bar and the other on the other end. Sight over these sticks. Are they parallel to each other? If not, the two areas where they lie on the bar are not in the same plane, i.e., the bar twists. Move the stick at the far end of the bar a couple of inches toward you and sight the sticks again. Continue testing the whole length of the bar. Without the winding sticks can you see these twisted areas? Test yourself– it is the only way to learn.

Dimension targets

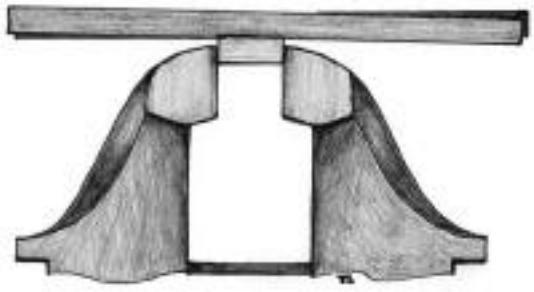
In a simple resizing exercise such as this, you should be able to work to plus or minus 1/64" in width and thickness of the bar. In other words, there could be as much as 1/32" of an inch dif-

16. Major problems like this are easy to see sighting down the bar, but more subtle ones become evident too. Can you see the 2 sharper bends in this bar?



17. Winding sticks placed on a bar.

ference between the thickest part of your bar and the thinnest. Use the calipers as your standard. Feel how they fit on the bar. Can you rattle the tips back and forth? If so, you are undersize. Perhaps you are evenly undersize. Compare the rattle at different



18. Sighting winding sticks to locate twist.

points along the bar. At the loosest spot, how thick a feeler gauge can you readily slip between the bar and the point of the caliper?

Perhaps you have thick spots. The calipers slip over the bar but you can feel them sprung open. Test along the bar. Get a sense for the amount of spring necessary to use the caliper. This tells you in a relative way how much oversize you are.

If you have a dial caliper, use it to take measurements at several places along the bar. What is the difference between your largest and smallest measurement? Is it greater than 1/32 of an inch?

On a cold bar use your fingers to feel for thick and thin areas. They can be more sensitive than your eyes.

The calipers, feeler gauges, straightedges and winding sticks are training tools. Can you see where the major problems lie without them? Work to identify these problem areas as you forge.

As an experiment, forge the first 3 or 4 inches of the bar carefully to dimension, using the calipers as a reference. Then forge the next section just trying to match the first by eye. Cool the bar and check your dimensions. You will be surprised at how close you can get.

Texture targets

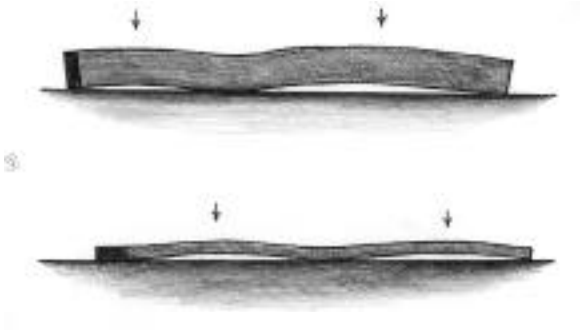
One of the hallmarks of skilled work is the quality of the hammered finish. On your resized bar you want a smooth, even texture. No one hammer blow should jump out as distinct from the rest. Likewise, the surface should be free of loose scale and from evidence of overheating. Comparing your work to the photos will be the best initial guide to evaluating its texture.

Time targets

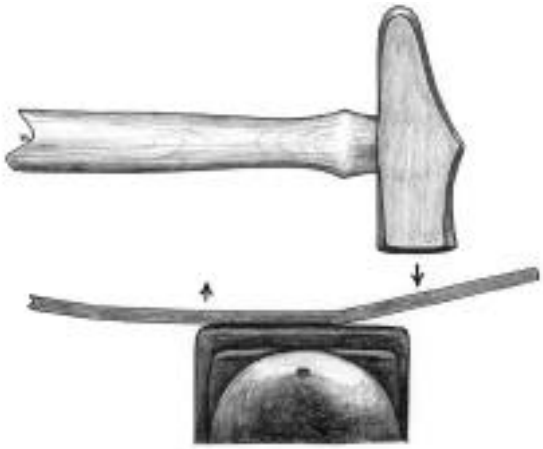
For your first efforts, time is largely irrelevant. Going through this exercise a few times, you ought to be able to reforge two inches of the original bar to final size in two heats.

This article will continue with Part Two- Straightening- in the next issue of the *Hammer's Blow*.

Drawing Down- Part Two



Areas to address for straightening.



Ineffective approach to straightening

by Jay Close
Illustrations by Tom Latané, photos by Jay Close and Jane Gulden

Lesson # 11- Drawing Down- Part Two

Definition: Reducing the cross-sectional area of a bar.

Lesson: Resizing a 1/2 inch square bar into a 1/4 by 5/8 inch rectangular bar by hitting the bar “on the flat.”

Troubleshooting

Straightening

Straightening could be a lesson of its own. These comments will get you started.

For the sake of these directions, assume that bends, twists and dimensional issues are all independent problems that can be addressed independently. This is far from the case in reality.

If you have kept the bar relatively straight as you worked it, little additional attention to this is needed at the end of reshaping. That needed attention can be done at room temperature.

Straightening is not a single operation but a series of corrections starting from the major working toward the subtle, a process of progressive refinement.

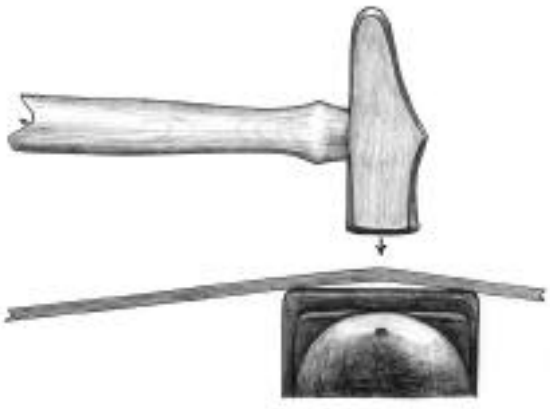
Approach straightening with a strategy. Some work from one end of the bar to the other. Some start in the middle and "chase" any crookedness out to the ends. These approaches work well for subtle correction.

Generally it is best to tackle the big problems first, then work on the more subtle ones.

Decide which plane of the bar needs most correction. Start where the most work is needed, sorting out the major issues first.

In practice you will likely work back and forth, correcting problems both on the edge and on the face.

Putting the bar on the anvil with the concave part of the bend up makes for ineffective straightening. The correcting blow just levers the holding hand up. This works much better if the bar is hot.



Proper approach to straightening

More effective is to place the bend with the convex portion up. The bend is supported on either side by the anvil creating a "bridge" effect. Then your correcting blow will drive the bend down and straight.

Experiment making your correction different places and orientations on the anvil face. One correction might need to be angled across the face to support a long, gentle curve. A more "spot" correction can be made with a sharp blow over the hardie hole.

When straightening, as in all forging, be decisive. Inspect your work. Decide where the problem lies and how to hold the work on the anvil to correct it. Take one, maybe two, correcting blows at the appropriate spot and check your progress.

Avoid a multitude of random, light, pecking blows. Hit with authority and immediately inspect your work. Always seek to make the needed changes with as few hammer blows as possible.

An isolated bend in an otherwise straight bar.

Secondary bends revealed after correction of the primary bend.

Sometimes correcting one problem reveals another. In the case below, correcting one bend as illustrated shows there are really two more bends that need addressing.

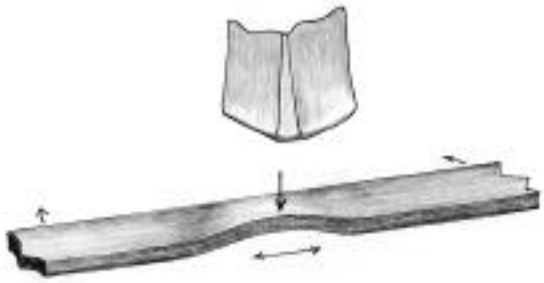
Once the bar is fairly straight along one plane, repeat the straightening on the other. Recheck the bar for straightness and start to work on more subtle problems. To accommodate the inevitable thick and thin places, and wide and narrow areas, keep in mind that the goal is the mass of the bar evenly distributed around an imaginary center line.

Dealing with twist:

If you have kept after the twisting as you worked there will be little remediation needed when finished.

A variety of small problems can mask a more subtle twist, so it is often best to work on the small problem areas first. You can then be left with one or two gentle twists to correct at the last.

If the twist is localized so it can be supported on either side by the anvil, treat it like a bend. Put the twist up and hit an authoritative corrective blow.



Correcting a localized twist.

This kind of twist and this kind of correction will show that the bar is actually bent at that spot. After flattening the twist, you will have to remove a bend.

For twists that can not be readily supported on either side by the anvil, the simple cant of the bar that worked well while the iron was hot is unlikely to be effective cold.

Photo 11: Correcting a twist with a pair of tongs and the bar held in the vise horizontally.

Sometimes you must resort to the vise and a pair of tongs or twisting wrench to eliminate twist. Situations will vary, but working from the middle of the bar out to the ends is frequently convenient.

Photo 12: The bottom bar has been burned. The top bar has been burned then slightly up set and reworked– alas, the damage has been done.

Hold the bar with the twist exposed just past the vise jaws. Place the tongs or wrench at the point needed to make the correction and bring the twisted bar in alignment. Hold the bar either vertically or horizontally, as seems most handy.

Texture

Your quest for a smooth, hammered texture on the bar begins with where you heat it in the fire. Heat the bar in the neutral part of the fire. If it is poked down into the oxidizing zone, you will have increased scale and a smoothing challenge.

Do not overheat the bar. If your bar looks like a Fourth of July sparkler when taken from the fire, you have pitted its surface and made a smooth texture almost impossible, particularly if you are already near final dimensions.

Hint:: If you should overheat a section of your workpiece, immediately cool it in the slack tub to below burning temperature and get to work. You may save the bar.

If your hammer face is too flat or has sharp edges, this too will make a smooth texture challenging.

Photo 13: The marks left on the bar came from this poorly dressed hammer face.

Photo 13A: Can you see the corner that marked the bar?

Keep the anvil free of scale as you work. If the bar comes from the fire excessively scaly, scrape it clean on the corner of the anvil using the hammer to apply downward scraping pressure. Do not take much time doing this as you are wasting the best, softest part of the heat. But it is sometimes necessary. A wire brush could be employed, but that needlessly involves picking up another tool and delays getting to work with the hammer.

Photo 14: Scraping along a sharp anvil corner to get rid of scale before forging. Use the hammer head to apply downward pressure.

Remember to work all sides of the bar. Not only is this critical for achieving the proper shape, but it means that scale is not being trapped between the work and the anvil where it can impress an undesirable texture.

Finally, work the bar down to a dull red. The bar has stopped scaling by then. This is your opportunity to work the surface without troublesome oxide.

Photo 15: Four sections of re-sized bar exhibiting different textures. From left to right:

A. Smooth, even texture;

B. An acceptable texture from a hammer with a more radiused face than the first example;

C. A fairly even texture but definitely not smooth;

D. A poor texture achieved by heating in the oxidizing part of the fire, not cleaning the anvil of scale, and not working all sides of the bar to a dull red heat.

Photo 16: A close up of "D".

Photo 16A : A close up of "C".

Photo 16B: A close-up of "B".

Photo 16C: A close up of "A".

FORGING DYNAMICS

Cross-sectional area:

Comparing cross-sectional areas is a good way to compare the masses of two different bars or two different shapes. For example, suppose you wondered whether a bar 1/2-inch by 1/2-inch had sufficient material to allow forging into a bar 1/4-inch by 1-inch. Multiply the width times the thickness of each bar–

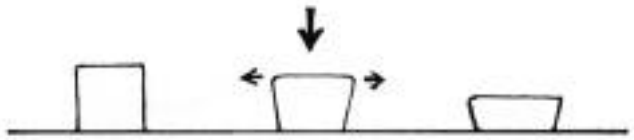
1/2-inch times 1/2-inch equals 1/4-inch

1/4-inch times 1-inch equals 1/4-inch

Each bar has the same cross-sectional area and it seems like you should be able to get the needed 1/4 inch by 1 inch bar from the one that is 1/2-inch square.

However, hitting with the face of the hammer spreads the work all directions from the middle of the face. Material is used stretching the bar longer as well as wider. In practice, you can not readily forge 1/4-inch by 1-inch bar from another bar with equal cross-sectional area.

Work all sides. Achieving a smooth, hammered texture is not the only reason to work all sides of the bar. It also helps to achieve the proper shape. The force of the hammer blow on the face of the bar is absorbed so that the force is not transferred all the way through. Were you to hit from only one side, particularly on a thick bar, you would soon create a trapezoidal cross-section.



Cross-section of a bar becoming trapezoidal when hit only from one side.

The I-beam effect:

You may notice the edges of your bar mushroom out, creating a hollow on the flat surfaces. The cross-section looks like an I-beam. This happens because you are working the edges (1) at too low a heat, (2) hitting too lightly, or (3) with a combination of the low heat and light hammering. The effect of your hammer blow is dramatically concentrating on the bar surface. The shape change is not being forced into the middle of the bar. (See Photo 18)

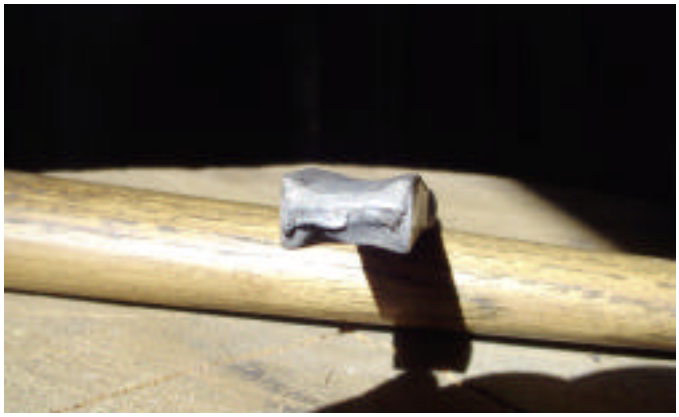


Photo 18: A really bad case of the the I-beam effect.

Ergonomic tips

Stand comfortably, weight on both feet evenly. Get close to the anvil so you can hit down on the work– you shouldn't have to reach for it.

Don't bend at the waist. It is hard on the back and makes your face more vulnerable to the rebound of a misplaced hammer blow. The bend at the waist also limits the acceleration of your hammer swing to a very small arc. An ineffective blow results.

Take long, smooth hammer strokes. As you raise your hammer, at the top of its swing it should be outside of your vision. If you can see your hammer head at all times you are limiting its travel, its speed and the strength of its blow.

Do not keep a white-knuckle grip on the hammer. Propel the hammer forward, then hang on for the ride. Feel how the hammer rebounds and make use of the rebound to help bring the hammer back.

Use the handle length. If you must choke up on the hammer handle, your hammer is probably too heavy for you. By using the

Photo 19: What is wrong with this picture? The bend at the waist is hard on the back. The face is more vulnerable to anything coming off the anvil. The waist bend also minimizes the travel of the hammer, hammer speed and the power of the blow are negatively effective. The grip close to the hammer head suggests the hammer may be too heavy. The "choked" grip shortens the arc of hammer travel. and the power of the blow.

Photo 20: Do not be afraid of the the anvil. Step up close to it so you are not reaching for the work, but can strike downward with authority.

full length of the handle you increase the speed and the power of the blow.

RELAX

Above all pay attention to your body and what it is telling you. Hand forging is physical. If you are not conditioned, injuries are a possibility even with the best technique. Warm up. Stretch and continue to stretch as you work. If it hurts, STOP! Evaluate what you are doing. Rest and recover. If problems persist, seek professional help.

Photo 21: Perhaps not the paragon of forge technique, this smith is standing upright and is close to the anvil. He is gripping the handle near its end. He has raised his hammer out of his field of vision and is thus beginning to maximize the effect of the hammer swing.

Forging a Shoulder

by Bob Fredell

Illustrations by Tom Latané

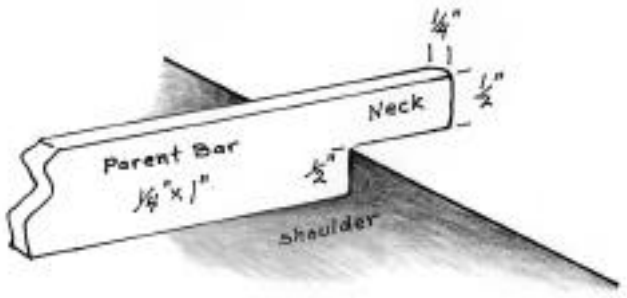
Lesson #12- Forging a Shoulder

Definition: A shoulder is the abrupt change in width and/or thickness of a bar. A shoulder is normally made by decreasing a dimension by drawing down, although it may be formed by upsetting.

Intent: To learn how to forge two different shoulders using a minimum of tools. The use of few tools emphasizes the hand-forging processes. which with practice, allows one to more readily master the procedures.

Near-side Shoulder

Definition: A near-side shoulder is formed on the near edge of the anvil with the neck extending from the end of the bar.



Near-side shoulder.

Tools: Anvil, hammer and center punch.

Materials- Mild steel 1/4"x1"x 24".

Intent. To forge a near-side shoulder on one side of a bar using the near edge of the anvil.

Note- See Drawing under Definition, above,

Step One

Place a center punch mark on the wide side of the bar next to the edge, and 1/2" from the end. This measurement will make a 1/4" x 1/2" x 1" neck.

Bar marked with punch.

Step Two

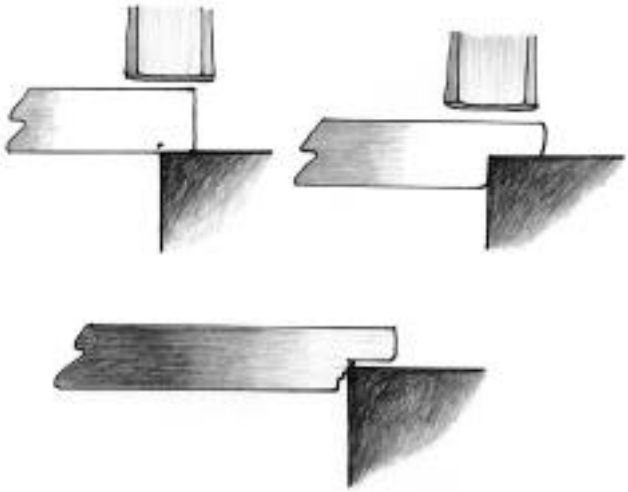
Heat two inches of the end of the bar to a light yellow. Place the punch mark at the near edge of the anvil with the 1/4" side of the bar flat on the face of the anvil (the bar is to be horizontal at all times to make the shoulder as close to 90˚ as possible.) Strike one or two light blows to establish this location on the bar, Be sure that (1) the face of the hammer is half on and half off the edge of the anvil and (2) the face of the hammer is parallel to the upper edge of the bar.

Continue forging until the shoulder is almost halfway through the bar.

Hint:

—Be sure to maintain a steady and gentle pressure on the bar to keep the now-forming shoulder tight to the edge of the anvil. Failure to do this will result in a ragged shoulder.

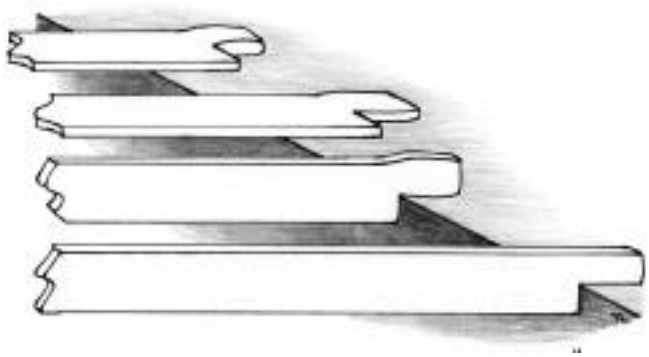
—Should a specific project call for an angled shoulder, the bar must be placed at an angle to the face of the anvil.



Shouldering on the near edge of the anvil with hammer blow half over anvil and half off. In the third example, steps and cold shuts formed when the bar bounces because it is not held firmly against the anvil.

Step Three

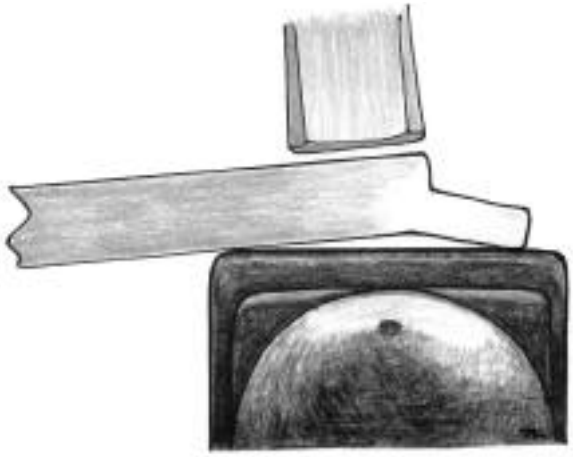
At this point, the bar has become thicker. Place the wide side of the bar on the anvil and forge it back to the original 1/4". Rotate the bar 90˚ and return it to the edge of the anvil with the shoulder facing down. Continue forging as in Step #2 and Step #3 until the shoulder is halfway through the bar (the neck will be 1/4"x1/2"x1").



Forging the thickness of the bar back to 1/4" and returning the shoulder to the edge of the anvil to reduce the width of the neck to 1/2".

Step Four

Depending on the effectiveness of Step three, the bar may be misaligned. The most common misalignment is a bend in the neck, away from the shoulder, caused by holding the end of the bar too high. This can be corrected by placing the bar on edge, shoulder up and striking the parent bar.



Correcting a bend.

Targets:

The neck is to be 1" long and 1/2" wide; the thickness remains 1/4".

To emphasize craftsmanship and accurate forging, the finished shoulder and neck should be within 1/16" of the required dimensions.

It is to be straight according to the eye, although a beginner may need to use a straightedge.

The angle of the shoulder may be slightly more than 90˚.

Note that the outside corner will not be 90˚ using this method. The material at the corner will be pulled down by the forging action.

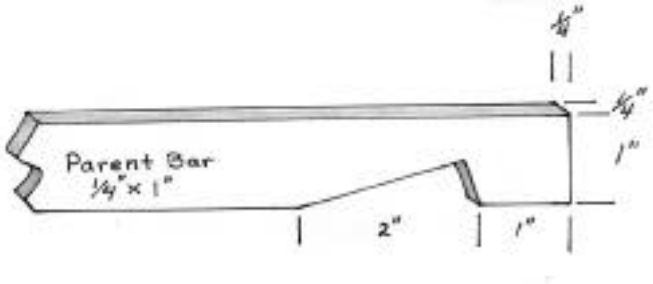
Practice this lesson until you can complete it in one heat.

Note: An alternative to using a center punch to mark where the shoulder is to be placed on the bar is to mark the face of the anvil with soapstone, chalk, or a felt tip marker. Mark the 1/2" length with a line on the face of the anvil, 1/2" in from the new side of the anvil. When the bar has reached forging temperature, place the end of the bar even with this line. Apply downward pressure to ensure that the bar does not move. Proceed to forge the shoulder as in Step two.

Soapstone and chalk marks are easily erased from the anvil's face. The felt tip marker will provide a line that lasts longer if you need to make several shoulders.

Part Two- Far-side Shoulder

Definition: A far-side shoulder is formed on the far edge of the anvil and will result in a taper from the full width of the 1" bar to the 1/2" inside shoulder.



Far-side shoulder.

Tools: Anvil, hammer and centerpunch.

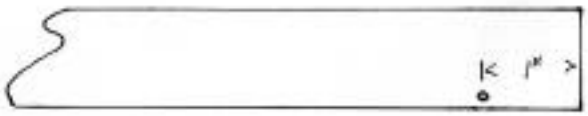
Material: Mild steel, 1/4"x1"x24".

Intent- To forge a far-side shoulder on one side of a bar using the far edge of the anvil.

Note: See drawing under Definition above.

Step One

Place a center punch mark on the wide side of the bar next to the edge, and 1" from the end.



Bar marked with a punch.

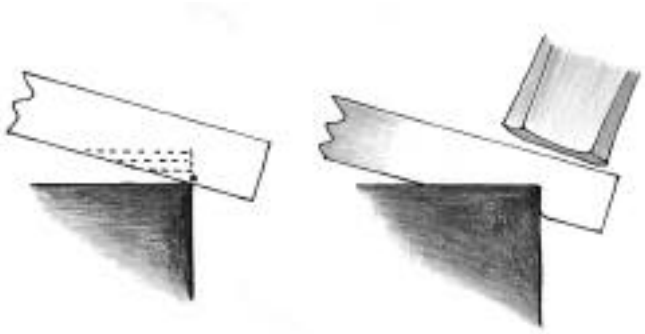
Step Two

Heat three inches of the end of the bar to a light yellow. Align the punch mark on the far edge of the anvil. The angle of the bar to the anvil face should approximate the angle of the finished 2" taper. Strike *one or two light blows* to establish this location on the bar.

Be sure that (1) the face of the hammer is half on and half off the edge of the anvil and (2) the face of the hammer is parallel to the upper edge of the bar.

Continue forging until the shoulder is not quite halfway through the bar and the hammer remains half on and half off the anvil.

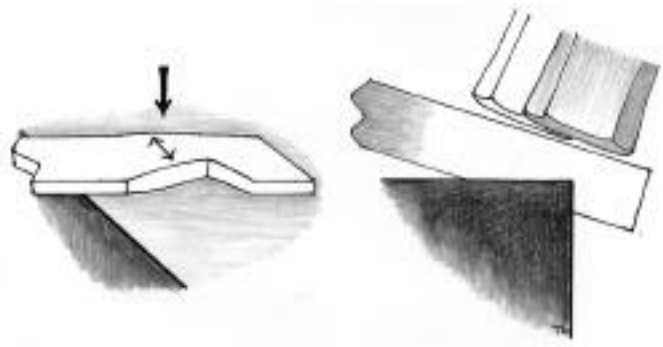
Hint: Be sure to maintain a steady and gentle pressure on the bar to keep the now-forming shoulder tight to the edge of the anvil. Failure to do this will result in a ragged shoulder.



Shouldering on the far edge of the anvil– matching the hammer angle to the angle of the bar.

Step Three

At this point the taper has become thicker. Place the wide side of the bar on the anvil and forge it back to the original 1/4". Rotate the bar 90˚ and return it to the edge of the anvil with the shoulder facing down. Continue forging as in Step two and Step three until the shoulder is halfway through the bar (the taper will be 2" long and 1/4" thick).



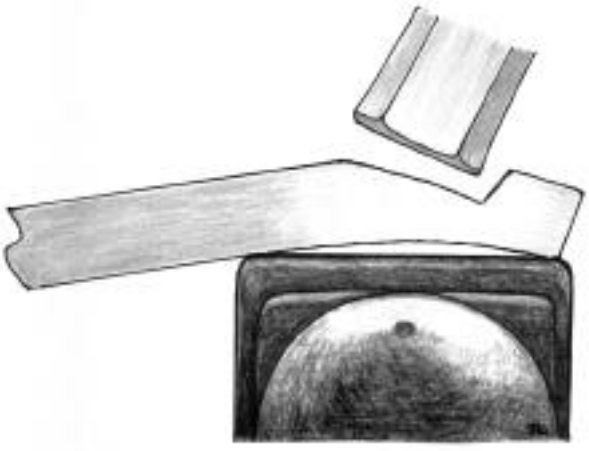
Forging the thickness of the bar back to 1/4", then dressing the tapered neck.

Step Four

The bar may have a tendency to form an arc. Straighten the bar by placing it on the anvil with the concave side of the arc down, making sure the two ends of the arc are touching the anvil. The taper is now facing up. Strike the taper with one or two decisive blows until the bottom edge of the bar is flat to the anvil.

Note: You may find (through forging dynamics) that from the initial downward blows to shape the shoulder, a thick mass is created in the neck, and when forging the neck back down to the original thickness of 1/4", this arched shape is eliminated during this part of the procedure.

Hint: To avoid nicking the taper with the edge of the hammer, be sure to match the face of the hammer with the taper.



Correcting a bend.

Note: An alternative to using a centerpunch to mark the bar where the shoulder is to be placed is to mark the face of the anvil with soapstone, chalk or a felt-tipped marker. Since the end of the bar will be placed off the far side of the anvil, (and you cannot draw a line in space), you must draw your line measuring 1" in from the far edge of the anvil on the anvil's face.

When the bar has reached forging temperature, place the end of the bar even with the far edge of the anvil. Next, take your hammer and press the edge of the hammer's face to the bar at the 1" line. Slide the bar and the hammer beyond the far-side edge of the anvil until the hammer edge meets the edge of the anvil and stop. Apply downward pressure to insure that the bar does not move. Proceed as in Step two.

Soapstone and chalk are easily erased from the anvil's face. The felt tip marker will provide a line that lasts longer if you need to make several shoulders.

Targets:

The shoulder is to be 1" from the end of the bar. Halfway through the bar, the thickness remains 1/4" and the length of the taper is 2".

The finished shoulder is to be within 1/16" of the required dimensions.

It is to be straight according to the eye. However, a beginner may need to use a straightedge.

The angle of the inside corner will be slightly more than 90˚.

Note that the outside corner will not be a 90˚ angle using this method because the material at the corner will be pulled down by the forging action.

Practice the lesson until you can complete it in two heats.

Alternate method: In Step two, we say "The angle of the bar to the anvil face should approximate the angle of the two-inch taper." It must be said that a far-side shoulder can be created with the edge of the bar laying flat on the anvil face. You may note when using this method that a longer taper is created, and a greater area must be forged back down to the original 1/4" thickness.

Other notes: You may desire to form sharper corners. To accomplish this, take a yellow heat and place the inside of the shoulder over the far-side edge of the anvil. Pull the bar towards you so it meets the far vertical side of the anvil. Proceed to upset the end of the bar by lightly hitting the end of the bar into the far vertical side of the anvil. Hitting the bar too hard may cause the bar to fold, and this error must be corrected by lightly hitting the width of the bar.

Note that this procedure will somewhat reduce the length of the end of the bar, and increase the thickness and the width of the bar. Forge the bar back to the 1/4" thickness, and the 1" width of the bar (Similar to Step three).

If a precise measurement is desired at the end of the bar, you may want to use a test bar to determine how much length (if any) is lost by this procedure.

Cutting a Bar

by Dan Nauman

Illustrations by Doug Wilson

Lesson #13

Definition:Cutting a hot bar using the hot cut hardy.

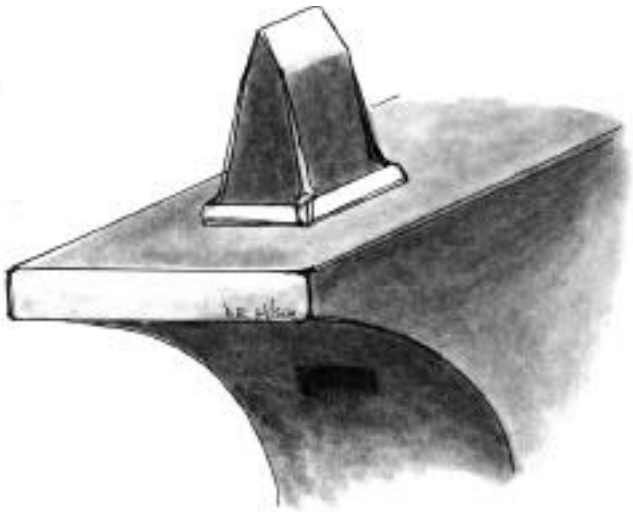
Note: A hot cut hardy has a cutting edge of about 25 to 30 degrees. A cold cut hardy has a cutting edge of about 60 degrees.

Intent: To learn to cut through a round, square, or rectangular bar using the hot cut hardy on the anvil, making a clean and even cut, with the resulting burr located in the center of the cross section of the bar. With the burr in the center of the bar, it will make life easier for following forging operations such as upsetting the end of the newly cut bar.

It must be said here that this method is not necessary for all cutting applications. A bar can be cut faster (and easier) by driving the bar down into the hardy from one side. This procedure will leave a burr on one side of the bar, and will also create an angled edge on the end. This edge may be desirable in some circumstances, i.e. starting a taper on the end of the bar, or an intentionally angled end of the bar to form a scarf.

Tools: Anvil; hot cut hardy; hammer; soapstone or chalk.

Material: 1/2" square x 12" mild steel.



A hardy, with the cutting edge parallel with the anvil's edge.

Forging Dynamics: The angle of the cutting edge of the hardy is important when cutting hot metal. With the narrower cutting edge of the hot cut hardy at 25 to 30 degrees, the material being cut will not only distort less, but the act of cutting will be more rapid. The wider 60 degree cutting edge of a cold cut hardy will tend to distort the material, i.e. creating a wide v-notch, and also potentially reducing the cross section of the bar from the additional hammer blows necessary to drive the bar through a thick wedge.

Step One

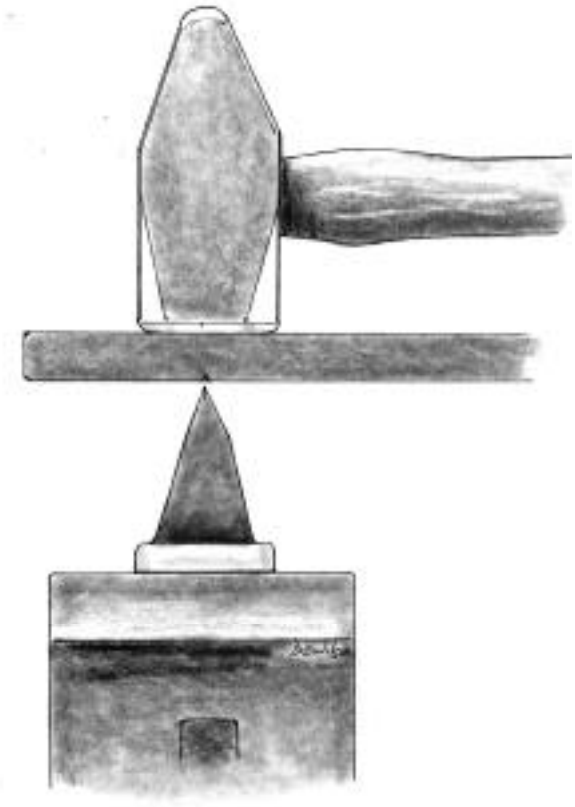
Measure 2" from the end of the bar and mark that distance with soapstone on the bar. Place the cold bar on top of the hot cut hardy edge, with the 2" mark directly above the cutting edge. Turn the bar up onto its corner, With your hammer, strike the bar down onto the hardy, hard enough to make a good nick. This nick will be used to indicate where the bar will be cut when hot. (For alternative marking methods, see "Notes" at the end of this lesson.)

Caution: Nicking the corner of a bar on a hot cut hardy as in the manner of Step One could damage your hardy's cutting edge if you are using cold rolled steel. Cold rolled steel (as milled) is harder than hot rolled steel of the same type. Once heated, or normalized, the cold rolled steel's properties match that of hot rolled steel.

Also, this method is never a good idea if forging high carbon steel. Review the alternative marking methods at the end of this lesson, and use good judgement.

Step Two

Heat the area to be cut to a yellow heat. Place the bar on the hardy, and move the bar back and forth to find the nick. Turn the bar onto its flat side (side "A") and hit a solid blow.



The hammer correctly placed over the bar and hardy .

Note: Keep the bar parallel to the face of the anvil, and 90 degrees to the hardy, at all times during this process.

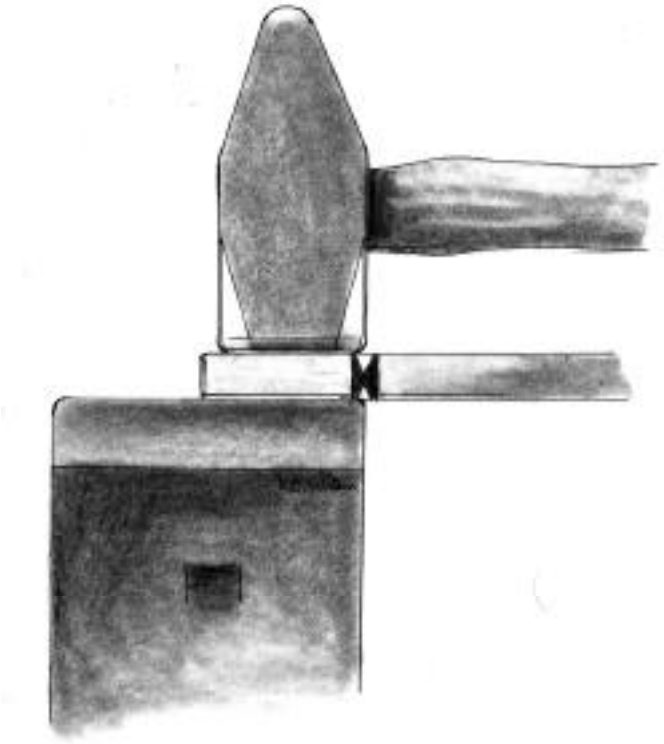
Turn the bar 45 degrees (right or left), and strike again lightly to mark the corner. Continue to turn the bar in the same direction to mark the next face with a sharp blow.

Reversing the direction you have previously turned the bar, turn the bar back to side "A", and then turn 45 degrees and lightly nick the corner. Proceed in the same direction to the next face, and mark this face with a sharp blow.

Next, turn the bar 90 degrees to the fourth face. Look down at the bar from a bird's eye view, and you should be able to line up the nicks on the bar with the cutting edge of the hardy. Once you have lined up the nicks, proceed to strike the bar solidly.

Continue rotating the bar to each face, and continue cutting into the bar. Cut until the thickness of the area uncut is roughly 1/8".

Note: Do not cut the bar all the way through….as you may sever the bar, and you may damage both your hammer as well as the hardy. Severing the bar could also send the very hot, cut-end of the bar sailing across your shop.



Weighting one end of the bar with the hammer to twist the bar.

Step 3

There are several methods to break off the end of the bar. You may:

A.) Hold the short end of the bar with tongs or hammer and bend up and down or twist until the end breaks off.

Alternate method of holding the short end with tongs to twist the bar.

B.) Shear the end of the bar by lining the cut up with the far edge of the anvil and strike down on the protruding end with your hammer.

C.) Quench the area cut with water. This will mildly harden the bar so that the bar can be snapped off easily.

Targets:

–You should be able to cut the bar in one heat.

–The cut should be even. No "corkscrewing" or misalignment of cuts.

–The bar should remain straight.

–The burr left on the end of the bar should be centered in the cross section of the bar.

Notes:

Some alternatives to nicking the bar on the hardy to mark where the bar is to be cut:

A.) For shorter cuts, you can draw a line on the face of the anvil. The line should indicate the length of bar you wish to cut. Measure from the near side edge of the anvil with chalk, soapstone, or for longer lasting lines, a felt-tip pen. Place the end of the bar even with the chalk line. Use the edge of your hammer face to indicate the line to be cut by lining it up with the edge of the anvil (with the hammer on top of the bar). Now carefully bring the bar and hammer to the hardy. Line the hammer edge up with the cutting edge of the hardy. Apply some downward pressure so the bar does not slide off the mark. Strike solidly and proceed as indicated in the lesson.

B.) Some smiths prefer to use a center punch, and others a chisel to mark where bar is to be cut. If using a center punch, make sure the punch mark is deep enough so that you can see it when you bring the glowing bar out from the fire.

C.) For marking cold rolled or high carbon steels, use soapstone to mark the cut, then take an initial low heat (bright red). The soapstone mark should still be easily seen at this temperature. Nick the bar, (with a hardy, chisel, or center punch) then reheat to make the final cut as outlined in this lesson.

Bending

Text and Photos by Dan Nauman

Lesson #14- Forging a 90-degree corner

Definition: Altering the centerline of a bar.

Intent: To learn how to forge a sharp 90-degree corner while maintaining the parent stock dimensions throughout the bend, and have the resulting two legs measure to a predetermined length.

Tools: Anvil, 16- to 20-ounce cross-peen hammer, center punch, steel square.

Material: 1/2" square x 20" mild steel.

Step One

Note: When producing a bend of this nature you will lose some length, equal to half of the parent stock thickness, on both legs.

Also, when figuring how much metal will be needed for this bend in a project, remember that your measurements should be taken from the center (or mean line) of the bar on your layout, and not from the inside or outside corners.

Our target length for the short leg that will be formed is 3 3/4", and a target length of 15 3/4" for the long leg. With that in mind, measure 4" from the end of the bar, and mark with the center punch.

Step Two

Heat the bar to bright yellow, with the center punch mark centered in the heat.

Note: A short heat for this step will reduce the work in succeeding heats. The length of the heat when initially pulled from the fire will be too long. If this heat is not minimized, the resulting bend will require more effort to achieve your goal.

The bright yellow heat will give you some time to quench the bar. Using a dipping can, quench the bar (with water) down to 1/2" on either side of the center punch mark so that the heated area is confined to about 1 1/2"… ideal for this initial bend.

After you have minimized the heat, make sure the center punch mark is visible on the side of the bar, and position the bar so that the center punch mark is over a 1/8" radius on the far edge of the anvil. Proceed to bend the bar over the edge of the anvil by striking the end of the bar down. Bend the bar so that it is at about a 100-degree angle. (See photo #1)

Notes- Do not use a sharp corner of the anvil or the vise to make the initial bend. This can lead to galling on the inside corner which may lead to forming a shut (overlap) during subsequent steps. A shut in steel can form into a crack, weakening the piece. A shut in wrought iron will cause the leg to fall off.

Our goal is to teach you to make this bend with a minimum of tools. However, some smiths prefer to use the vise to perform a controlled, gentle bend in Step Two (avoiding a gall), and then use it for a brace (or back-up) in succeeding steps. While this practice is not necessarily wrong, it must be noted that it takes precious time to place the piece in the vise. Also, the vise acts as a heat sink, robbing precious heat from the metal. These facts combined reduce your window of time to forge the corner.

Forging dynamics: From bending, the inside corner has now increased in cross-section from compression, and the outside corner has decreased in cross-section from stretching. This excess material on the inside corner can be moved to help replace the loss of material on the outside corner. The next step will help accomplish this task.

1. After the initial bend, the angle should be approximately 100 degrees, as shown here.

2. Position the hammer as shown when cross-peening the corner. Be mindful that you do not reduce the cross-section smaller than that of the parent stock.

3. Stand at the heel of the anvil to forge this form.

Step Three

In the same heat from step two, lay the bar on its side on the anvil so both legs are resting on the face. Using the cross peen of the hammer, carefully forge down the excess material on the inside corner back down to 1/2". The peen should strike the bend, perpendicular to the 50-degree mean angle, so that the metal pushes to the outside corner. The legs themselves will help prevent the metal from flowing into the inside corner. (See photo #2)

Step Four

Heat the bend to bright yellow. Quench the bar to concentrate the heat to 1/2" on each side of the bend.

4. Vertical blow– note the position of the hammer and the short leg.

Note: Your stance at the anvil is important for this step. It will be easier for you to swing the hammer if you position yourself with your shoulders square to the heel of the anvil. (See photo #3)

Place the short leg ten degrees to the right of vertical (ten degrees to the left if you are left handed), with the end down on the face of the anvil. Strike the bar five or six times with hard blows. The blows should be focused so that the hammer face is in the same plane with the long leg, and slightly to the inside of the axis of the short leg. (See photo #4)

In the same heat, position the bar ten degrees to the left (or ten degrees to the right if you are left handed), and redirect your blows with the hammer's face in the same plane as the short leg, and just below the axis of the long leg. (See photo #5)

5.Horizontal blow-Note the position of the hammer and the short leg.

Proceed to strike the bar with seven to nine blows.

Alternate back and forth from the short leg to the long leg until the metal reaches a dull orange color. Maintain an angle of about 100 degrees. Count your blows as explained above.

Forging dynamics: The reason you strike more blows horizontally is that your hand is not as solid a brace as the anvil is for the vertical blows, thereby requiring more blows to accomplish the same task of moving material towards the corner.

Also, using a lighter hammer such as a 16- to 20-ounce hammer minimizes the possibility of forcing too much material to the inside corner of the bend (which could happen when using heavier hammers). The force delivered by a lighter hammer is expended on the surface of the bar. (See photo #6 of 1.8# hammer vs.1# hammer.)

Step Five

Your work thus far has also increased the cross-section of the bar at the inside corner. As you did in step three, use the peen to

6. Use a smaller hammer to do this operation. The hammer on the left is a one-pound hammer– a good hammer weight for the task. The hammer on the right is a 1.8 pound hammer which is too heavy for this form.

simultaneously reduce the cross-section, and push the excess material to the outside corner. Smooth with the face of the hammer. Be careful, as you do not want to reduce the corner to less than the parent stock size.

Step Six

Repeat steps four and five until the outside corner is visibly sharp (no greater than a 1/32" to 1/64" radius).

Note: If the legs begin to bend during any part of these procedures, straighten them at once or the energy from your blows will do more to continue bending the legs, rather than forging the corner.

7. When trueing the angle to 90 degrees, keep the short leg away from the anvil as shown here. Doing so will keep you from reducing the cross-section of the bar beneath the parent stock size.

8. Check your work with a square. Note that the legs are square, but there is a gap near the corner of the long leg, which should be corrected.

Step Seven

Heat the corner to bright yellow. Quench as in step four. Lay the long leg on top of the anvil. The short leg should point down off the anvil, with the inside corner away from the side of the anvil. With light blows striking horizontally towards the short leg, close the angle of the corner to 90 degrees (See photo #7). The legs can be straightened by lightly tapping on the anvil in any orientation that suits the task. Use the steel square to check your progress. (See photo #8.)

Note: Resist forging down on the bar on the corner of the anvil to achieve the 90-degree bend, or to straighten the legs. What you are trying to do at this point is to bend the bar to 90 degrees, not forge the bar to 90 degrees. Forging down on the legs to achieve the bend will reduce the cross-section of the legs near the corner.

Targets:

-The short leg is 3 3/4" long, and the long leg is 15 3/4" long, plus or minus 1/16".

-Both legs lie in the same plane. No twists or bends.

-The stock size remains 1/2" throughout the forging.

-The corner is 90 degrees, with a radius of 1/64" to 1/32" for an outside corner.

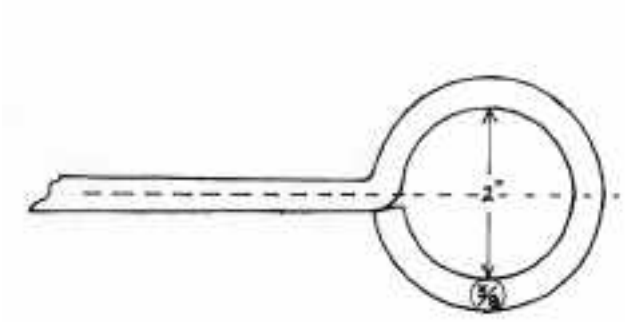
- The legs are straight, and do not slope down to the corner.

-The surface of the faces are smooth.

-With practice, the corner should be forged in five to six heats.

-There is no shut (overlap) on the inside corner.

Bending



Text by Bob Freddell, illustrations by Tom Latané

Lesson #15- Forge an eye on the end of a bar.

Definition: Altering the centerline of a bar..

Intent: To learn to forge a well rounded eye to a specific diameter.

Tools: Anvil, hammer..

Material: 3/8" square x 24" mild steel.

Note

The reader is referred to two earlier articles in the *Controlled Hand Forging* series: (1) *Bending Bar Stock* by Jay Close, *Hammer's Blow*, Vol. 11, # 2, Spring 2003, (2) *Drawing, Punching and Bending* by Peter Ross, *Hammer's Blow*, Vol. 11, #3, Summer 2003. Read these articles. They detail the forging dynamics and the process of bending bar stock. The directions in this lesson are not as comprehensive as the two previous lessons.

Step One

The formula to determine the length of material needed for the eye is:

Inside diameter of the eye + thickness of the stock x π = length of stock.

OR

2"+ .38"x 3.14 = 7.5", or 71/2".

The numbers for this lesson are written using decimals. If you prefer to use fractions, 3 1/7" is used for π and 3/8" for stock size.

Tip: If you are overwhelmed by the mathematics, the same information can be gleaned from a full sized sketch of the finished eye. Use a piece of wire or string along the median circumference of the sketch to get the needed stock requirement for the bend. Or step it off with dividers set at, say, 1/2 inch. Lifting dimensions from a drawing is an important skill to develop. Many forms– such as scrolls– will not readily submit to a mathematical approach.

Center a punch mark 7 _" from the end of the bar. There is more than one way to hold the bar while center punching. It may be placed in the corner of the anvil's step, or set on the vise with the jaws opened to slightly less than the diameter of the bar.

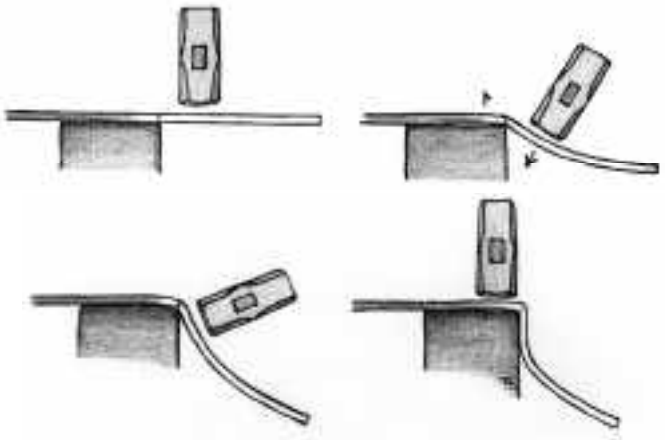
Step Two

Heat the entire 7 1/2" portion of stock, plus about another inch, to light yellow.

a.) Place the punch mark at the far rounded edge of the anvil with the punch mark facing to the side where you can see it and keep track of it.

Be certain to keep the bar stock horizontal and flat to the anvil face.

Strike next to the bend–not near the tip of the bar, and bend the bar down 90°. As you do this you will probably note two



Making the first bend and correcting the counter bend.

counter bends.

b.) The portion of the heated bar on the face of the anvil will likely have lifted slightly off the anvil in a counter curve. This is caused by the edge of the anvil acting as a fulcrum. As you strike down on one side, the bar levers up on the other. Forge down this unwanted counter bend without reducing the bar dimension.

If you have directed your bending blows near the bend itself, you will likely notice the tip of the bar curving up. The inertia of the bar's end is tending to keep it stationary as the remainder of the bar is forced to bend. The result is a curve like a reversed "J". Do not straighten this! Use it in the next step.

Step Three

Go to the anvil horn quickly to use the same heat as in Step Two.

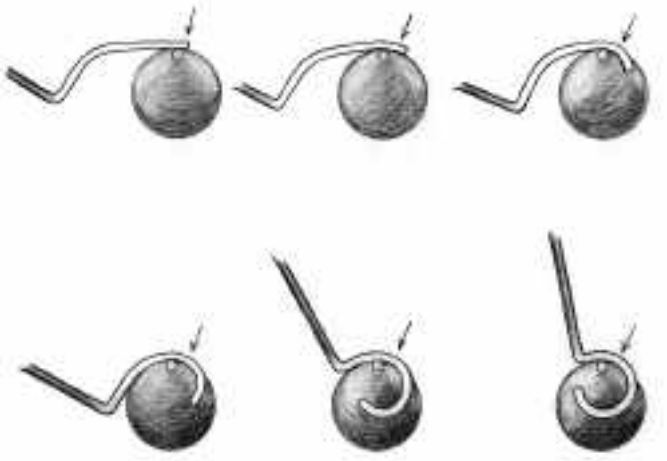
Flip the bar over with the bent portion pointing up.

Raise the hand holding the bar high so you can place the tip of bar horizontally on the anvil horn.

The tip should extend over the horn about 1/4". You have a head start if the tip already has a slight bend (see Step Two).

To make it curve, strike the hot bar that extends beyond the horn. You are working on the side of the horn that is furthest from the smith. Do not pinch the bar between the hammer and horn, as that will not bend it. That will only reduce its dimensions by drawing it out.

Continue to feed the bar across the horn in short increments of about one half of an inch. Never strike the bar twice in the same place. Continue working in this manner until the hammer blows approach the point of the initial 90 degree bend of Step Two.



Progressive bends form the eye.

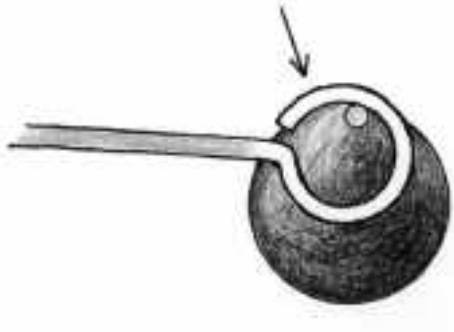
Inspect your progress frequently. Are you bending a sufficient curve? Is the curve too tight? You may need to go back to an already bent section of the eye for correction. Alter the position of your holding hand– raising it or lowering it–- so that the correcting blow is as near vertical as possible.

Sometimes the eye seems to spiral like a coil. Pay attention to how it contacts the horn and how you hit it. Remove the coil effect with a flattening blow or two on the anvil face.

Note: A common error is to hold the hammer at such an angle that the hammer edge strikes the hot bar making unwanted dents. Only the hammer face is to strike the hot bar.

Depending on how the eye is forming, you may find it necessary to flip the eye so the termination is on the top-side of the horn. In this orientation the bending hammer blows will come on the side of the horn nearest the smith.

Returning the eye to the proper plane.



Eye flipped to an area of insufficient bend.

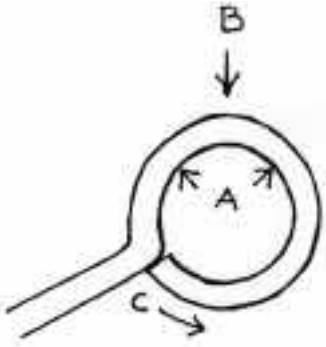
Note- Making such a bend is really a matter of approximations and on-going corrections.

With experience, this step can be completed in one heat. However, the beginner should work for control and accuracy, not speed.

The eye is now formed, but may need further refinement.

Troubleshooting and corrections

-Look at the eye you have formed. Make mental notes if it is not true to your specifications. It may exhibit "kinks" where the

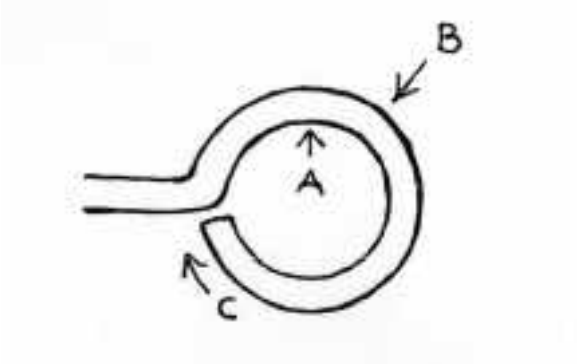


Opening a kink– eye contacts horn at points A, struck at point B, resulting in movement at C.

curve is too tight and "flats" where it is too gentle.

-To remove a kink, with the eye heated to a light orange, place the high spot of the kink on the top of the horn where the horn is wide enough to support the eye on either side of the kink. Sometimes you need to angle the work on the horn to get such a bridging effect with a small diameter. Strike the top of the kink, then make a note of any change of shape, i.e. not enough, too much, or just right.

-To remove a flat spot, place the flat spot on the top of the horn so that the flat spot is supported. Gently strike the eye on the far side of the horn slightly past where the bar contacts the horn.



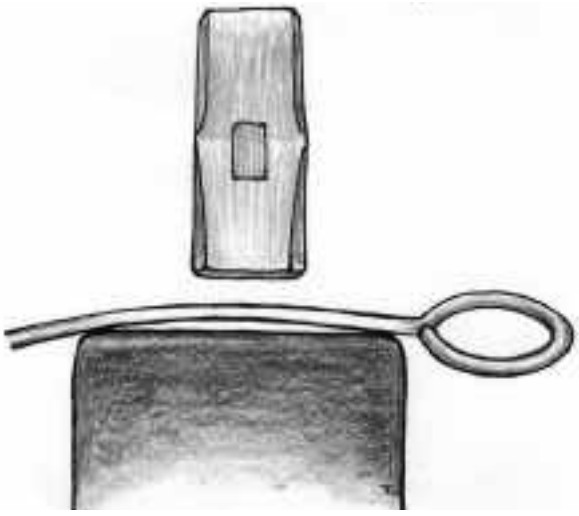
Removing a flat spot– eye contacts horn at point A, struck at point B, resulting in movement at C.

Check your progress. Is the adjustment better, worse or just right?

-These techniques are also used to adjust the tip of the eye to meet the parent stock.

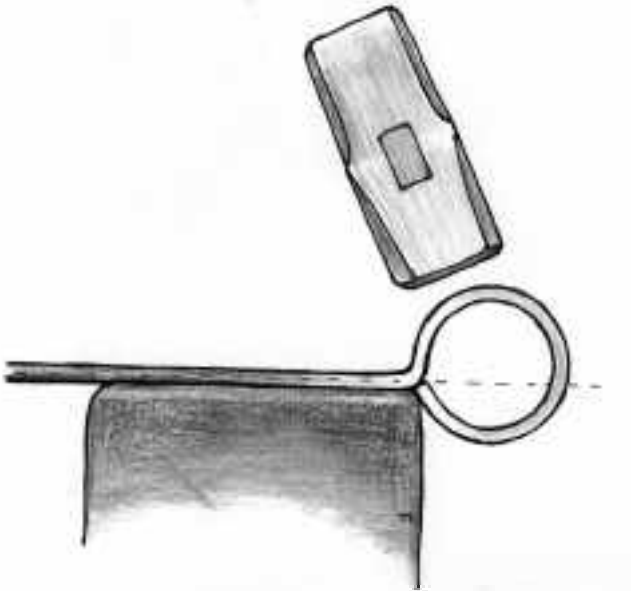
-You may need to raise or lower the holding hand as needed to present the correction conveniently to the hammer.

-The handle and its alignment with the eye may need correction. If so, first straighten the handle so you can accurately read its relationship to the eye. Once the handle is satisfactory, assess its alignment to the eye. The handle must point straight to the center of the eye.



Straightening the "handle" portion of the bar.

-If the eye is out of alignment, proceed by heating the area of the initial 90 degree bend. Lay the handle across the anvil with the bend on the far rounded edge and the eye placed so that any offset is up. Forge it down into alignment and then make any small corrections to the eye and handle that may be needed.



Aligning the eye to be centered on the bar.

Targets:

-The eye has a 2" inside diameter, and has an error of no more than 1/16".

-The end of the bar that forms the eye is to touch the bend at the handle.

-No twists, kinks, or flat spots.

-The handle is to point directly to the center of the eye.

Drawing Out

1. Shelf bracket made by Peter Ross. The snub end scrolls were made by making a very long ribbon taper, then tightly rolling the taper to form the snub end. This method of forging snub end scrolls was typical of English 18th century ironwork.

by Dereck Glaser

Photos by Dan Nauman

Lesson #16- Forging a Ribbon Taper

Definition: Reducing the cross section of a bar

Overview:A ribbon taper tapers in thickness while the width of the parent bar remains constant.

Intent: The student will forge a ribbon taper with a resulting taper length of 2 3/4", while maintaining the width of the original parent stock..

Tools: Basic tools, including a straight edge, and outside calipers.

Material: Mild steel, 1/4" x 3/4"x 24".

2. Notice the angle of the hammer and of the bar, as well as bar placement on the anvil.

Forging dynamics: In Step One, your task is to produce a "set up shape." (See *Terms* at the end of this lesson for a definition of set-up shape.) The set-up shape you will produce reduces width and increases thickness. This shape facilitates the drawing of the ribbon taper in Step Two. Were the thickness reduced first, the resulting increase in width makes the bar difficult to forge back down to the parent stock width, as the material wants to fold. (See photo 4a)

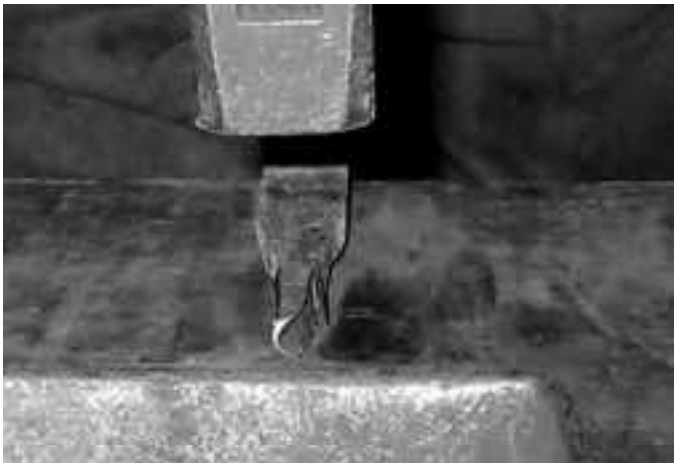
Step One

Take a bright yellow heat two inches long. Place the heated portion level on the anvil with the end even with a rounded far edge of the anvil to prevent the angled edge of the hammer from contacting the anvil face. Place the bar standing on edge so that you are looking at the thickness of the material, and with the end you are holding slightly elevated. Begin to forge the end with a

3. Side view of the set-up shape. Notice how the thickness of the parent stock has increased towards the tip.

3a. Top view of the set-up shape. Notice that the width of the par - ent stock has decreased towards the tip.

4. Correct position of the bar and set-up shape on the anvil to begin drawing out the ribbon taper.



4a. If the set-up shape is forged too thin, the metal will fold when drawing out the ribbon taper, as shown here.

slightly angled hammer, just about the width of your hammer face. (See Photo 2) Continue forging to lengthen the taper to produce a symmetric angle to both sides, being careful to keep the taper centered to the parent bar.

Forging dynamics: If you only work one side of the bar, mushrooming of the metal on one side will occur. This happens because more force is coming from the hammer, displacing more material than the force from the anvil. You will need to rotate the bar 180 degrees, alternating blows on the opposing sides, to avoid this problem.

At this point, the bar has decreased in width, but increased in thickness. This is your set-up shape, and should measure 1 1/2" long. (See Photo 3, and 3a)

Step Two

Take a bright yellow heat two inches long, placing the end being forged in the same area of the anvil as in Step 1, with the wedge perpendicular to the face of the anvil. (See Photo 4) Keep the bar parallel to the face of the anvil as you re-establish the thickness. You will witness the width you reduced begin to widen as the thickness begins to reduce. Forge rhythmically and symmetrically, rotating the bar 180 degrees at regular intervals to maintain an even width.

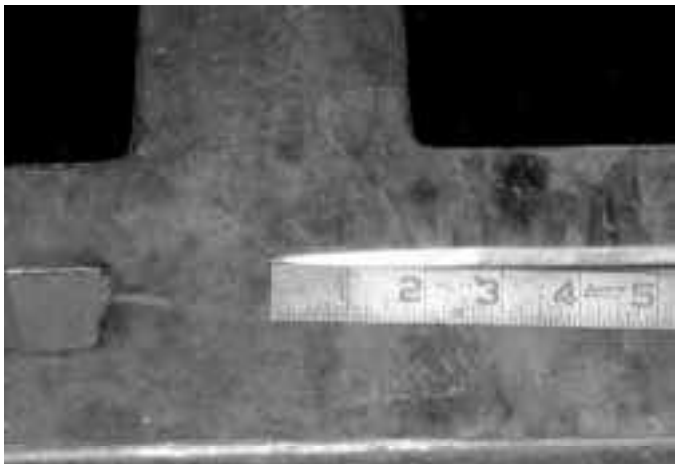
Next, slightly elevate the holding hand and begin to forge the very end of the bar, angling the hammer face in a complimentary angle to the raised bar. (See Photo 5)

As you forge, you will see the set-up shape begin to transform into the intended shape. As your proficiency of forging grows, alternate the blows to forge the thickness and the blows controlling the width. Rhythmic forging is important, as it allows you to incorporate more forging blows of various purposes into each heat; enabling you to get more work done. Keeping the taper on center is an ongoing process, and best not left to waiting until the taper is completed. (See CHF lesson #11 for straightening techniques, the *Hammer's Blow*, Vol 13, #2, Spring 2005.)

To increase the length of this type of taper, first make sure that the width has been established. Then proceed to forge the bar back, behind the tip, drawing out more of the parent bar into the taper. (See photos 6 and 7 for the final shape of the ribbon

5. Correct position of the bar on the anvil to finish the ribbon taper. Notice that the bar is slightly elevated on the holding end. Note also the angle of the hammer.

6. Top view of finished ribbon taper



7. Side view of finished ribbon taper, and checking with straight edge.

taper.)

Targets:

-The taper should be centered on the bar.

-Edges should be straight, faces flat. (No concavity or convexity. Check with a straight edge.)

-The bar should maintain the original parent stock width. (Check with outside calipers, see photo 8.)

-With practice, you should be able to make this taper in one heat. -Two to three heats would be acceptable for the first attempts.

-The finished taper should be 2 3/4", plus or minus 1/16".

Note: If you subtract the non-forged portion of the bar from the overall length of the starting length, the difference will tell you how much of the bar was used for the taper. This is useful information, providing you observed the original stock size.

-The end of the bar should not be more than 1/64" (one sixty fourth of an inch) in thickness.

8. Checking width of ribbon taper with outside calipers.

Note: An alternate process to minimize the 360 degree spread of material would be to use the horn of the anvil to draw out the taper. This could be done in conjunction with the set-up shape (resulting in vastly different results), or by itself, eliminating the set-up shape altogether. The rounded shape of the horn acts as a cross peen, or fuller, directing most of the material in two opposing directions.

Terms

Set-up shape- A shape that is made early in the forging process to facilitate, anticipate, and define the final shape of the forging.

Drawing Out

by Dan Nauman

Drawings by Tom Latané

Lesson #17: Forging a square bar into a round bar.

Definition: Reducing the cross-section of a bar

Intent: The student will learn to take a bar with a square cross section, and forge it into a bar with a round cross section, maintaining a consistent diameter throughout the length of the bar.

Tools: Basic tools, 1/2" "V" tongs.

Material: 1/2" square x 6". (One half inch square x six inches.)

Step One

Heat 4" of the length of the bar to a bright yellow heat.

Note: Do not leave your tongs in the fire when heating the bar. Doing so could heat the tong jaws to a malleable temperature, and will cause the jaws to distort when pressure is applied by grasping the bar.

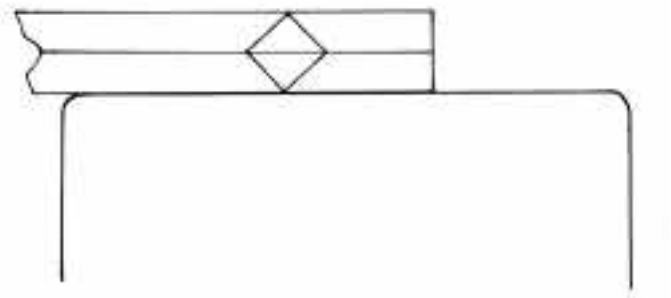
Your goal in this first step is to form the bar into an octagon.

Place the hot end of the bar, with one corner level on the anvil face. Make sure the opposing corner is directly above; not leaning to the right or to the left. (See drawing #1.)

Note: This initial position of the bar is important, as you will be making the square bar into a perfect octagon before forging it round. If the corners of the bar are not positioned correctly on this first step, the bar will twist, and you will get more of an oval cross section than a round cross section later in the process.

The end of the bar should be placed at the midpoint of the anvil face. Begin striking the end of the bar, with the hammer face parallel to the anvil's face. The facet you forge should be about 3/16"- 7/32".

Note: Do not chase the bar with the hammer. In other words, after each blow, feed the bar forward about half the width of your hammer's face. The hammer blows should remain concentrated in the same area of the anvil as your first blow. Since the position of the bar is moving, and the hammer direction is constant, you will find it easier to maintain control of the blows.



1a. The bar on the diamond, held level with the anvil face, resting on one corner.

After each blow of the hammer, assess the impression to see if your hammer is maintaining a nice flat facet. If the previous blow shows a mark from the edge of your hammer, or a facet tendency to the right or to the left, adjust your hammer to make the correction. A proficient smith constantly assesses every blow, and adjusts the hammer head, the bar position, or both without breaking the rhythm of his/her blows.

Be attentive to maintain a constant material thickness along the length of the area you are forging.

Note: Right handed smiths will have a tendency to forge the facets with a lean to the right, and visa versa for left hand smiths. (See drawing #2.)

Continue forging down the length of the heated bar. Then rotate the bar 90 degrees (right or left) to forge down another corner the full heated length of the bar.

You have now forged four square corners of the square bar into facets.

Forging dynamics: The anvil is also flattening the opposing corner. Note that the width of that facet will be narrower, and will need to be dressed with the hammer.

The metal itself is acting as a shock absorber. The more stock between the anvil and hammer, the less force applied by the anvil

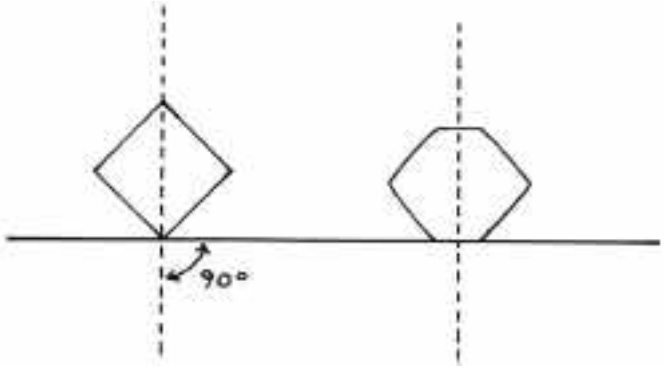
Also, the original four facets will begin to slightly bulge. (See drawing #3.) This is caused by the force of the hammer blows, and since the bottom of the bar is supported by the anvil, the metal will seek the path of least resistance. These facets will need to be lightly dressed with the hammer to have eight uniform and flat facets.

These dynamics will be more apparent when working larger bar stock. The 1/2" bar that you are forging in this lesson may show little visible difference in facet width or bulging.

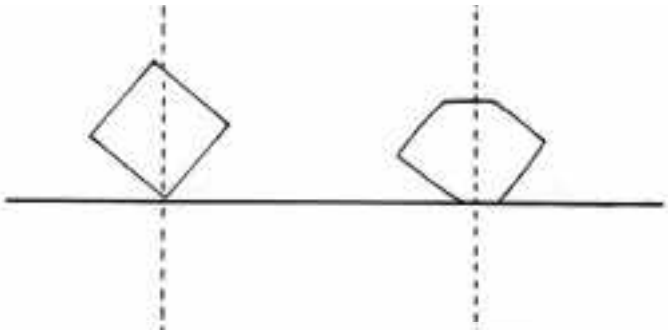
Rotate the bar 90 degrees in the same direction as you did earlier. This facet was forged by the anvil face, and will need to be lightly dressed, as will the next successive facet at 90 degrees.

As you are forging these facets, be aware of the width of the original four facets, as they are now becoming narrower, and have slightly bulged. The heat in the bar has diminished by this point. If the bar still has some dull orange color, begin to dress the all facets to a uniform width, with lighter blows. If the bar is more red than orange, reheat to a medium orange, and dress all the facets.

Note: Do not make the mistake of trying to dress the facets at a high heat. The facets of the bar are difficult to see when the bar is heated brighter than a medium orange. If the bar is forged, even though the facets cannot be readily seen, the result is a bar with mis-aligned facets, twisted facets, or corners that have been nicked.



1b. When the bar is held correctly, with the line between the top and bottom corners perpendicular to the anvil face, the resulting facets will be centered on that line.



1c. If the bar is not held with the top and bottom corners lined up perpendicular to the anvil face, the first few hammer blows will cause the bar to twist and the resulting facets will be skewed.

As the bar cools, and the facets and their respective corners are becoming uniform, lighter blows may be used to smooth the eight facets, and to sharpen the eight corners. This is often referred to as a "finishing heat."

Step Two

Turn the bar around, and heat four inches to a bright yellow heat. You will be heating the bar partially into where you have already forged. You do this so that the area you wish to forge remains hot enough to forge the rest of the bar into an octagon.

Proceed to forge the end of the bar as in step one, and gradually work towards the middle of the bar until the facets blend into one another. Be careful to maintain the bar level on the anvil, and to keep your hammer blows parallel to the anvil face.

Note: It is at this point you will find out if you have a tendency to forge with your hammer head to the right or to the left. When you forge the facet on the opposing side of the bar, the facets should meet on the same plane. If there appears to be a twist at the point where your facets meet, you are probably not forging with the hammer head parallel to the anvil face, or you are not holding the square corners of the bar perpendicular to the anvil face. The correction is a delicate matter. With lighter blows, dress the errant facet to the correct plane by altering the position of your hammer before proceeding to forge the succeeding facets.

If there is a constant twist throughout the bar, again this is a result of a right or left forging tendency. It could also indicate that you are holding the bar with the corners out of a vertical line. This twist is difficult to correct.

To correct a slight twist, reheat the twisted bar to a medium orange. Place a facet flat on the anvil face, with the middle of the bar at the near side of the anvil. (See drawing #4.) With light blows, strike the far end of the bar with the hammer face parallel to the anvil face. Proceed with your blows to the middle of the bar. Repeat this on all eight facets, or until the twist has been removed. Turn the bar around and repeat if necessary. The danger in this corrective action is that the bar's cross-section may be reduced undersize, and could require upsetting to regain the proper thickness. A radically twisted bar (more than 1/8 revolution) more than likely will prove impossible to correct in this manner.

Of course, the bar could be heated to a dull orange, then placed in the vise and twisted to remove the twist. It is the aim of these lessons to teach the student to use the basic tools to increase hammer control, and less reliance on peripheral tools.

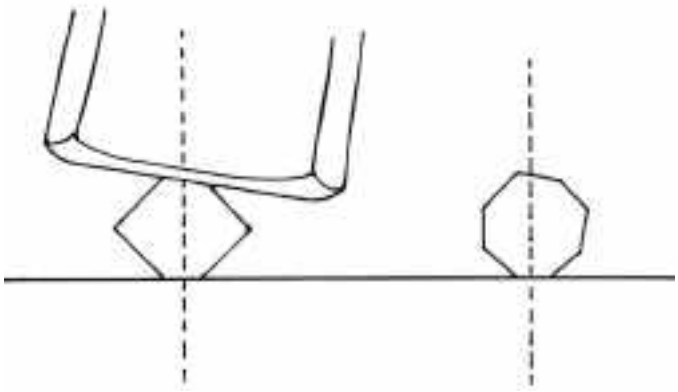
The best way to avoid the twist is to be careful and forge square to the anvil, and also to hold the steel in the proper position.

Step Three

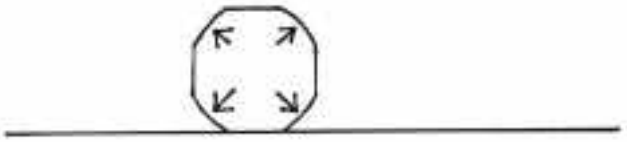
You should now have a uniform octagon. Check the bar thickness on all sides with an outside caliper. The facets should all be uniform in width, and the corners sharp.

The bar should also be straight. Check with a straight edge. The bar should also be 6 5/8" long, and the width across the facets between 17/32" to 9/16".

Forging Dynamics: Note that the cross section of the bar appears to have grown in size. The measurement across the diamond of the parent square bar is just under 11/16". What has happened is that the metal in the corners has been redistributed by forging, and in actuality, the cross section has been reduced, and the length of the bar has increased.



2. The result of the hammer blow tilted to one side.



3. The remnants of the four original faces of the bar are shown bulged by the displacement of the metal as the corners are forged.

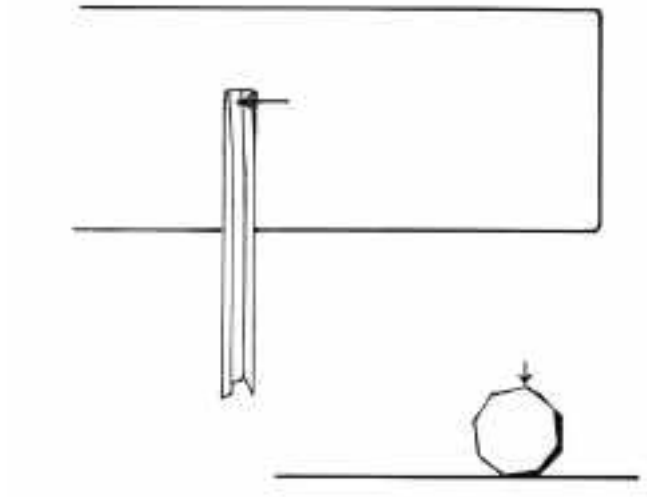
You may also find that the ends of the bar are thinner than in the middle. This is because there is less resistance at the ends of the bar, so the bar stretches easier at these points.

If your bar's ends are thinner, you will need to upset them and redress the facets to obtain a uniform cross section.

Step Four

You are now ready to forge the bar into a round cross section. The bar is longer as you have drawn out the bar to make the octagon. Heat four inches of the bar to a medium orange. Place the end of the bar in the middle of the anvil face with the bar lying level on one corner. With quick light blows, proceed to forge down the length of the hot bar as you did in Step One. Rapidly repeat on all corners. (See drawing #5)

When you have knocked all the corners down, place the end of the bar back at the center of the anvil, and begin to rock the bar back and forth 180 degrees. Then with light rapid blows, begin to refine the bar into a round cross section. Your goal in this step is to erase any sharp edges and facets. Aim the hammer at any sharp edges that remain on the bar. If you continually strike the facets, they will increase in width and the bar will not be forged



4. Correction of a slight twist may be accomplished by light flat hammer blows to the high corner at the end of the bar while the middle of the bar rests with a facet flat on the near side of the anvil.

to round. Work the bar about one width of the hammer's face until the bar is round (no facets or sharp edges.) Then feed the bar forward, and repeat the process, consecutively working only the width of the hammer's face at a time. Reheat to medium orange if necessary to complete this side of the bar. Rotate the bar to the radius that faced the anvil, and proceed with the rocking motion and continue refining to round.

Note: Working the bar in hammer face width segments makes it easier to maintain a uniform diameter.

You may work the bar to a black heat (finishing heat) to refine the bar, but do so only with very light rapid taps, and only if the major facets and edges have been removed.

Forging dynamics: The black heat is a brittle heat, and cannot

5. Sixteen rough facets are created by forging the eight corners of the octagon. Light rapid blows are then directed at the high spots while the bar is rolled back and forth. Continually rolling in one direction can cause a twist in the bar.

take the abuse of a heavy blow. Heavier blows at a black heat will result in cracking, splitting, or snapping.

Step 5

Turn the bar around, and repeat the process as in Step 4.

Targets

–The bar should be straight.

–The bar should have no facets or edges.

–The bar should have a uniform 7/32-9/16 diameter throughout its length.

–The bar should be 6 3/4 inches long, plus or minus 1/16".

Drawing Out

Text and photos by Jay Close

Drawings by Tom Latané

Lesson #18: Using the peen

Definition: Drawing down is the reduction of the cross sectional area of a bar.

Intent: This lesson will review the proper shape of a peen for the cross-peen forging hammer. Through two exercises the smith will learn to use the peen to gain increased directional control of the drawing-down technique.

Overview: The cross-peen hammer is the basic blacksmith's hammer. It offers two striking surfaces: the face and the peen. While smiths may disagree about the ideal shape of the peen, the peen illustrated in figure 1 is much too sharp for our work. It would create narrow, deep fissures in the bar surface that would be difficult to smooth and likely result in cold shuts. Figures 2 and 3 illustrate the same peen ground to a more useful shape, a shape that will leave behind a bar surface more easily refined, yet a shape that still demonstrates the special forging capabilities of the cross-peen hammer. The two essential features of this reshaped peen are its increased width (3/8 inch to 3/4 inch wide) and the well-rounded corners.

Fig.1 Sharp peen on hammer as purchased.

Peening introduces a wedging effect to the hammer blow. A blow with the face will tend to spread the work 360 degrees; a blow with the peen will spread the metal more perpendicular to the length of the peen. You will see some spread in all directions, but most shape change will occur as illustrated in figure 4. This allows a degree of directional control that is less evident in a flat blow with the hammer face.

Tools: Basic forging tools only.

Material: Mild steel 1/4 inch by 1 inch and about 24 inches long (or as convenient to hold).

Exercise One- Step One

At a full yellow heat, lay one inch of the bar flat on the anvil face as in figure 5. Use a part of the front edge of the anvil that has a rounded corner when you do this. Imagine placing a square of the material on the anvil surface. Get used to making shape judgments by eye.

Figs.2 and 3. Reshaped peen ground wider with rounded corners.

Hold the bar held horizontally and perpendicular to the front edge of the anvil. Reference figure 6.

Standing with your shoulders roughly perpendicular to the front edge of the anvil (see figure 7), strike with the peen in the middle of the square of material on the anvil face.

Hit with the peen parallel to the anvil surface but with about 75% to 80% of the peen length over the anvil face and the remainder off the face. This is a partial peen blow.(Figure 8.)

Fig. 4. Peen pushes metal to either side.

Fig. 5. One inch of the bar on the anvil face.

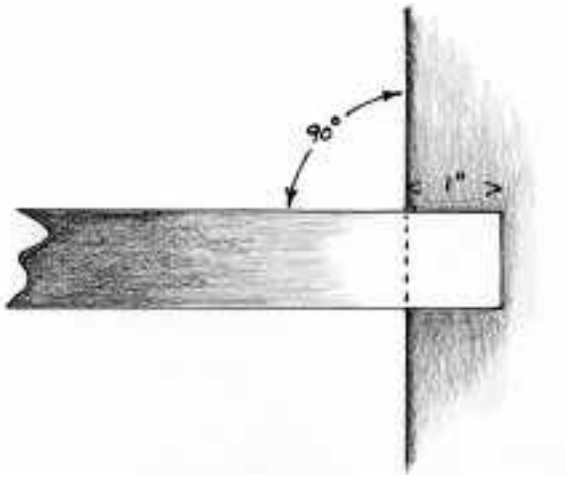


Fig. 6. Bar placed horizontally and perpendicular to the anvil edge.

Keep your bar-holding hand relaxed. Separate the action of the hand swinging the hammer from the other holding the work.

Having hit one blow in the middle of the bar, strike there repeatedly until a troughlike thin area develops, maybe 1/16 inch thick or less. When peening for width, always work the middle of the bar first, as this is the easiest time to spread that center section.

Fig. 7. Stand with shoulder of hammer hand facing the anvil.

At the time of impact of the peen with the workpiece, the hammer handle should be horizontal. This helps insure that the blow is not inadvertently pulling or pushing the material unevenly. Figure 9 illustrates the result of a blow in which the peen hits at an angle. The spread you witness should be even and the shape you create symmetrical.

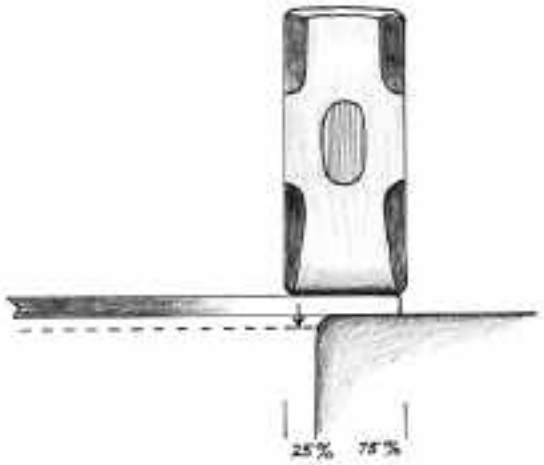


Fig. 8. Peen hits an overlapping blow– mostly on the anvil, but partially off.

The end of the bar should look like figure 10 on the top side and like figure 11 underneath. Note that the rounded corner of the anvil will have begun a defined transition on the bottom of the workpiece.

Also note that all peen marks are parallel to each other and parallel to the length of the bar.

Step Two

Work each half of the peened section sequentially.

Forge the far half first as most people find peening away from themselves more awkward than peening toward themselves. It is always a good rule to do the hard or more awkward tasks first. Figure 12 illustrates the sequence of work: middle first, then the half farthest from you, finally the half nearest you.

Heat the bar on edge with the thick part you intend to work placed down in the fire and the part awaiting shaping uppermost. See figure 13. You should be able to get a full yellow heat

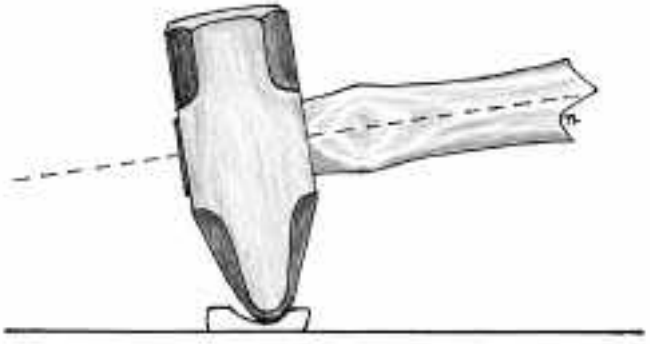


Fig. 9. Metal driven more in one direction by angled blow.

Fig. 10. Top of the bar showing peened middle trough.

on the edge without endangering either the thinned middle section or the thick opposite edge.

At a full yellow heat come back to the anvil as in Step One. Feel the slight shoulder you started rest against the rounded corner of the anvil.

Now hit just to the far edge of the central trough. The harder you hit and the higher the heat, the more smoothly the bar will move in front of your hammer blows. You want each hammer blow to be placed parallel to the one before and just slightly further into the thick bar. Keeping the hammer blows parallel to each other maximizes the sideways spread and (with practice) increases control of the final shape.

Try for a consistent pattern of parallel peen marks and a consistent average thickness in the bar. It will take time to develop the confidence and hammer control necessary to do this well, but

Fig. 11. Bottom of bar showing transition made by rounded corner of the anvil.

practice will make it second nature.

Note that near the edge of the bar, as the path of resistance is lessened the metal moves more dramatically. It is, therefore, easy to get the edges much thinner than the middle. A consistent thickness is the goal.

At the end of this second heat the end of the bar should look something like figure 14.

Step Three

The bar goes back in the fire but this time with the opposite, still-thick side down and the thinned edge uppermost. Once more you should be able to get a good yellow heat on the thick section without endangering the already thinned areas. See figure 15.

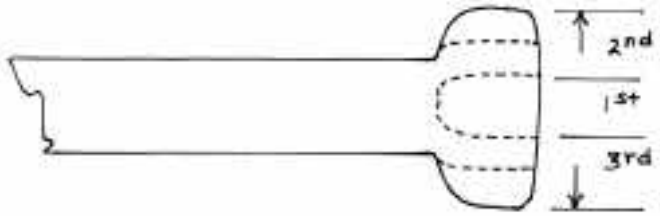


Fig. 12. Work the middle, then the side furthest from you, then the side nearest you.

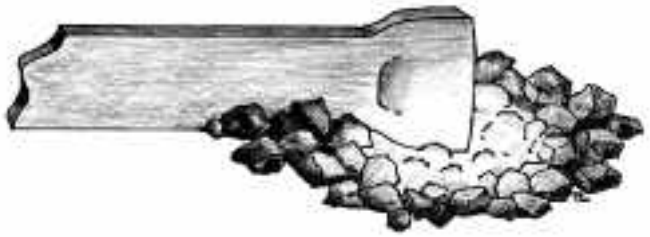


Fig. 13. Half to be worked placed edge down in the fire.

Proceed just as in Step Two, but instead of working your peening blows away from you, bring the hammer blows slowly toward you.

Hit hard and with confidence. If the bar is hot and you hit hard the shape will bloom before your eyes. It is actually better to hit hard and sacrifice (initially) some accuracy than to hit timidly.

Your result should resemble figure 16. This is an exaggerated shape designed to show the potential of peen work. Observe these points:

(1) the peen marks are parallel to each other

(2) the peen marks are aligned along the length of the bar

Fig. 14. Top view of the bar with one half spread.

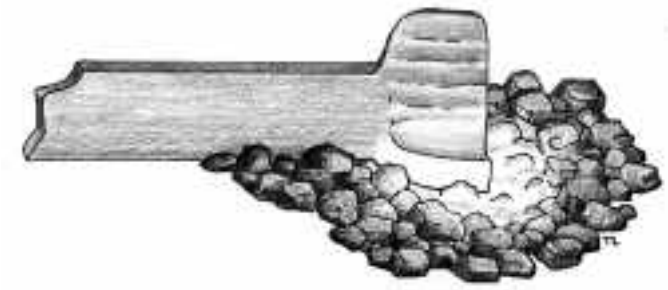


Fig. 15. Bar heating on edge with thinned area upper most and portion to be worked down.

(3) the peen marks are even and the bar a consistent average thickness

(4) the shape is symmetrical

(5) on the opposite side of the bar there is a clean and definite shoulder.

You started with a 1 inch by 1 inch square of material on the anvil face that was 1/4 inch thick.The bar grew a little in length, but you ended with a wide oblong form that was much thinner. The mass of material was redistributed mostly to the sides, perpendicular to the run of the bar.

As an experiment you may want to try the same exercise but hitting only with the flat face of the hammer. You will end with a very different form, perhaps like figure 17.

Step Four

As a final step, take an overall light orange heat on the thinned part of the bar and come back to the anvil. Place the bar as

Fig. 16. Finished peening.

before, feeling for the shoulder underneath against the anvil corner. Using the face of the hammer, smooth the peened part the bar, allowing the anvil face to planish the opposite side to a near-burnished finish. See figure 18.

Watch the rate at which the bar cools. Thicker areas will hold heat longer and show where more forging is needed. Areas that cool quickly are thin and you should stay away from these.

To test for how even you have forged the end of the bar, cool the bar and then use your fingers as a gauge to test for thicks and thins. Commonly, the middle is thick and the edges thin. Reheat the bar– being thin, this will be fast– and address any unevenness you find. If you have left the center heavy, it will thin with reluctance.

Fig. 17. Flattened bar using the face of the hammer.

Fig. 18. The smoothed shape.

Exercise Two

Step One

The shape you achieve when you peen a bar in width is a thinner and sideways stretched version of the shape you started with. Exercise One started with a thick square and ended with a thin, oblong and roughly rectangular form.

Figs. 19 & 20. A triangle-shaped set up.

Starting with a different initial shape we can create different, thinned expressions of it. These initial shapes are called "set ups." Exercise Two introduces a different set up.

At a yellow heat, forge the end of your bar on edge to an even taper. Work at a high heat and hit hard to avoid or minimize the chance of a cold shut on the very tip.

Keep the taper short and retain the original 1/4-inch thickness of the bar. Figures 19 and 20 show what you are after. This triangular shape on the bar end is the set up for a different peened shape.

Step Two

Start peening as in Exercise One.

At a yellow heat, place the base of the triangle that you created flat on the rounded edge of the anvil with the entire taper lying on the anvil surface. See figure 21. The bar must be horizontal and perpendicular to the anvil front. Stand as you did in the first exercise: roughly perpendicular to the anvil with the shoulder of your hammer arm facing the anvil.

Begin peening in the middle as you did before until you have a central trough like figure 22. Hit flat with the peen parallel to the anvil face and the hammer handle horizontal at the time of impact. Keep the length of the peen aligned with the length of the bar.

Step Three

Put what will be the far half of the shape down in the fire, but be careful of the tip as it is vulnerable to burning.

Fig. 21. Place just the set-up flat on the anvil face.

At a yellow heat, peen the material working away from you. Keep an even average thickness and symmetrical shape. Concentrate on keeping the peening blows parallel to each other and the hammer handle horizontal at the time of impact.

Step Four

Reheat with the bar on edge in the fire. The thick part of the shape should be down while heating and the thinned area uppermost. This is just as you did in Exercise One.

From a yellow heat peen the metal toward you in this step. Figure 23 shows the final shape.

See the previous exercise for points to watch.

Step Five

Take an overall light orange heat to smooth the shape with the face of your hammer.

The results should look something like figure 24.

Fig. 22. Central trough on triangle set-up.

Fig. 23. Final peened triangle set-up.

To check for even thickness, cool the bar and use your fingers as a thickness gauge. If you find heavy areas, the thin shape will reheat quickly in the fire for additional attention.

Troubleshooting

One of the biggest issues to overcome is inaccurate hammer blows. A misplaced blow with the broad face of the hammer is often of little consequence and easily obscured or corrected.

Fig. 24. The smoothed shape.

Figs. 25 and 26. Corrections to alignment.

When you are attempting to push material in front of the peen, especially as the material is getting thinner with each blow, a misplaced blow is sometimes hard to correct. The beginner will often become timid in the use of the peen, taking short pecking blows, and multiple heats to achieve the shape. This should be avoided. High heats and hard hammer blows are the key to successfully thinning a set up. The only way to achieve the accuracy needed is to force yourself to forge with confidence and hit with purpose.

Sometimes a significant asymmetry emerges as the peening progresses. If you are certain that the peening was accurate and even, then that asymmetry may have existed in the original set up. Even a slight unevenness in the set up will be magnified many times as the bar gets thinner. Just make the set up as even and symmetrical as possible and deal with emerging asymmetry as you work. Sometimes this involves leaving half the flattened area a bit thicker than the other. Some selective peening to spread one area more than another may also be needed.

In making these in-process corrections, there is no "step by step" or easily followed formulations. Forging with confidence helps. Keeping the peen marks parallel to each other even when making corrections also seems to help. Practice is the most important aid.

Frequently the peened shape will be even but slightly canted from the center line of the bar. With the shape already thinned, it is not advisable to correct the shape by a simple straightening blow on the edge of the thin shape. Rather, slightly thin (with peen or face of the hammer) the base of the shape to stretch material and move the thinned form in the needed direction. For example, stretch the base of the thinned triangle on the left side to swing the form to the right; stretch the base of the triangle on the right side to swing the form to the left (figures 25 and 26).

Forging Dynamics

In drawing down, the mass of a piece of iron is retained but the distribution of that mass is altered by often dramatic reduction of the cross-sectional area. By creating different prepared shapes called "set ups" and by use of the hammer peen, you can control the final shape of a thinned section with economical use of material.

The center section of a bar being peened is most resistant to shape change. This is because the hammer blow must push against material in all directions to make a change in thickness. The edges are easiest to thin as they have little resistance to their spread.

As the bar gets wider, even if thinner, this resistance of the middle to shape change only increases. The hammer blow must now push against stiff edges that are being forced to move through their thickest dimension. This is why in thinning a bar we try to work the center of the bar first. This is also why it is so easy to get a thinned section that is relatively thick in the middle and thin on the edges.

Targets:

–The peened shape should be even thickness and symmetrical.

–The peened shape should be in alignment with the length of the bar.

–The surface texture on both sides of thinned area should be smooth without obvious hammer marks.

–Take one or two heats for more complex set ups like the triangle taper.

–Take three heats to peen these shapes and a single heat to smooth them.

Remember, these are targets or goals. It will take much practice to achieve these results.

Author's Note:

All forging for this lesson was done with the inexpensive hammer shown in figures 2 and 3. You do not need esoteric or expensive equipment to practice and improve your forge work.

Thanks to Bob Ouellette who posed for figure 7. Bob is a student of mine in the American College of the Building Arts bachelors' degree program in forged architectural metals.

Splitting the End of a Bar

Text and photos by Dan Nauman

Drawings by Tom Latané

Lesson #19. Unit: Cutting

Definition: Using a sharp edged tool to cut or alter a bar, or to remove material from a bar.

Intent: To learn to use a hot-cut chisel to cut down the centerline from the end of a bar.

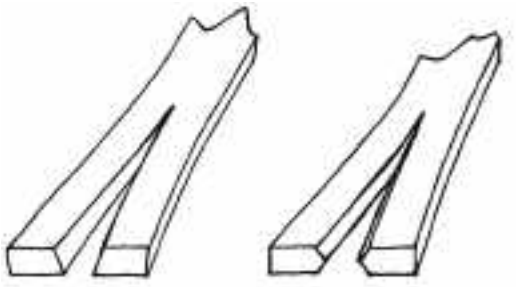
Tools: Basic tools, plus a hot-cut chisel, cutting plate or saddle, tool to hold the hot cut, tool to hold the work-piece.

Material: 2 pieces of 1/4" x 1" x 24".

Note: There are two methods of cutting we will teach in this lesson. Method one(M1) will teach cutting a bar from one side all the way through. Method two(M2) will teach cutting a bar from opposing sides.

Each method leaves a very distinctive kerf. (See Drawings #1 and #2.) Image #1 shows the kerf made by method one. Image #2 shows a kerf made by method two.

It is important to determine which method to use in order to achieve a specific goal. Thinner materials, 1/4" (one quarter inch) or less, are often (but not always) cut using method one. Thicker materials are often (but not always) cut using method two.



1 &2. Method 1 kerf, left, and method 2 kerf, right

Forging Dynamics: On either side of the kerf, the bar-stock will be displaced by the thickness of the chisel. The chisel should be thin so the amount of stock displaced is minimal. As the bar begins to split, the opposing sides of the kerf (legs) will peel away from the line of the cut. This stretching is caused both by the material being pushed apart by the hot-cut chisel.

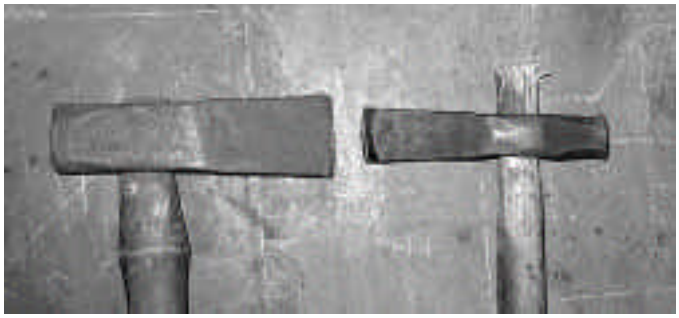
Note: It is important to use the correct chisel. A cold-cut chisel, as the name implies, is used to cut cold stock. This type of chisel needs to be heavier, or backed up by enough material so the chisel does not snap or crack from the shock of cutting the harder cold stock. Because it is cutting softer material, the hot-cut chisel receives less shock, and can have a more acute bevel. (Photo #3 a+ b shows the difference in blade bevels of the hot-cut chisel and the cold-cut chisel.) Note that both chisels have

3. Notice the difference in the thickness between the cold cut (left) and the hot cut (right).

rounded, not square edges. This allows the chisels to easily track in the kerf, and in some cases, allows you to make a curved kerf. (Photo #4 a+ b shows the side shape of the two chisels.) A square chisel is harder to control, as the abrupt wall left by its impression makes it necessary to lift the blade out of the kerf track to advance. (See Drawing # 5 of the potentially bad kerfs made by a square chisel) In this lesson, we will be using the hot-cut chisel.

The specific purpose of the cut may determine which method you choose. For example, if the legs formed by the cut are to be drawn out, it would be easier to draw out a M2 kerf, which has a center crown, being beveled from both sides, rather than a section with one tall beveled edge as seen in the M1 kerf. On the other hand, an M1 kerf might be desirable as the naturally beveled edge left from cutting may serve as a decorative accent. Method one could be used for making a split scroll with a beveled edge, while method two could be used for beginning the end of a fork.

Holding the bar steady while cutting must be considered. There are several methods of holding the bar for cutting. One method



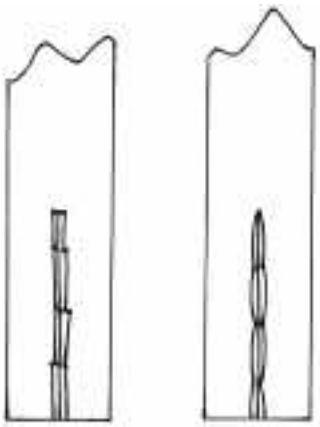
4. This photo shows the rounded edges of the hot and cold cut, which allows the tool to slide along the workpiece more easily. than if the edges were square.

for cutting short bars is to use a holdfast, as seen in Photo #6. A holdfast can easily be made out of mild steel, of a slightly smaller diameter than your anvil's pritchel hole. To use the holdfast, simply slide the shank into the pritchel hole, and place the flange on top of the work-piece. Lightly tap the top of the holdfast to secure the work-piece onto the anvil.

For longer bars, you could use a "blacksmith's helper" which is an adjustable stand. Some smiths prefer to use a weight to keep the piece steady while cutting. One way to apply the weight is to attach a chain to an "S" hook, and attach the weight at the end of the chain. (See Photo 7.) When using the blacksmith's helper, adjust the stand so the bar rests flat on the face of the anvil.

The important thing is to keep the piece flat and stationary on the anvil while cutting. If the bar is not resting flat on the anvil face, the bar will bend more dramatically, and the impact of the chisel will be lessened as well.

Holding the chisel is also a consideration. If you have a chisel with a long enough shank, you may be able to hold it while cutting without burning your hand. It might be easier for some to use a pair of chisel tongs to hold the chisel. Many smiths prefer



5. Scars potentially produced by a square-edged chisel and a wavy cut potentially produced by an overly rounded chisel.

to use a chisel with a solid handle of either a bar wound around the chisel, or a wood handle that pierces the chisel. (See Photo #8 showing the tongs, and two types of handles) For this lesson, we will use a chisel with a wooden handle.

Cutting Method #1

Step One

Measure 2" from the end of the bar, and with a centerpunch, mark the exact center of the bar. Make the punch mark large enough to see when the bar is hot, but not too large, as a large punch mark might remain visible after cutting.

Step 2

Heat 3" of the end of the bar to yellow. Place the end of the bar flat on the anvil. Place the center of the chisel on the end of the bar at the bar's center. Lightly tap the chisel to create a light impression, about 1/32" or less deep.

Note: In this step, you do not wish to drive the chisel through the bar, nor create a bold kerf as you need to first establish the proper kerf track. If your judgement is off, the light impression will not usually be deep enough to ruin the project, and can be corrected by simply adjusting the chisel to create a new kerf. The new kerf will push material towards the old kerf, closing it up. Unless you are dramatically off in your initial judgement, this correction will likely be undetected in the finished piece.

In the same heat, move the chisel by sliding, not lifting it, one half the width of the chisel, and take another light tap. You should always slide the chisel towards you, as you can see where the chisel is in relation to the bar. When moving the chisel, always leave a portion of the cutting edge in the track of the kerf

6. The holdfast slides into the pritchel hole, and holds the workpiece firmly with a light tap of the hammer above the holdfast's vertical shank. To remove the holdfast, lightly tap the side of tool's vertical shank with the hammer.

from the previous blow. Some smiths prefer to linearly rock and then slide to advance the chisel. These procedures insure that a double kerf line isn't accidentally formed.

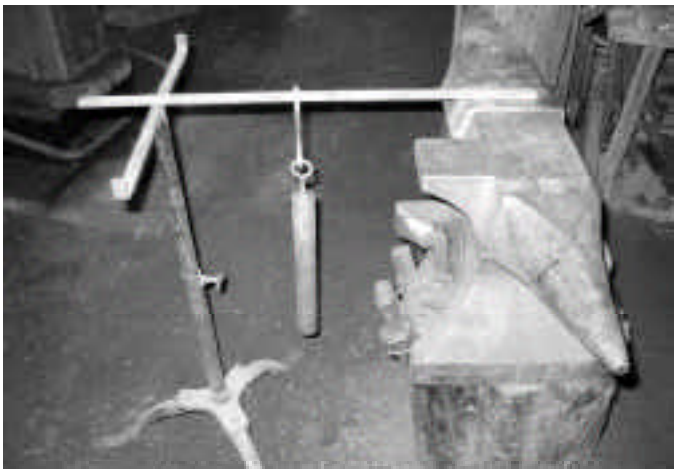
Continue the light kerf all the way down to within 1/16" of the center-punch mark, making sure you remain in the middle of the bar. If you make an errant blow along the way, make the correction immediately before continuing down the bar. Make sure the chisel remains perpendicular to the workpiece at all times.

Forging Dynamics: The bar will begin to curl upward as the force of the chisel makes impact. To cut properly, the bar must be tapped down flat on the anvil every time you retrace the kerf to deepen the cut.

Note: When cutting heavy stock, some smiths prefer to quench the chisel after four or five blows to keep the chisel blade cool. This is more important when using a chisel of simple carbon steel.

Step 3

Take another yellow heat 3" long. Place the bar on the cutting surface.



7. A blacksmith's helper stand helps to hold longer bars. The attached weight helps keep the workpiece steady. Adjust the blacksmith's helper so the workpiece lies flat on the anvil or cutting saddle.

Note: STOP! Do not even think about cutting through the bar on an unprotected anvil. It is believed by some that the table of the anvil, sometimes referred to as the step of the anvil, is to be used for cutting. Doing so will only scar the surface to the point where it is no longer useful. The bottom of the hot bar will sink into the scars left by the chisel from past cuttings, leaving unsightly marks on the work piece.

A piece of 1/8" to 3/16" thick (or thicker) plate of copper, brass, or a piece of low carbon steel can easily be used as a base beneath the bar being cut. Make sure it is large enough to effectively support the workpiece. Some smiths prefer a more stable cutting surface, and may shape the cutting plate to fit snuggly over the edges of the anvil. This tool is called a cutting saddle. (See image 9 of a cutting saddle.) This not only protects the anvil, but also protects the chisel edge. When the surface of the plate or saddle becomes scarred, simply throw it away and make a new one, or if it is thick enough, you may remove the scars by grinding or forging.

8. A wooden-handled chisel, left, dedicated chisel-holding tongs, center, and a wrapped handle (on a punch), right.

As you did in step two, place the chisel at the end of the bar and this time strike the chisel with a medium to heavy blow as now your aim is to drive the chisel through the bar.

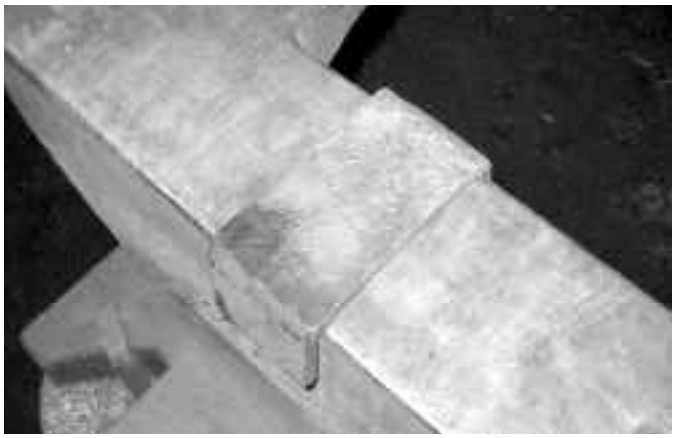
Move the chisel down the bar as you did in step two, creating a deeper kerf. Again, stop short of the center-punch mark. If you have not split the bar at this point, repeat the process until the bar is split through, hitting with less force to save the cutting plate from getting deep scars.

Step 4

You now want to finish the cut with a nice square edge at the bottom of the cut. The reason the initial cut is not cut right down to the center-punch mark is that since the chisel is curved, you will not have a clean square kerf at the end of the cut.

Note: In some cases, a tapered kerf at the end of the cut may be desired as a design element. For the purpose of this lesson, we are explaining how to finish the cut with a squared termination. (See image 10 showing the two types of terminations.)

To finish the cut, place the bar tightly in a vise with the center-punch mark 1/4" above the vise jaws with the legs in the vertical position. Place the chisel between the legs of the cut and carefully drive the chisel straight down until the chisel just pierces the center-punch mark. This last step can be done at a low orange to orange heat. A lower heat may be easier to control, as the chisel will meet more resistance, and you are less likely to cut too deep. Properly executed, the bar should now look like image 10.



9. This cutting saddle was made from 1/2" x 3", lies flat on the anvil face and fits snuggly over the edges. The thickness has been reduced by re-dressing the surface to eliminate surface scrars made from cutting through the workpiece."blacksmith's helper so the workpiece lies flat on the anvil or cutting saddle.

Targets

- The kerf must be through the middle of the bar within 1/32" per side.
- The kerf must have a clean appearance, with no ragged edges.
- There must be no double kerf lines.
- The kerf must be 2" long within 1/64" (one sixty fourth inch).

- The face of the bar must be flat.

- The inside end of the kerf must be square to the face of the bar.

- You should be able to split the bar in three heats. With practice, you could split it in one heat.

Cutting Method #2

(Review method one for forging dynamics, and notes to the cutting procedure.)

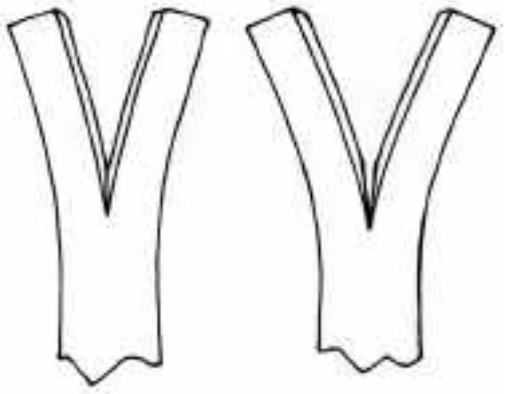
Step 1

Measure 2" from the end of the bar, and with a center punch, mark the exact center of both sides.

Step 2

Heat 3" of the end of the bar to yellow. Place the end of the bar flat on the face of the anvil. Place the center of the chisel on the end of the bar at the bar's center. Lightly tap the chisel to create a light impression, about 1/32" or less deep. Move the chisel by sliding, not lifting it, one half the width of the chisel and take another light tap. Continue the light kerf down to within 1/16" of the center punch mark.

In the same heat, tap down the end of the bar to regain a flat bar. Retrace the kerf with the chisel, taking a heavy enough blow to cut half-way through the bar.



10. A tapered kerf end, left, and a straight kerf end, right.

Step 3

Heat 3" of the end of the bar to yellow. Rotate the axis of the bar 180 degrees. As you did in step two, cut a light kerf to within 1/16" of the center punch mark, then tap the end of the bar to regain a flat bar.

Note: Accuracy is important! If you do not cut a line down the middle of the bar, you will get a kerf offset from the kerf on the other side. (See Drawing #11 of offset kerfs vs. two opposing kerfs.) To make sure you begin the second kerf in exact opposition to the kerf on the other side, look at the end of the bar to view both kerfs simultaneously. If they are offset, make the correction immediately.

Next, with heavier blows, retrace the shallower kerf with the chisel, and drive the chisel through the bar. Remember to use a cutting plate or saddle!

Step 4

To finish the cut, at an low orange to orange heat, place the bar tightly in a vise with the center punch mark _" (one quarter inch) above the vise jaws, with the legs in the vertical position. Place the chisel between the legs of the cut and carefully drive the chisel straight down until the chisel just pierces the center punch mark.

Targets

- The kerf must be through the middle of the bar within 1/32" (one thirty second inch) per side.

- The kerf must have a clean appearance, with no ragged edges.

- There must be no double kerfs.

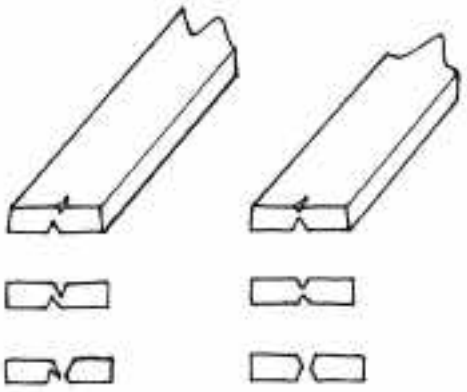
- The opposing kerfs must meet cleanly; no heavy burr from offset kerfs.

- The kerf must be 2" long within 1/64" (one sixty fourth inch.)

- The face of the bar must be flat.

- The inside end of the kerf must be square to the face of the bar.

- You should be able to split the bar in three heats. With practice you could split in two heats.



11. The result of offst kerfs (right) compared to opposing kerfs (left).

Notes about dressing the edge of the kerf:

1.) The kerf can be filed to suit the job.

2.) The legs can be bent away in a “Y” shape to 90 degrees, or one leg may be gently folded over the bar. The kerf can then be lightly forged with the face of the hammer, retaining the beveled edge. Afterward, the legs may be bent back.

3.) The legs can be bent or folded as above, then the kerfs can be forged so the cut edge is square to the face of the bar.

Forging a Fishtail

Text and photos by Dan Nauman

Drawings by Tom Latané

Lesson #20. Unit: Forging a Fishtail

Definition: Drawing down is the reduction of the cross-sectional area of a bar.

Intent: To continue learning aspects of using the cross peen accurately for controlled tapering and even spreading.

Tools: Basic forging tools.

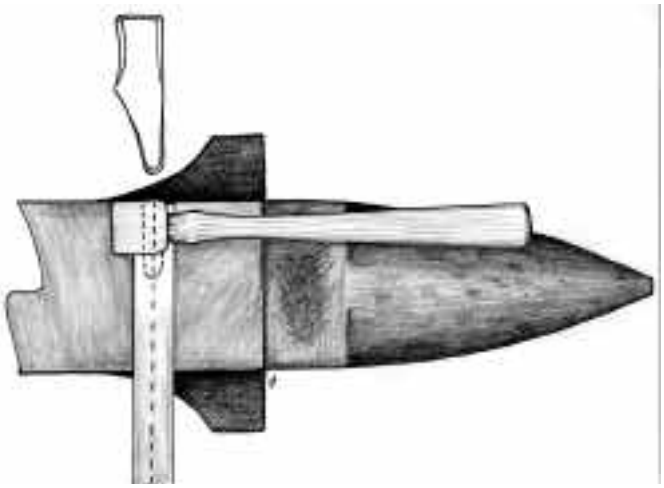
Material: 1/4" x 1" x 18".

Note: You may wish to review Lesson #19 which explains how the cross peen should be dressed, basic cross-peen forging, and cross-peen forging dynamics.

Step One

Heat 3" of the end of the bar to a full yellow heat, then lay the bar flat on the anvil with the end of the bar 1/8" in from the far edge of the anvil. You should be standing with your hammer arm's shoulder next to the anvil, and your body perpendicular to the anvil.

With the peen pitched down about ten degrees towards the end of the bar, and with the peen parallel to the length of the bar, begin striking the middle of the bar. (See image #1.)

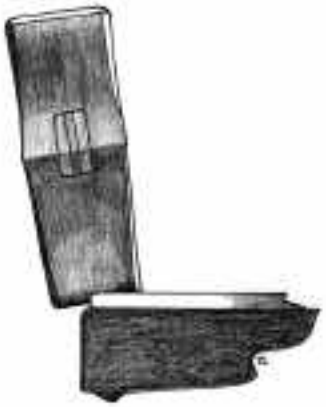


1. With the bar held perpendicular to the anvil and its end even with the far edge of the face, the first blows of the peen land in the center of the bar.

The reason the peen is pitched is to begin forming the taper. The bar is near the edge of the anvil to reduce the chance of an errant blow damaging the face of the anvil. (See image #2.)

When the middle of the end of the bar has been reduced to 1/16" in thickness, slowly begin working the peen back into the bar, taking overlapping blows and creating a trough down the middle of the bar. Continue to work back into the bar with the peen pitched. As you work back, begin to lighten your blows so that the trough feathers out to the full thickness of the bar. The trough should end about 2 1/2" from the end of the bar. (See image #3.)

2a. The hammer head is tilted so the peen strikes the bar at the angle of the desired taper.



2b. Because the bar is held even with the far edge of the anvil, the corner of the hammer peen should never come in contact with the face of the anvil even if the blow lands a little wide of the mark. Working at a slightly rounded edge will prevent damage to the squarest edge of the anvil, should the bar slip back from the edge.

Step Two

Heat 4" of the bar to a full yellow heat, being careful not to burn the thinned middle section of the bar. You can tilt the bar on edge to keep the thin middle section out of the direct blast of the fire. Place the bar on the anvil as in Step 1. Continue peening the bar, starting from the middle of the bar, then gradually moving out to the far edge. As the middle is already thinner from step 1, be careful not to get the middle of the bar any thinner than 1/16". Always maintain the peen parallel to the length of

3. Centered trough formed by cross peen, 2 1/2" long.

the bar. Move the peen in small increments, overlapping the track of each previous blow. Continue until you reach the corner.

It is interesting to note that the length of the bar doesn't change dramatically in this process, because the shape of the peen is primarily forcing the metal to change the bar's width. Correctly executed, you will develop a corner as seen in image #4.

Step 3

Heat 4" of the bar to a full yellow heat (remember to tilt the thin side away from the fire blast), placing the bar on the anvil as you did in prior steps. This time begin striking the bar again in

4. After Step 2, the far corner should look like this.

the middle, but now gradually work the peen towards the near edge of the bar, maintaining the peen parallel to the length of the bar. Again, move the peen in small increments, overlapping the track of the previous blow. Continue until you reach the corner.

Do not get frustrated if the shape in this step starts out somewhat lopsided, as this is actually how the shape should look at this point, and through controlled blows, will begin to blossom into a fine and symmetric fishtail shape. (See image 5.) Note that the end of the bar remains fairly straight and perpendicular to the sides of the bar when properly executed. Though you should strive for this feature, do not get overly concerned if the end is not perfectly straight and perpendicular, as refining it will come later in Step 5.

As you get more experienced, you may choose to perform this step in the same heat along with Step 2.

If you encounter shapes as seen in images 6 and 7, you can work the area lightly with the cross peen to fill in the gaps in image 6, or to straighten the edges of image 7.

5. Both corners have been peened out in this photo. This is what the fishtail should look like before refining with the face of the hammer.

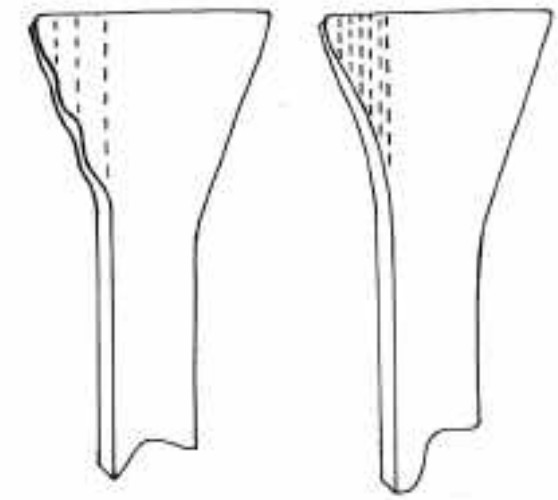
Step 4

Heat the entire fishtail to a full yellow heat. With the face of the hammer, smooth out the cross-peen marks, maintaining an even lengthwise taper.

Step 5

In this step we are going to refine the fishtail, by making the rounded corners of the fishtail more crisp and sharp, and refining the end and sides to straight lines. We will use the hammer's face to do the work.

Take a medium orange heat on the entire fishtail. Lay the bar across the anvil with the fishtail extending two inches beyond the far edge. Holding the cool end of the bar tightly against your thigh to help absorb shock, direct rapid light blows upon the end of the fishtail, driving the material toward yourself. If the fishtail buckles during this upsetting process, move the fishtail to the anvil surface to flatten. There may need to be several alternate rounds of upsetting and flattening blows before the end of the bar is straight and perpendicular to the centerline of the bar, along with a consistent lengthwise taper.



6. A wavy-edged flare results when the blows of the peen are too far apart. Narrow portions of the edge are thick portions of the taper. Direct blows at these spots.

Take another medium orange heat. Lay the bar on edge, with the beginning of the fishtail at a rounded portion of the near edge of the anvil, making sure the straight portion of the bar is off the anvil (See image 7.) Lightly hit the side of the fishtail to sharpen the corners. You will note that the corner you hit with the hammer sharpens faster than the corner on the anvil. Alternate sides so the corners sharpen evenly. If the fishtail begins to fold, stop hitting the edge, and flatten the fishtail back down with taps just hard enough to flatten, but not to squeeze the metal, which would further thin your work.

You may need to repeat this step, and take several heats to accomplish the desired shape (See image 8.)

Note: You do not want to get the metal any hotter than medium orange, as the material needs to be stiff enough to support the refining blows without folding over readily. This is one of the few times when cooler material is better.

Forging dynamics: Image #9 shows the finished fishtail shape

7. This is the position of the fishtail on the anvil to refine the shape. Refine at a low heat to reduce buckling.

8. The refined fishtail shape. Note that the centerline of the parent bar is centered also in the fishtail.

(left) that was made by the cross peen. The forging on the right, made by only the hammer face, has the same taper and end thickness, but not the same width as the forging on the left. Because the hammer face spreads material in all directions, for this exercise, it cannot forge the material as wide as the cross peen.

Targets

• Try to perform Steps 1-3 in one or two heats.

• The length of the fishtail should be 2 1/2" .

• The width of the end of the fishtail should be between 2 3/16" and 2 3/8" .

• The flared sides of the fishtail should be straight, and the end should be perpendicular to the length of the bar.

• The centerline of the fishtail and the parent bar should be the same.

• The fishtail should have a slow and even taper in its lengthwise cross-section.

• There should be no cross-peen marks in the bar.

9. The forging on the right was made using only the hammer's face. It has the same taper and end thickness as this lesson's forging on the left, but could not achieve the desired width without sacrificing the other two dimensions.

Forging a Square Punch and Drift

Text by Tal Harris

Drawings by Doug Wilson

Lesson #21. Unit: Forging a Square Punch and Drift

Intent: The student will learn to forge a square punch and square drift. Heat treating the punch will be covered in a future lesson. These tools will be used in a to produce a 3/8" square hole in a piece of 3/8" x 1" flat stock.

Tools: Basic tools, including tongs to hold the piece being forged.

Materials: For the punch- 3/4" square W-1 Tool Steel, six inches long. W-1 is a water hardening tool steel that is suitable for tools that come in contact with hot metal such as the subject application. W-1 is readily available in small quantities shippable by UPS. A tool properly made from this steel will last for many years.

For the drift- 3/8" square hot-rolled mild steel stock 2-3/4 inches long.

Forging a Punch

Step 1

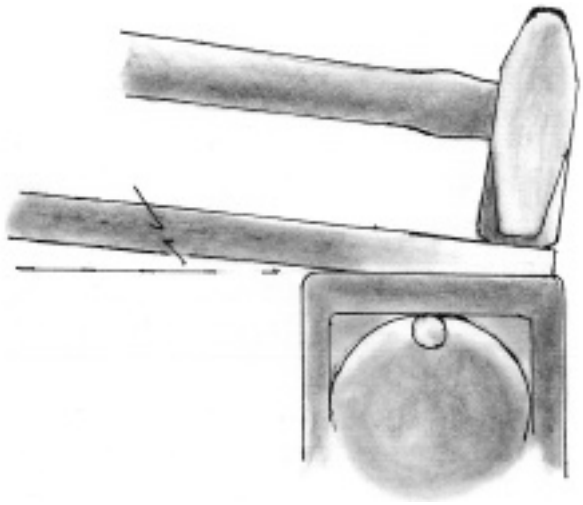
Forging the end of the punch that will be used to produce a hole.

To forge the end of the tool that will be used to punch a hole (hereafter called the “working end” of the tool), heat the end of the punch material to an orange-yellow heat and forge a taper three inches long.

Note: Tool steels typically are not forged as hot as mild steel. The alloying elements found in tool steels lower the melting point, thus the forging range. Overheated tool steel will generally fracture when forged, sometimes falling apart like cornbread. Ideally, tools should be forged in as few heats as possible to minimize decarburization or “decarb” for short. Decarb is the loss of carbon at the surface of the material due to carbon migrating from the high-carbon tool to the lesser-carbon atmosphere. Carbon is the key alloying element in W-1 that allows it to be hardened. Loss of carbon lessens the degree or surface hardness the material can attain. A coal fire minimizes this affect as the coal provides a carbon-rich atmosphere.

To forge the three-inch taper start at the tip and forge back up the bar. Start forging the taper at the end of the bar, holding the end of the material being forged near the far edge of the anvil. This will allow the taper to be forged without hitting the face of the anvil with the hammer. To forge a taper that is centered, the material should be held at a 4-degree angle to the face of the anvil as represented in the drawing, with hammer blows being struck with the hammer face at an angle of 8 degrees to the hammer face. Forge to a square cross-section, rotating the bar 90 degrees back and forth between hammer blows. If the proper holding and hammer angle has been maintained, the taper should be centered. Once the end of the bar has been reduced to 5/16" square, continue to forge up the bar three inches to complete the transition to the parent material. If more than one heat is required, be careful not to burn the material as the reduced section will heat quickly (you can tell you are burning the material because it will spark while in the fire). The taper should make a smooth transition from the parent material to the end of the piece without any twist. W-1 is a tough material. With experience this taper should be able to be forged in three to four heats.

Step 2



1. Holding the material at an angle to produce the desired taper

To forge the striking end of the punch, follow the same directions for the working end, but the taper should be short, 1 inch long, tapering from the parent material to 5/8" square. The angle of the taper will be almost identical to the working end of the tool. As this taper is short, it can be forged entirely over the face of the anvil and should be able to be forged in one or two heats. Occasional hammer blows directed at the end of the punch, as if striking it during actual use, will keep the end flat so no filing is necessary to achieve the properly shaped tool.

The purpose of this short taper is to delay the tendency of the striking end to “mushroom.” It also helps to center the force of the blow during the hole-punching process.

Step 3

Once forged, it is best to anneal the tool to relieve forging stresses and soften it for any cold working operations such as filing. During forging, tools steels tend to get “uptight.” Just as a person who gets uptight needs to relax before they “snap,” the same is true for tool steel. One definition of annealing is “The heating of metal and then cooling it at a slow, consistent rate, thus reducing internal stress in the work piece and making it softer and easier to perform cold operations including filing.”

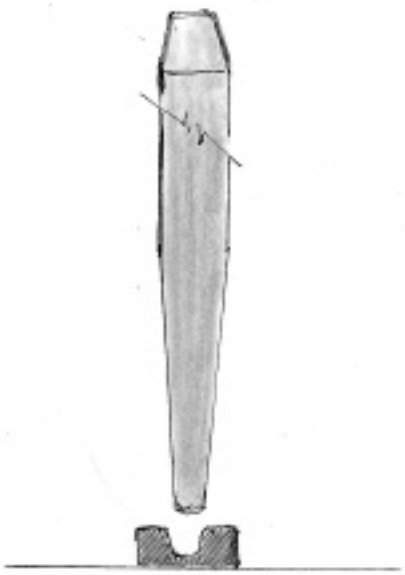
In this example, to anneal the tool it should be heated uniformly to an orange heat and then buried in lime or wood ashes to allow it to cool slowly. For a tool of this size, the quantity of lime or ashes required is about a gallon. The intent is to surround the tool completely so it is thoroughly insulated. It will take several hours to cool, so don't be impatient and search for the tool with your hand as a severe burn could be experienced. If properly annealed, the tool should cut easily with a sharp file. If not, repeating the annealing process may be necessary.

Note: Forge scale can greatly reduce the life of a file. An easy way to remove this scale is to soak the piece overnight in vinegar. Vinegar contains acetic acid and will dissolve the scale.

Step 4

Once cooled (and only if necessary) file the ends of the tool to remove any unevenness from the forging. The working end of the tool should be square with sharp corners so it cuts its way through the material being punched. Important! Remember to file from the body of the tool towards the end to avoid getting cut on sharp edges of the tool. A tool that is not sharp will result in a hole that has a reduced thickness around it due to the "drag" of the tool.

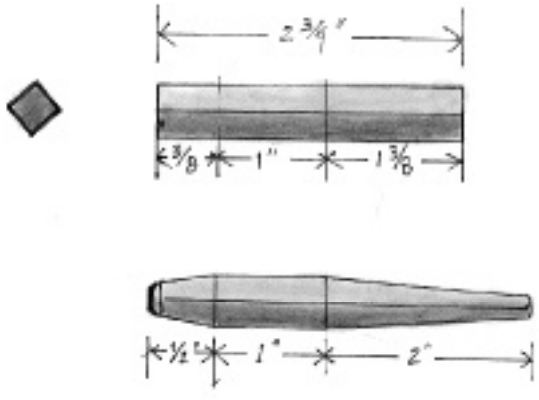
As W-1 is a tough steel, and mild steel heated properly to punch



2. "Drag" caused by a dull tool. Drag is the tendency to pull some of the surface of the steel down into the hole to be punched, rather than cutting cleanly.

and drift a hole is very soft, this tool may be used successfully in the as-forged condition, i.e., not fully heat treated.

Note: The square section of the punch has several advantages. Since the tool was forged without twist, the end of the tool that produces the hole is aligned with the body of the tool. This makes placing the tool to produce a hole of desired orientation much easier, whether the tool is hand-held or held with tongs.



3. Starting stock size and finished dimensions of the punch.

Also a tool forged from square stock will not roll off the anvil.

The tool described is intended to be used as a hand-held tool. As always, extreme caution should be exercised when using any hand-held tool. Remember that a misplaced blow places your hand between a hammer and a hot place. Often the material being punched will automatically lead us to whether a tool can be hand-held or should be held by some other means, such as tongs. Small-sized stock does not radiate as much heat as a larger piece and a punch can be held with a wet or Kevlar- gloved hand. For hole punching heavier sections the use of a handled tool is required. One will also find that the force required to punch a hole in larger sections will tend to bend the punch if it is too long. A shorter punch directs more force to the working end of the tool, making the work more efficient. The short tool uses less of an expensive material and eliminates the problem of bending when using a heavy blow. Complete and proper use of the punch and drift will be covered in a future lesson.

Targets:

-The tapered sections of the punch should be straight, centered and without twist.

-The faces of the taper should have no concavity or convexity.

-The long taper of the punch should have sharp corners as should the end of the punch that will produce a hole. This will allow the material to be sheared out cleanly when producing a hole.

-The taper on the striking end of the drift should be easily made in two heats. The opposite end should be able to be finished in three to four heats, the final heat being used to smooth and accurately center the taper.

-The length of the taper on the striking end of the punch is 1".

-The length of the taper of the working end is 3".

-The final length of the entire punch should be 7-3/8" and the working end of the tool 5/16" square.

Forging a Drift:

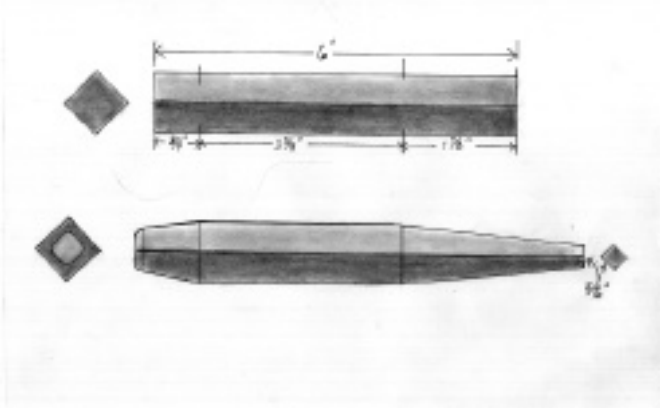
Step 1 - Forging the Working End of the Drift:

Following the same steps as when forging the punch, heat the end of the drift material to a yellow heat and forge a two-inch long taper using the face of the anvil, tapering from the parent stock size to 1/4" square, with the taper centered on the bar. 1-3/8 inches of 3/8" square material will be needed for this taper. *Note:* The small end of the drift will need to be able to be placed in the hole produced by the punch. As before, if more than one heat is required, be careful not to burn the material as the reduced section will heat quickly. The taper should be even, centered and without twist. The long taper on this end of the drift, allows it to be easily driven into the hole being drifted. In actual use the end result will be a hole that has a nice bulge without the stock being reduced in thickness near the hole. Reduction in thickness near a punched hole is commonly referred to as “drag” and is affected by the taper of the end of the tool producing the effect. The shorter or more blunt the taper, the greater the drag. Alternatively, a longer and more gradual taper minimizes this effect.

Step 2 - Forging the Striking End of the Drift:

Follow the same directions for the working end. *Important!* The taper on the striking end must be longer than 3/8", the thickness of the material being drifted. Otherwise the drift cannot be driven through from one direction as it will get stuck in the hole being produced. A taper 1/2" long produced from 3/8" long of the starting stock will be correct for this tool.

As the drift is intended to be used only on hot material, it is not necessary that it be made from anything other than mild steel. If forged carefully, little or no filing will be necessary. Quenching mild steel from an orange heat will stiffen the drift and provide better service.



3. Starting stock size and finished dimensions of the drift.

Note: The drift forged in this example will result in a hole that is slightly less than 3/8" square when the workpiece cooled. This is due to shrinkage that occurs between the time the hole is drifted and the piece cools. If a 3/8" square bar is to pass through the hole, then the drift material would need to be upset slightly prior to Step 1. To accomplish this, take a yellow heat on the starting material, stand it on end (vertically) on the anvil, holding it from the side with a pair of tongs. Strike a few light blows on the end of the material to increase its cross-section. Usually when the material has moved sufficiently to cause the scale to fall off, it is upset enough to allow a bar to pass through the hole.

Targets:

-The tapered sections of the drift should be straight, centered and without twist.

-The faces of the taper should have no concavity or convexity.

-The long taper of the drift should have sharp corners but the end geometry is not critical as long as it extends through the 3/8" thick bar when inserted into the hole. The aim dimension for this end of the drift is 1/4" square.

-The taper on the striking end of the drift should be easily made in one heat. The opposite end should be able to be finished in two heats, the second heat being used to smooth and accurately center the taper.

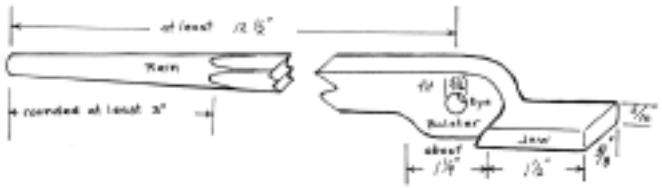
-The final length of the drift should be 2-1/2 inches.

Forging Tongs- Part One

Lesson 22A- Forging the Jaws
Text By Jay Close
Photos by Jane Guilden and Jay Close
Drawings by Tom Latané

Introduction: There are many tong forms serving myriad functions, and there are diverse approaches to this common tool. Some smiths collect tongs in profusion; others get by with a small number. Some like alloy steel for tongs; others find mild steel adequate. The tongs discussed here are basic, forged from mild steel and, except for those used in punching, these tongs can be made without the use of tongs.

Intent: The lesson is designed to familiarize the learner with the basics of tong forging. The student will practice basic forging operations including drawing down, hot punching, drifting, shouldering, rounding, cutting and upsetting. These operations come together forging a set of flat jaw tongs using 5/8 inch square bar and drawing down the reins. Drawing 1 illustrates one side of the tongs discussed here. Dimensions and the terms used for the major parts of the tongs are included.



Drawing 1.

Material: 5/8 inch square mild steel at least 24 inches long.

5/16 inch round mild steel for the rivet.

Tools: Basic forging tools including a hot punch and drift to make a 5/16 inch diameter hole; a post vise will be useful but is not a necessity; layout tools including a rule, dividers and center-punch.

Procedural Overview: Each half of the tong is forged identically; there is no left and right jaw.

To create the jaws and pivot bolster, three, one - sided shoulders are forged on the rounded edges of the anvil. Become confident with these three shoulders, their order and where on the anvil they are forged before proceeding. There is no time to puzzle over where to hit. Rehearse these shoulders in the workshop between your ears.

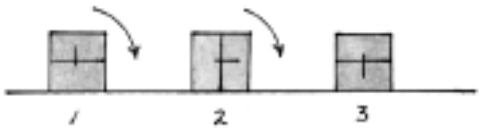
Photos 1 through 5 show the shoulders that start the tongs. You will review these photos later in the lesson too.

Hint: For a learner without an experienced coach, it may be wise is go through the procedure with an appropriately sized "bar" of modeling clay.

Shoulder One– made on the near rounded edge of the anvil.

Step in the bar about one half of its thickness the full amount of the stock lying on the anvil. Address sideways spread keeping the jaw the same width as the parent bar. (Photos 1 and 2).

Shoulder Two– made on the far rounded edge of the anvil after tumbling or rotating the bar 90 degrees to the left. That is rotate



Drawing 2- Tumbling a bar around its long axis, as viewed from the free end of the bar. The rotation would be to the smith's left.

the bar around its long axis so the adjacent face of the bar is positioned uppermost. Drawing 2 illustrates the idea.

This shoulder comes at the base of the first one. Many smiths will also slightly angle the bar at about 30 degrees off perpendicular to the axis of the anvil. Here you want sideways spread. Again, reduce the bar thickness by about half. See Photos 3, 4 and 5.

Shoulder Three– also made on the far rounded edge of the anvil after another left hand turn or tumble of 90 degrees. Photo 6.

This shoulder defines the pivot bolster and the start of the reins.

After the jaws are forged and the pivot bolster defined, a pivot hole is hot punched and drifted.

The reins are drawn out using the anvil horn and the reins are smoothed on the anvil face.

The two tong halves are riveted together. Once assembled, they are sized to fit a specific bar thickness.

Note: directions assume a right handed smith forging tongs used principally in the left hand. Tongs for a left handed smith that will be held primarily in the right hand are sometimes made with 90 degree tumbling to the right. The slight offset in the handles to the left or to the right seem to better conform to the anatomy of the left or right hand. Many smiths do not bother with the distinction or bend the reins in vertical alignment creating a neutral grip

Step One (layout):

Cut a length of 5/8 inch square mild steel a minimum of 24 inches long. This will provide sufficient length to forge both halves of the tongs without use of tongs.

Put two centerpunch marks (or some other permanent layout mark) on the bar. The first should be 5 and 1/2 inches from the end of the bar and the second should be 11 inches from the end.

See Photo 7 for the layout. These marks indicate the material for each tong half.

A layout easily seen when the bar is at heat can be made by placing a deep centerpunch mark very near the edge of the bar. If the mark is near enough to the edge, the steel bulges out from the bar looking like the bulging eye of a frog. Prominent "frog's eye" layout marks save precious time lost searching for more subtle indicators.

Step Two (first shoulder):

The student should review previous lessons on shouldering at the near and far edges of the anvil using half faced hammer blows.

Photo 8.

Heat the end of the bar to a yellow and place 1 inch of it on the anvil face at the near rounded edge of the anvil. Hold it horizontal and perpendicular to the edge of the anvil as in Photo 8.

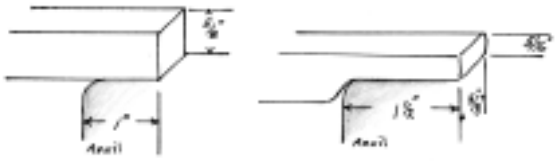
Hint: if you need, place a chalk or soap stone mark on the anvil so you can readily repeat the over lap. With practice such an aid will not be necessary.

With half face hammer blows sink a vertical shoulder reducing

Photos 1 and 2.

the thickness of the bar by about half all the way to the end of the bar. You want a parallel sided extension that will become the tong jaw.

Eliminate sideways spread, keeping the bar 5/8 inch wide as you forge. See Photos 1 and 2.



Drawing 3- The first shoulder, made on the near edge of the anvil, to form the jaw.

The higher the heat and the harder you hit the more readily this shoulder will develop.

Drawing 3 shows the needed result with approximate. dimensions.

Target: This shoulder is readily forged in one heat. With practice you may be able to forge more than one shoulder on the same

Photos 3 and 4.

Photos 5.

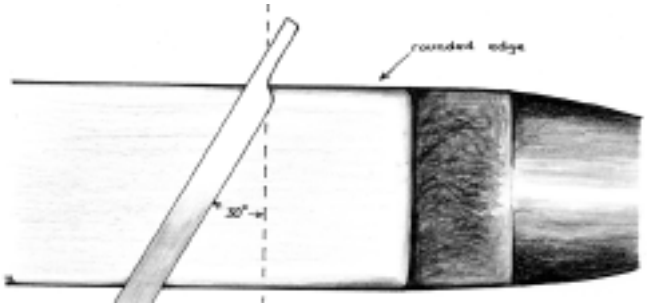
heat, but it is critical to set shoulders at the highest possible temperature. Do not extend a heat attempting to do more than the temperature allows.

As the bar drops to orange temperature, get it back in the fire.

Step Three (second shoulder):

The second shoulder is made by tumbling or rotating the bar 90 degrees to the left and repositioning it on the anvil. See Photos 3, 4 and 5.

Place all of the drawn down portion of the first shoulder extend-



Drawing 4- The second shoulder, made on the far edge of the anvil, to form the bolster. The 30-degree angle forms a slightly stronger transition between the jaw and bolster..

Photos 6 and 7.

ing off the far side of the anvil so the base of the shoulder aligns with the far rounded edge. Keep the bar flat on the anvil face. Drawing 4 shows the positioning of the bar for the second shoulder. Note that the bar is swung about 30 degrees to the left. This makes the joint a bit more refined. It is permissible to simply hold the bar straight across the anvil.

At a yellow heat, hit flat, half-faced hammer blows.

Thin the bar to about half of its starting thickness and create symmetrical sideways spread. You ought to be able to get 1 inch of spread and about 5/16 inch thickness. Photo 5 shows the result.

Work this reduced thickness down the length of the bar for about 2 inches. This gives a head start in drawing the reins. See Photo 6.

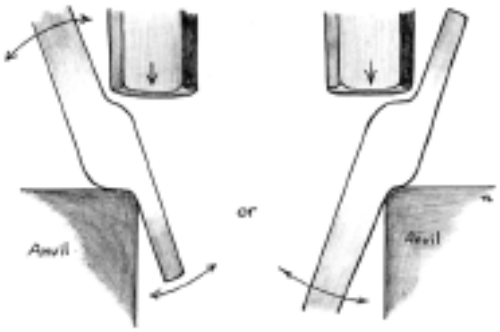
Photos 9 and 10.

Forging dynamics– because this spreading and shouldering is accomplished entirely from one side of the bar, the spread in cross section can be expected to be slightly wider on the top than the bottom . This is evidence of the differential impact of the hammer blow as opposed to the anvil on the hot bar. The harder you hit and the hotter the temperature, the less this asymmetry develops.

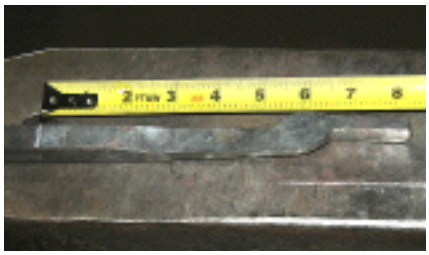
Step Four (third shoulder):

The third shoulder requires another tumble of the bar 90 degrees to the left. This orients the flat you made in Step Three vertically.

If you spread the bar to one inch in width when making the second shoulder, you now want to place that same amount of the spread bar extending off the anvil. Compare Photo 9 and Photo



Drawing 5- Dressing the shoulders, which defines the bolster.



Photos 11 and 12.

10. These photos show use of dividers to compare dimensions for explanatory purposes; in forging make this an eye judgement.

At a yellow heat, hit hard, half face blows to forge the third shoulder. Be sure you are using the rounded edge of the anvil. See Photo 11.

Control the bar dimensions. Define the pivot bolster and begin to draw the start of the reins. At this point retain the 5/8 inch width of the bar but reduce the thickness to match that of the bolster.

You results should look like Photo 12.

Hint: After the third shoulder is established use the horn of the anvil as much as possible to do all subsequent drawing out of the reins. The rounded form will greatly enhance the stretching effect of your hammer blows and speed the work significantly.

You can refine the bolster shape by working it on the anvil as shown in Drawing 5. You can even selectively cool one edge to retain its form while the opposite side is altered. You want a symmetrical “football” or lozenge shape to the bolster area.

Often the transitions between the first shoulder and the second when forged on the rounded edges of the anvil will develop a “web.” The transitions will not be crisp and angular, but will flow into each other reflecting the curve of the anvil edge. Attempting to forge this web away will often result in a cold shut, so it is preferable to leave it for now and do a bit of file clean up as necessary prior to final assembly.

Photos 13 and 14.

Step Five (punching):

Review previous lessons on punches and hot punching.

The most efficient forging procedure is one in which each section is completed before moving to the next. This avoids reheating areas that have been left incomplete after they are cool.

While some smiths will reheat and punch the pivot hole after the rest of the tongs are done, efficiency dictates that now is the time to punch the pivot hole. With care drawing the reins, there should be little or no distortion of a hole punched at this stage.

Punch the center of the bolster using a hot punch about 1/4-inch diameter on the end.

Remember to start punching from the outside of the joint with the jaw off the anvil at the far rounded edge. See Photo 13. When you flip the work 180 degrees to complete the hole and then move to the pritchel hole or punching block to free the slug or "biscuit," the flat outside of the joint will lie flat on the anvil face. See Photo 14.

Drift the hole to 5/16 inch diameter.

Target:

Punch and drift the hole in a single heat. The hole should be centered in the mass of the pivot bolster.

This lesson is concluded in the next issue with Controlled Hand Forging Lesson 22B, "Drawing The Reins."

Acknowledgments: Photos by the author and by Jane Gulden. Thanks to the American College of the Building Arts (www.buildingartscollege.us) for encouragement writing this lesson.

Forging Tongs- Part Two

Lesson 22B- Drawing the Reins, Assembly and Adjustment
Text By Jay Close
Photos by Jane Guilden and Jay Close
Drawings by Tom Latané

Lesson 22B- Drawing the Reins, Assembly, and Adjustment

Step Six (drawing the reins):

There will be about 2 inches or 2 and half inches of unworked bar left before the layout mark you made in Step One. Photo 15 shows the bar, the forged jaw and pivot bolster with punched hole along with the unworked bar left to form the reins.

Ideally, the jaw and pivot bolster are in their final form and there should be little reason to reheat them. Efficient forging technique dictates that the reins be drawn out sequentially working from the bolster to your cut-off mark, finishing each section before moving to the next.

Photo 15.

We are forging tongs without using tongs so heat transfer to the holding hand may be an issue. A longer starting bar can overcome this, but too long a bar can be awkward. A gloved hand is an option, but this too has drawbacks (see note below regarding the gloved hand). Regular cooling of the bar in the slack tub is also a useful strategy.

Another technique that can be used is to forge a “heat stop.” When an abrupt change in the bar mass exists and the heat is transferring from the smaller mass to the larger, the heat transfer will be dramatically slowed at the juncture of the two masses. We can use this to good effect in forging these tongs.

Take a yellow heat on the area near the layout mark. Set the bar on the near rounded edge of the anvil with the layout mark about 1/2 inch from that edge. See Drawing 6. Keep the work as horizontal as possible. Forge a shoulder here on two adjacent flats of the bar.

Hit the bar with half faced hammer blows driving it into the rounded corner of the anvil. Rotate the bar 90 degrees– left or right, it does not matter– and forge in a shoulder adjacent to the first. Work back and forth between the two shoulders using the "hit turn, hit turn" rhythm you learned when drawing a taper.

Work these two shoulders until the bar is reduced to about half of its original dimension or 5/16 inch square at the shoulder. Photo 16 shows the result.

Drawing 6.

Target: Take no more than two heats to reduce the bar to 5/16" square at the shoulder.

You have dramatically reduced the bar mass at the adjacent shoulders. This should help reduce heat transfer to your holding hand.

Photo 16.

You have also established a target dimension on the small end of the reins. With the pivot bolster forged to final form and the small end target dimension established, the drawing down of the reins becomes a matter of working the mass in the middle into final form.

Move to the horn and draw the rein striving for a an even taper in width from the bolster at about 5/8 inch wide to the adjacent shoulders at about 5/16 inch wide. Retain the bar thickness of about 5/16 inch from the bolster to the shoulders.

Use the horn to accomplish 90% of the mass reduction and then move to the anvil face to refine the shape and surfaces. Even using the horn to best effect expect to take several heats to draw down the mass of the rein. (Photo 17)

Once the mass in the middle of the rein is reduced over the horn and the rein has begun to stretch, you should re-establish the linear and sequential approach to drawing down: work a short section complete in each heat; rough it on the horn and finish on the anvil face; work down the length of the rein finishing the area near the "heat stop" last. Compare Photos 17 and 18.

Photo 19 shows the reins drawn and the shape refined.

At the end of your heat cut the bar free on the hot hardy (Photo 20).

The shape is shown in Photo 21 compared to a completed forging.

Photos 17 and 18.

Step Seven (finishing the reins):

The tong blank should be at least 12 inches overall. With care this is enough length to hold the jaw in the hand while finishing. The faster you work the less heat transfer there will be, but if the jaw gets uncomfortable to hold, cool it in the slack tub.

As the bar heats in the forge, keeping a sopping wet rag on the end you want to hold is another strategy to help maintain a bar cool to the touch.

Photos 19, 20, and 21.

Hint: As a point of preference many smiths work with a gloved left hand which allows them to hold a workpiece that might otherwise be too hot to handle. The drawback to this practice is that it can instill the habit of grabbing a bar without first testing for radiant heat. Tongs are designed for holding hot bar. Otherwise, keep the bar cool to the touch.

With a yellow heat on the end of the bar, draw the remainder of the 5/8-inch square stock. Continue the taper from the bolster to the end.

To keep a cold shut from developing, your first hammer blows on each shoulder should hit at an angle. This pushes the upper edge of the shoulder forward toward the end of the rein. Photo 22 shows the shoulders being struck this way.

Note (forging dynamic): The forged material will move in the path of least resistance. When striking straight down on a corner, the path of least resistance is into the open air. The corner flows out. If that corner is the top of a shoulder being forged flat, the outward flow can result in a cold shut as illustrated in Drawing 7. Avoid this by first hitting the corner at an angle.

Photo22.

Forge the end of the rein to 5/16 inch square using the horn to accomplish most of the forging (Photo 23).

Round the square section end of the rein. It should look like Photo 24 with at least 3 inches of the rein rounded in section for a comfortable grip. See previous lessons on the proper rounding technique.

The tong blank should look like Photo 25 and measure at least 12 to 13 inches from the center of the pivot hole to end of the rein.

If needed, adjust the jaw on the anvil so that it is parallel to the rein. We will alter that in fitting to a specific bar thickness, but parallel is a good place to start. Drawing 8.

Step Eight (the other half):

If you began with a 5/8-inch square bar 24 inches long, 18 1/2 inches of it remains after cutting away the first tong half. Keeping the held end cool, repeat the above eight steps forging the second half of the tongs.

Photos 23 and 24.

Step Nine (assembly):

Match the tong halves for length of the reins measuring from the center of the pivot hole. Match for the width and thickness of the jaw. It may require reheating one or both of these tong halves to make needed adjustments. Once assembled, changes are awkward.

Photo 25.

Assure yourself that the halves accurately mate with the punched holes aligned. Sometimes the bottom of the shoulder at the base of the jaw needs to be filed so the halves lie flat to each other. This is the "web" mentioned in Step Four. Photo 26 shows the problem area corrected.

Drawing 8.

Use a convenient length of 5/16 inch diameter bar for the rivet. It should be an easy sliding fit in the two pivot holes. If not, slightly forge the rivet stock smaller in diameter or open the pivot holes by re-drifting (they may have distorted in completing the jaw blank) or by filing with a round file.

At light orange heat cut a ring around the bar on the hot hardy 1

and 1/4 inches from the end so that it is almost cut through. See Photo 27. A set of dividers with this distance between the points makes a useful reference. This length of stock will allow a bit more than the equivalent of one diameter length of the stock to extend on either side of the join. Reference Drawing 9. Keeping the rivet stock attached to the end of the bar provides a handle for the next heat.

Take a light orange to yellow heat on the rivet. Holding the tong halves in their proper orientation, insert the rivet and twist off the excess stock setting it aside.

Work quickly with the peen of your forging hammer to spread the rivet on one end. Flip the assembly to address the other end

Photo 26.

in the same way. Keep the tongs properly aligned and the inside surfaces of the pivot bolsters in contact.

Make sure that the amount of rivet on either side of the joint is approximately equal. Make needed corrections by placing the short side into a thick bolster block or into the pritchel hole and tapping the long side down to match. See Drawing 10.

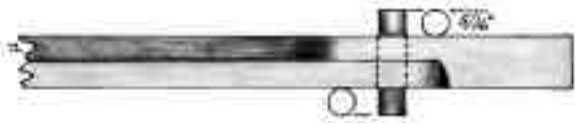
Photo 27.

Switch to the face of the hammer and flip the tong again. Forge down the edges of the peened end. Angle your hammer to make a short pyramid shape like Photo 28 on one side then flip to develop it on the other end.

Turning back to the initial end (which will have lost its peak) work around the circumference of the head forging the edges down. Repeat on the other side.

You can continue to work opposite ends of the rivet this way as long as there is visible heat in the material. Once that visible heat has been lost, stop forging. The steel will be most prone to cracking at this temperature.

Photo 29 shows the assembled tongs.



Drawing 9.

Drawing 10.

Hint: If the rivet is not sufficiently headed on this one heat, you can work the head once it has cooled to room temperature. If you feel it necessary to take an additional heat to finish, do so with the following caution: heating in the forge it will be impossible to heat the rivet without also heating and softening the bolster around it. In re-heading, if you hit straight down on the rivet you will upset it through its entire length. It will quickly shorten as the hole surrounding it will widen to accommodate the rivet's increased girth. Worked to an extreme, you can forge the rivet flush with an ever expanding bolster and no rivet head. Consequently, when taking a second heading heat , only work the edges of the rivet head, angling your hammer and drawing the edges down to the bolster surface.

Note: Some smiths use a round faced hammer for heading rivets in this way or a ball peen. Both can be effective, but the job can

Photos 28 and 29.

be accomplished well with the regular cross peen forging hammer too.

Step Ten (freeing the jaws):

Likely you have riveted the tongs tightly together so they will not move. Free the jaws by putting the pivot area of the tongs in the forge fire and heating to a bright red or orange heat. Pull them from the fire and work the reins open and closed through their full range of movement. Keep moving them as the tongs cool to well below red.

Make sure the tongs do not distort while doing this.

Hold the tongs horizontally as if gripping a bar. The tongs should fall open when the fingers release the bottom rein. There should be no sticking or tight spots. If this is not the case, they

may need another round of heating and working.

Step Eleven (adjustment):

These tongs can be sized to hold anything from sheet to a bar about 1/2 inch thick. Above 1/2 inch thick usually requires a slightly different set up for the jaws.

We will size these tong to hold 1/4 inch thick flat bar.

Select a short piece of 1/4 inch thick scrap bar as the "sizer." Three or 4 inches long is plenty.

Heat the jaws of the tongs to an orange heat and grab the sizer bar in the tongs. There ought to be enough grabbing effect even with the heated jaws to accomplish this.

Place the jaws on the anvil and forge them to fit with careful hammer blows. Work both jaws equally so they are pushed into full length contact with the sizer bar.

If a post vise is available, it can be used to squeeze the jaws to the sizing bar. Photo 30.

Photo 31 show fitted tong jaws with each jaw making full contact with the bar.

In a similar fashion, the reins can be adjusted to a comfortable hand hold. Small adjustments can easily be done cold on the anvil. Greater change is best done at heat.

This is mostly a matter of changing the angle the reins make where they intersect the pivot bolster. Small changes there will cause significant changes in distance between the two reins where they are held.

A red heat on the area where the reins meet the bolster is usually sufficient, but creativity is often call for holding the assembled tongs on the anvil to effect the needed alteration.

If you have adjusted the reins on the anvil you will probably also need to recheck their fit to the sizer bar.

A post vise can ease the task of rein adjustment. Heat the reins where they meet the bolster and then put the sizer bar in place. Hold the jaws and sizer bar in the vise as illustrated in Photo 30 and manually adjust the reins for comfort and symmetry.

Targets:

It is most important that the two halves of the tongs match. The measurements shown in Drawing 1 are a good guide. Following the method outlined you ought to match the dimensions of one tong half to the other to within plus or minus 1/8 of an inch in linear dimensions. Widths and thicknesses can be forged to within plus or minus 1/16 inch.

Plan on a heat each for the three shoulders needed for the jaws and pivot bolster.

Photos 30 and 31.

Use one heat to punch and drift the pivot hole. That hole should be centered in the area of the pivot bolster.

Drawing down the reins may take several heats. From the point that the bolster is punched and drifted, use no more than ten heats to produce a ready-to-assemble tong half.

The tongs should tightly grip the bar they were sized to fit, in this case 1/4-inch-thick flat bar. Hold the "sizer" bar in the tongs and the free hand should not be able to easily dislodge the bar from the tong grip.

The joint should work freely without sticking. With the tongs horizontal, as if holding a bar, the bottom rein should fall completely open without sticking when it is released by the fingers.

The reins should be a comfortable distance apart when holding the appropriate dimension bar stock.

The reins should be symmetrical, virtual duplicates of each other.

Further Steps:

Now that you can make tongs, having tongs opens up two more effective approaches to their forging.

1. The first alternative is to proceed as outlined above through Step Five (punching of the pivot hole). At that point cut the forging free at the layout mark. Then use tongs to hold the jaw while the rein is drawn down. Try to organize your forging in a sequential manner. Heat a small section to yellow and draw it on the horn of the anvil. Finish the shape on the anvil face to final dimension then move to the next section.

2. The second alternative forge welds round stock onto the jaw blank using a drop tong scarf weld. This, of course, saves the effort of drawing down the reins. Review the prior lessons on welding.

Less than 3 inches of the 5/8 inch square stock will be needed for each jaw. About 9 inches of round stock 3/8 inch in diameter is about right for each rein.

After forging the third shoulder and drawing a bit of the transition to the reins, leave the bar about _ inch square on the end and forge a scarf. Note that the scarf must be oriented so that the jaw blank will lie on the anvil face for the weld.

Upset the round stock (the vise and a light hammer is useful for this) and forge it to about _ inch square on the upset end and provide it with a scarf.

The drop tong weld proceeds in the normal fashion. After the two parts are joined, forge the area at the weld into a smooth transition from rectangular section to round section. Finally punch and drift the pivot hole.

A refinement of the welding procedure is to weld one jaw section to a round about 18 inches long, enough for two reins. Then weld the second jaw to the other end of the round and cut the two halves free before assembly.

Acknowledgments: Photos by the author and by Jane Gulden. Thanks to the American College of the Building Arts (www.buildingartscollege.us) for encouragement writing this lesson.

Drawing Out Round Stock to Square

Lesson 23 by Bob Fredell

Drawings by Brian Gilbert and Tom Latané

Minneapolis, Minnesota

Introduction: The student should be able to correctly draw out a square bar before attempting this lesson. Drawing round to square is more difficult than drawing square to square because of the added difficulty to register an exact 90º rotation.

Intent: This lesson is designed to teach the student:

(1) How to accurately rotate the bar 90º;

(2) To develop hand-eye coordination in the rotation process;

(3) To gain a feel for the hit-and-rotate rhythm.

This will result in smooth and efficient drawing-out. This lesson uses round stock because it eliminates the initial guidance of the flat side of square stock on the anvil, thereby requiring the student to develop the three goals stated above.

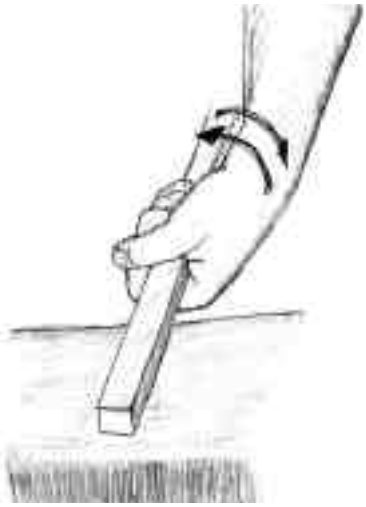
To accomplish this goal, the student will forge a 5/8"x 24" round bar to square having 7/16" sides.

Material: Mild steel round bar, 5/8"x 24", square bar 1/2"x about 24".

Tools: Anvil, hammer, outside calipers, straightedge, tongs for 7/16" square.

Step One

This step is practice to get the feel of how much to rotate the wrist to turn the bar 90º. Hold the cold square bar flat on the anvil and rotate it 90º from one flat side to the next. Be aware of the amount of wrist rotation as the sides of the bar make contact with the anvil and observe the position of the sides of the bar in relation to the anvil. This process will aid the student in becoming confident developing the rhythm of making 90º rotations.



Drawing 1.

Step #2.

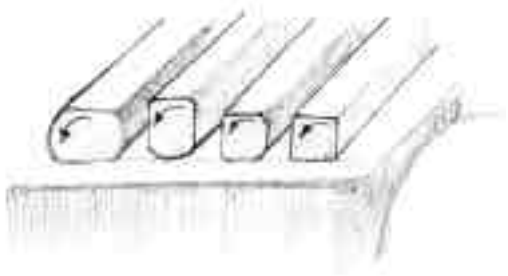
Heat 5" of the bar to a yellow heat and place it flat on the face of the anvil. It is always good to properly heat a slightly longer section than is to be forged. Starting at the end of the bar, strike a series of 4 or 5 overlapping blows to a length of 4". Be sure to critically observe the result of each hammer blow as you are forging the bar. This will enable you to make corrections of incorrect rotation and incorrect angle of the hammer during the forging process.

Drawing 2.

Next, rotate 90º. Draw out the top-facing side of the 4" section as described above. The 4" section is now becoming square.

Then, rotate 90º in the same direction. The first side that was worked is now flat on the anvil. Draw out the 4" section as described above.

Again, rotate 90º in the same direction. Draw out the 4" as described above.

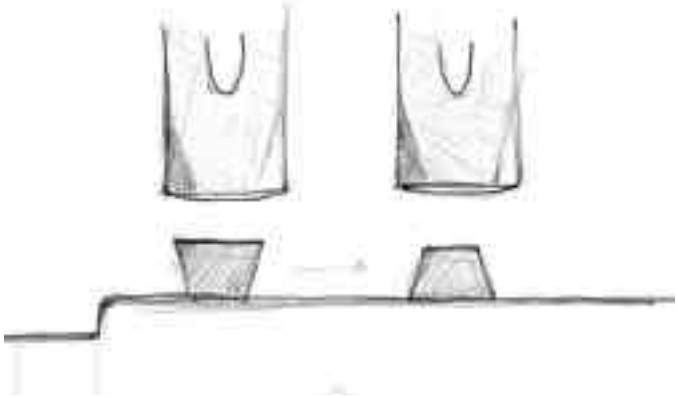


Drawing 3.

Note: The entire process will take several heats. Stop forging when the temperature drops to a dark orange heat even if the bar is not fully reduced, as the mild steel does not easily move with lower heat. Reheat and continue drawing out, as described above, until the sides are 7/16". Crisp corners can be made by using a lower heat and lighter hammer blows when making the final adjustment to size. Initially you may need to use the calipers to measure. With practice your eye will be a fairly good judge of the correct size. It is important to establish well-defined sides and crisp 90º corners. Straighten the bar with light blows as necessary.

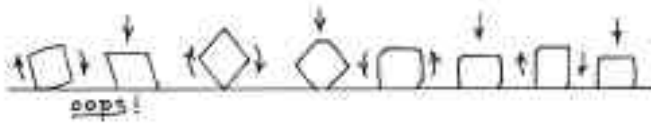
This is not a contest with yourself to see how much work you can do in one heat. Focus on 90º rotation, rhythm of rotation and accuracy of blows. The hammer blows should be only as fast as you can control the hammer. Speed will come later.

Forging Dynamics: When forging the bar, light blows and a low heat may result in the side of the bar being struck by the hammer to be drawn out more than the side facing the anvil, resulting in the hammer side being wider than the anvil side. The correction for this problem is to place the wide side (the side formerly struck by the hammer) down on the anvil and strike. Rotate the bar so the second wide side faces the anvil and strike. Continue to draw out as described above. It is necessary to work all four sides of the bar to achieve a uniform result.



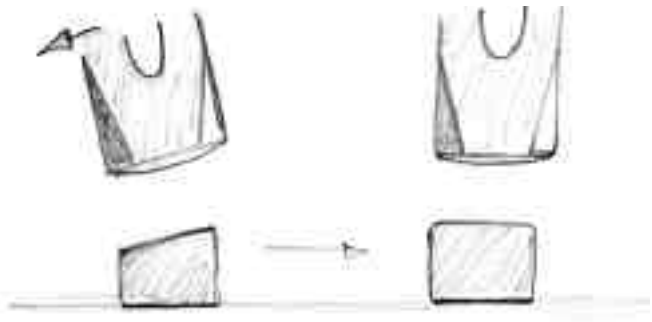
Drawing 4.

Note: If the rotation is more or less than 90º, a parallelogram will result. Stop as soon as you see this developing and make corrections. Correct by hitting the corner of the long diagonal; then return to forging the flats of the bar. The sooner you catch this error the easier you may correct it. This is because as you approach your target size, you will not be able to eliminate the facets made by this correction without further reduction of the bar. This would then result in a cross-section smaller than desired.



Drawing 5.

Note: If the opposite faces of the forging are not parallel, it is because the hammer has not been landing parallel to the face of the anvil. Stop as soon as you see this happening and make corrections by making sure that the hammer face is parallel to the anvil.



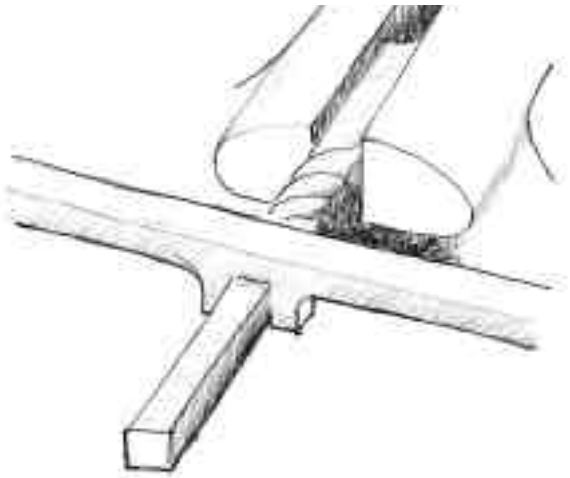
Drawing 6.

Step #3.

Be sure the square portion is straight, square, and is the correct size before working the next round portion. Errors are always more easily corrected early on in the process.

Heat the next five inches and draw it out four more inches, as described in Step #2. The square portion will now grow to eight inches. Continue this process until you can no longer comfortably hold the round bar. Then, hold the square end with tongs and continue to draw out the entire length of the round bar as described above.

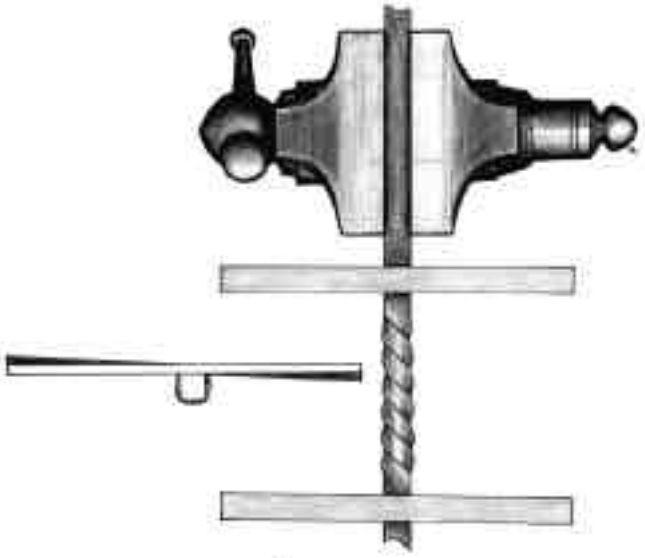
Note: As the square section becomes longer a twist may develop, caused by incorrect rotation and hammer angle. Should this occur, heat the twisted section to a red heat, place the end in the vise and reverse-twist with tongs or twisting wrench. Finish at a low heat on the anvil with light hammer blows.



Drawing 7.

Note: An easy way to see a twist is to place the bar horizontally in a vise. Then place a series of 3 to 5 flat bars (say 3/16" x 3/4" x 4") on the bar, and sight down the length of the bar. The flat bars will dramatically show where the twist is.

The beginning blacksmith who is not familiar with strike-and-turn rhythm may need to make several, or even multiple tries of this lesson. Don't be discouraged; focus on your rotation and hammer angle. Get the feel of the rhythm.



Targets:

1. The corners are 90º measured with a square.
2. The sides are 7/16" measured with calipers.
3. The corners are sharp with no visible facets.
4. The bar is straight as checked with a straightedge.
5. The surface smooth as checked with the straightedge.
6. An additional way to determine how closely you met the first five targets is to measure the final length of the now-square bar. The mathematically derived length of the bar is 38 1/2". The closer you met the first five targets, the closer your bar will be to 38 1/2". A slight loss of material results from scale.

Making a Round Drift

By Dan Nauman

Drawings by Tom Latané

Minneapolis, Minnesota

Lesson #24. Unit: Drawing Down

Definition: Reducing the cross-section of a bar.

Intent: The student will learn how to make and control two round tapers from a round parent bar by making a round drift.

Tools: Basic forging tools,1/2" V-tongs, (or 1/2" bolt tongs), 3/8" V-tongs, (or 3/8" bolt tongs).

Material: 1/2" x 3 1/2" round stock

Drift definition: A drift is a tapered tool for enlarging, tapering, or dressing a hole, to a desired size. Its shape is dependent on the procedure. Some examples of drifts are:

1.) A round or square-bodied drift used to size an existing hole to a specific diameter/width throughout the length of the hole. In this case, the drift will have two tapered ends, so when the major diameter/width of the drift has sized the hole, the drift can easily exit the hole. The length of the driving taper (or trailing taper) should be longer than the thickness of the bar so that the drift does not get stuck. The driving taper also allows for the inevitable mushrooming that will occur from repeated hammer blows.

2.) A drift for a pick eye is tapered on one end only, and is not driven through the hole. This leaves an evenly tapered eye.

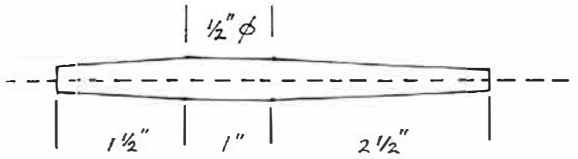
3.) A drift for a hammer-head eye is also tapered on one end only. However, in this case, the drift is driven from both sides to create an hourglass-shaped hole

4.) Yet another drift is used as an anvil. Once inserted into the bar, it allows the sides of the bar to be forged without collapsing the hole, i.e., the hole in a latch handle that receives the thumb-piece.

In this lesson, we will make a drift as mentioned in example #1. The taper initially inserted into the hole to be drifted needs to set itself in a stable position when placed into the rough hole so as not to require peripheral tools to hold it vertical. Usually a long taper provides this stability.

The drift should be made as short as possible, as this will shorten the time it takes to drive it through the piece, and will to some degree prevent the drift itself from buckling. (See drawing #1 of a 1/2" round drift.)

The drift we will be making in this lesson will be for sizing a 1/2" diameter hole in bars up to 1 3/8" thick. It will have a long taper (the leading end) of 2 1/2", a mid-section of 1", and a short taper (the driving end of the drift) of 1 1/2", for a total length of 5".



#1. Drift with a long, leading taper, straight middle section, and short trailing taper, all concentric along the long axis.

Step #1

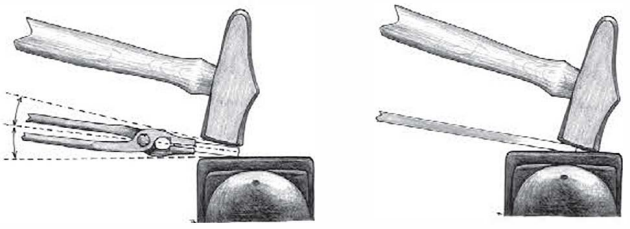
In this step, you will be forging the leading, tapered end of the drift. Your goal is to initially forge a 2" square taper, with straight, flat facets.

Using the 1/2" V-tongs, place the bar in the fire and heat 3" of the 1/2" round bar to yellow.

Caution! Do not leave the tongs in the fire, as they will get hot and will distort when forging.

Note: Sometimes it can be tricky to remove a short bar from a coal or charcoal fire. The tongs used to hold the bar can be clumsy, as bits of coal or charcoal block a clear path to grab the bar. If you have a pair of pick-up tongs, (tongs with narrow, flat bits) they may come in handy to pull the bar from the fire. Once you have the bar out of the fire, quickly change to the appropriate size tongs for the job.

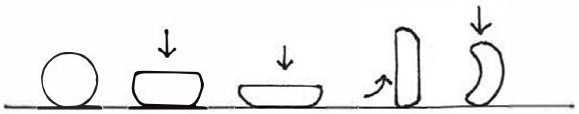
With your 1/2" V-tongs, place the end of the bar on the face of the anvil at a 10-degree angle. With the hammer's face angled at 20 degrees, strike the end of the bar two or three times. (See drawing #2a, and 2b.)



#2A, left. Hammer angle to the bar is equal to the bar angle to the anvil for an even taper.

#2B, right. Damage may occur to the anvil face if hammer blows land beyond the end of the bar.

Next, tumble the bar in place 90 degrees and strike two or three times. Repeat this action several times, working on the bar, until the end reaches about 5/16" square. Once the square end has been established, lay the taper flat on the anvil and work the taper back a bit, so the taper ends up at 2" long. The intent is to keep the cross-section as square as possible during this process. Continue working until the facets are straight, and the corners sharp.



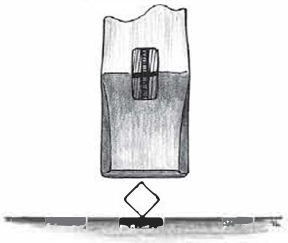
#3. Drawing down one dimension too much before rolling the bar may result in the material folding upon itself.

Caution: Drawing the bar down too thin in cross-section will cause the bar to fold rather than extrude. (See drawing #3 of a bar drawn down too thin.)

At this stage, the end of the taper should be 1/4" square.

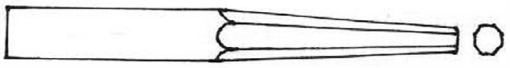
Step #2

Your goal is to now forge an octagonal taper, with eight equally tapered facets.



#4. Striking the square on the diamond

Heat 3" of the end of the bar to bright yellow. Be careful not to burn the now-narrower tip. Place the taper of the bar flat on the face of the anvil, but this time place the bar on the diamond (See drawing # 4.) Begin forging the sharp corners, starting from the end, and coming back towards the main body of the bar. Your blows should be light towards the end of the taper, and gradually increase in force towards the middle of the drift. Tumble the bar 90 degrees as you did in step one, until the taper has eight equally tapered facets. You should be able to do this in one heat. (See drawing #5 as to how the bar should look at this point.) The end of the taper should be 1/4" across the facets.



#5. Octagonal taper produced from a square taper.

Step #3

Your goal in this step is to forge the octagonal taper into a round taper.

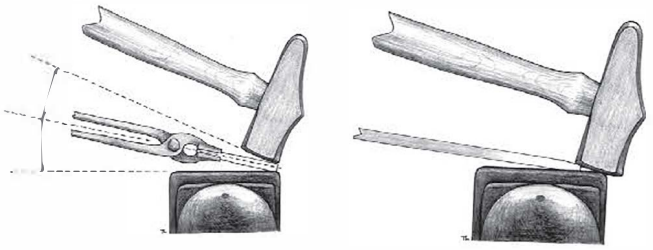
Heat 3" of the end of the bar to bright orange. Place the bar so one of the eight corners of the taper lies flat on the face of the anvil. Begin to lightly forge each corner its entire length, then indexing to the next (right or left....it is up to you which direction.) At some point, the facets will be too numerous and small to define.

When this happens, simply roll the bar left to right, right to left repeatedly while striking light but rapid blows of the hammer on the very end of the taper first (so you utilize the heat in the bar where it cools rapidly.) Watch for high spots. Lightly tap them with the hammer, not too hard as you will create new facets and high spots. Work your way up into the larger diameter of the bar until you have a smooth and round finish, free from facets and high spots. Because in this heat your intent is not to make major changes to the bar but rather refine the surface, it is acceptable to work well into a black heat. Your taper should be 2 1/2" long. The end of the taper will be slightly less than 1/4" in diameter.

Step #4

In this step, you want to forge the short taper on the driving end of the drift, which will be 1 1/2" long. You will utilize what you learned in step one, but alter the angle of the bar to the face of the anvil more severely than in step #1 to 20 degrees. The steeper angle will help to produce a shorter taper. The hammer blows should begin at 40 degrees.

Heat 3" of the opposite end of the bar to bright yellow. In this heat, place the end of the bar at the far, rounded edge of the anvil. Note: Because you are working at a more severe angle, you may risk accidentally hitting the face with the hammer. Holding the bar at the far edge of the anvil reduces the chances of marring the anvil face with an errant blow. (See Drawing #6A and 6B) As you did in step one, tumble the bar 90 degrees (right or left) after three or four blows of the hammer, thereby forming the initial square taper. Once the taper's end reaches about 5/16" square, with a taper length of 1 1/4" long, place the taper on the diamond, and proceed to forge the square taper into an octagon as you did in step # 3, with eight equally tapered facets. The end of the taper should be 5/16" in diameter.



#6A, left. Forging a taper at the far edge of the anvil with the bar held at the median angle between the hammer and anvil.
#6B, right. Hammer face and anvil edge may be damaged if the end of the bar is not kept at the edge of the anvil.

In the same heat, forge this short octagonal taper into a round taper, similarly as you did in Step # 4. This step should complete shaping the drift.

Step #5

This step is only necessary if the drift is shaped incorrectly along its axis.

Inspect your drift to see whether the tapers are concentric around the axis of the main (middle) body of the bar. (See drawing #7 of a drift with misaligned tapers.) Roll the drift on the

#7. Misaligned tapers– not concentric along the long axis.

anvil face. If the tapers wobble, you need to align them to the center of the drift. You might also be able to see the error by sighting down the drift as you would a rifle barrel.

Next, determine where the taper(s) need to be adjusted. Lay the errant taper across the hardy hole, with the straighter edge facing down. Tap the taper with your hammer head over the hardy hole once or twice. This should bend the drift slightly to correct the problem. Re-inspect and repeat until the error has been corrected. This can be accomplished cold, as long as you haven't quenched the bar at a high heat.

(Refer to drawing #1 to see how the finished drift should be shaped, with the points of the taper aligned with the axis of the middle.)

Note: When a bar cools, it shrinks. There will also be some shrinking in the hole that was drifted. For instance, if your hole needs to be 1/2" in diameter, and no less, you will need to slightly increase the diameter of the middle of this drift by upsetting it. Do this before you make the tapers; otherwise, you will distort them.

Step #6

Do not leave the end of the driving taper ragged, as the hammer will not transfer the energy efficiently to the drift. Dress the driving taper end of the drift to a flat or to a crown. Crowning can insure that the drift drives in more reliably, with less deflection from an errant blow. A crown also resists mushrooming.

Targets:

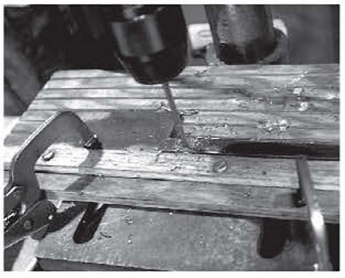
1. The drift is to be free from facets.
2. The drift is to be 5" long.
3. The short taper is to be 1 1/2 " long, and 5/16" in diameter at the end.
4. The long taper is to be 2 1/2" long, and 1/4" in diameter at the end.
5. The drift is to have 1" of the middle at 1/2" in diameter.
6. The drift's tapers are to be concentric around the axis.
7. The end of the driving taper is to be dressed.

Easy T-Nuts

by Brian Gilbert

Chattanooga, Tennessee

I recently had to make a number of T-nuts for my milling machine, and I came up with a simple setup for drilling a number of parts accurately and quickly. This is very basic to those of you with machine shop experience, but it might help those of us who are more in the beginner's category... myself included.



I made a drill press fence that is nothing more than a small strip of wood screwed to a piece of plywood. It's easily clamped to the drill table with welding clamps, and also easily renewed when it gets full of holes. I added a small piece of metal on one side to act as a stop. Using this fence and the stop, I aligned the setup using an existing T-nut. A tiny drill bit chucked in the press served as a locator, and I moved the base around until the drill bit appeared centered in the existing hole. I then marked the fence with the length of the finished piece.

I chucked in the correctly sized drill bit. A short length of 1/2"x 3/16" stock was finished on one end and placed on the fence, and then drilled. A sharp drill bit helps keep the tip from wandering, and it was drilled without a centerpunch.

After drilling, the piece was marked with a square. Since these T-nuts are very small, they were cut using a bolt cutter. This also helped chamfer the edges, reducing cleanup time.

Once cut, the sharp edge was sanded off with the belt grinder, the bar dressed, and the whole process repeated. I had eight T-nut blanks in no time.

But they had to be tapped, and I'd heard of a high-speed way for this as well. A bar of 1/2" square stock was drilled just undersize of the tap. This became my tapping guide. I used the same setup in the drill press, I just changed the bit. Next, I drilled a clearance hole in a 1/2"-thick piece of wood and clamped this in my vise. The guide was clamped over the T-nut blank, with a spacer on the back of the guide to keep it square. Then I ran the tap into the whole pile... these small holes would usually tap within ten seconds. Occasionally I'd have to reverse the drill to clear the chips, but the chuck slipped at just the right moment to prevent breaking the tap... just like an expensive tapping head. It worked like a charm!

Forging Right-Angle Bends

By Tal Harris

Photos by Kim Harris

Waxhaw, North Carolina

Lesson #25.

Definition: Forging Two Right-Angle Bends to a Desired Dimension

Intent: The student will learn how to make two right-angle bends with sharp outside corners in square stock, maintaining a small radius on the inside corner, with the corners a prescribed distance apart.

Tools: Basic forging tools: a hammer weighing about 1 1/2 pounds is recommended, steel square, center punch, twisting wrench (just in case).

Material: 1/2" x 1/2" square stock, 30 inches long.

In this lesson we will make two right-angle bends as noted in Figure #1. From the end of the bar that is visible to the outside of the next corner is 5 inches. The measurement from the outside of the first corner to the outside of the second corner is also 5 inches.

Step #1

In this step, you will be marking the bar in preparation to forge the first right-angle bend.

The target of this lesson is not only to form a proper square corner, but to make it in a desired location. Once completed, the measurement from the end of the bar to the outside of the first corner should be 5 inches. Make a heavy center punch mark on the bar 4 3/4 inches from one end. When forming the corner using this mark as a reference, the desired outside dimension will be achieved. This mark must be visible at a yellow heat in order to control the bending and forming of the corner.

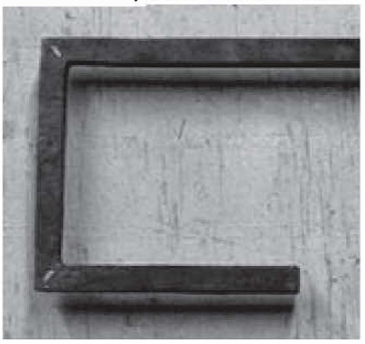


Figure 1- The completed forging.

The center punch mark denotes what will become the center of the bend when viewed from the side of the piece. Refer to Figure 1. The small diagonal lines between the inside and outside corners were originally center punch marks that were deformed when the corner was formed.

Step #2

The area that has been marked with a center punch should be heated to a bright yellow. Using water poured from a can, quickly localize the heat to a 2-inch long area, with the center punch mark in the center.

Safety note: *Care should be taken to keep the hand away from the steam generated when localizing the heat.*

With the bar lying perpendicular to the long axis of the anvil and the heated area located just beyond an anvil edge with a minimum of 1/4-inch radius, make an initial 90-degree bend by directing downward hammer blows to the end of the bar. If the bend was properly made, the result should look like Figure 2 when the piece is viewed from the perspective shown. The material should have no twist, have an inside and outside radius, and the center punch mark should be located in the center of the bend. A common error in learning this technique is to make the initial bend too sharp. This almost always results in a shut, or fold, in the inside corner. Twist can be removed by placing the bar in the vise (at an orange heat), appropriately positioning a twisting wrench, and making the necessary corrections.

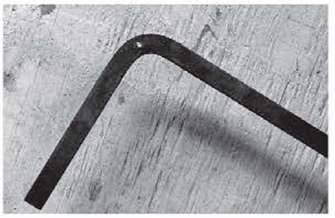


Figure 2.

Step #3

In this step you want to start transforming the bent corner into one that has a small (1/16-inch) inside radius, while the outside corner becomes a sharp 90-degree angle. Heat the corner to a bright yellow by placing the piece in the fire with the corner pointing downward into the center of the fire, and the end you are holding at a 45-degree angle.

Figure 3A.

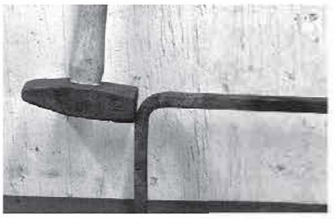


Figure 3B.

Once the metal is at forging temperature, start forming a sharper corner by first hitting the area noted in figure 3A with light, rapid blows, followed by similar hammer blows delivered to the area noted in figure 3B.

It should be stated that the downward blows where the material is backed up by the anvil are more effective than blows delivered towards the hand. Therefore, more blows are required when striking towards the hand. Some references state 4 blows towards the hand for every 3 towards the anvil, but the important point is that the center punch mark remains in the center of the bend while the corner is progressing. Resist the temptation to upset the piece while the corner you are trying to form is against the anvil, as this only results in upsetting the material adjacent to the corner and does little to form the corner itself.

Continue to deliver blows as described above, being careful to keep the areas on either side of the corner straight and free from twist as described previously. Correct these conditions as they are occur, for they will only worsen and make forging the corner more difficult. If possible, make corrections before returning the metal to the fire so that progress, rather than corrections, can be made at the highest temperature when the bar is next removed from the fire. Once the piece has cooled to an orange, it is time to once again heat the piece to a yellow and continue forging until the outside corner is sharp, there is a small inside radius of 1/16-inch, and all material has been forged to its original size of 1/2 x 1/2-inch square. When this has been successfully completed, the piece will look like the representation in figure 3C.

Figure 3C.

It is important to note the resulting dimensions of the bar at this point. The measurement from the end of the bar that is visible to the outside corner is 5 inches. Remember the initial reference center punch mark of the centerline of the corner was made 4 3/4 inches from the end of the bar. Understanding the movement of the material is key to forming these bends to a required dimension.

While the bar is cool, locate the bend for the second corner 4 3/4 inches from the outside corner of the first bend as shown in Figure 3D.

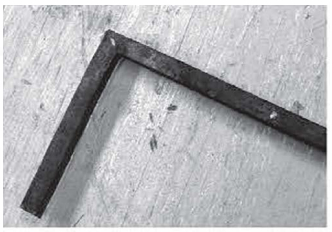


Figure 3D.

Step #4

Take a bright yellow heat and reheating as needed, repeat the process described in Steps 2 & 3. Refer to Figure 4. While forging the corner, the material near the corner upsets– that is, it shortens and therefore becomes larger in cross-section. This can be corrected by forging the stock to its original size, being careful not to reduce the section below its original dimension.

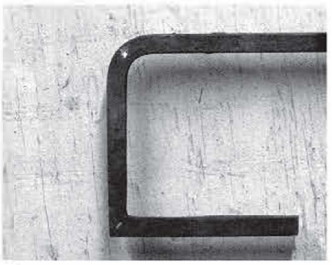


Figure 4.

As stated previously, resist the temptation to upset the piece while the corner you are trying to form is against the anvil, as this only results in upsetting the material adjacent to the corner and does little to form the corner itself.

Once the outside corner has become sharp, make sure that the surrounding material is at its original dimension, the outside corner is sharp, the inside corner has a radius of 1/16-inch, the angle measures 90 degrees when checked with a square, and does not contain any twist.

Allow to cool and check dimensions of the piece. The result should match the dimensions and photograph in Figure 1 at the beginning of the lesson.

Note: When a bar cools it shrinks. Once formed, the measured dimensions will change as the material cools. Allowance for shrinkage is achieved by leaving the dimension longer than the finished dimension. For this scale of work, leaving the dimension 1/16-inch long while the piece is visibly red will result in a cold measurement that is very close to the intended measurement. This degree of accuracy is not always needed, but knowing how to control the work to achieve a desired result is a valuable skill.

Targets:

The dimensions will meet the requirements of Figure 1.

The material will be free from twist.

All stock will be 1/2" x 1/2" square.

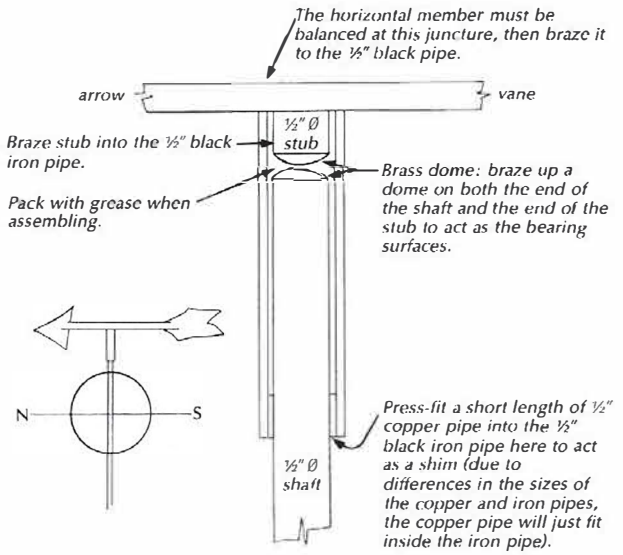
Uses for this technique- Primarily gate and grille frames.

Weathervane Bearing

Doug Hendrickson

Lesterville, Missouri

From The Anvil's Ring, *Vol 14, #1, Summer 1986*



Forging Right-Angle Bends

By Jay Close and the CHF Committee

Photos by Jane Gulden and Jay Close

Charleston, South Carolina

Lesson #26A.

Part One: Forging Two-sided shoulders on the Near Edge of the Anvil

Intent: The student will learn to forge two-sided shoulders on the near edge of the anvil using only the forging hammer to control the location and dimension of the shoulders. This will be a first exercise laying the foundation for a more challenging two-shoulder exercise to follow.

Introduction: Matched two-sided shoulders as in photos 1 and 2 are features of much ironwork. Artifact photos appended show these shoulders on historic hardware collected in Charleston, SC. While such shoulders are effectively created using top and bottom fullers and a striker, or through the use of a spring die or guillotine tool, it is a skill worth pursuing with forging hammer alone. This pays dividends in increased hammer control, and for many projects it is a quick, efficient method. Most learners find that forging matched shoulders on the near edge of the anvil is easier than a similar pair using the far edge. Instruction begins with the easier challenge as shown in Photo 1.

Photo 1.

Photo 2.

Successful completion of these exercises both requires and develops good hand/eye coordination and overall hammer control. At the heart of such control is a relaxed and comfortable stance at the anvil. Smiths tend to adopt one or the other of two effective stances when forging these matched shoulders.

In the first instance, the smith approaches the anvil in a "normal" way with his or her shoulders roughly parallel to the anvil (Photo 3). The workpiece may be held slightly in front of the body. The shaping of a set of shoulders forged on the near edge of the anvil is mostly effected by the bottom edge of the hammer as indicated in Photo 4.

Photo 3.

Photo 4.

The alternate stance positions the smith's shoulders roughly perpendicular to the front edge of the anvil (Photo 5). Here the workpiece is held on the anvil away from the the smith's body but parallel to his or her own shoulders. When working at the near edge of the anvil, the right hand edge of the hammer (shown in Photo 6) matched with the edge of the anvil forms the shoulders.

Photo 5.

There are pluses and minuses to both stances, but the work required of the hammer is the same in each.

Tools Needed:

Basic forging tools only.

Note: This lesson, and the one that follows, are accomplished with your basic forging hammer and the rounded edges of your anvil. The article titled *Safety, Ergonomics, and Shop Layout* by Dan Nauman (*Hammers Blow*, Fall 2002) gives guidance in hammer selection and anvil set-up.

Photo 6.

The learner might also read *Drawing Down-Part One* (*Hammer's Blow*, Winter 2005) for discussion of the face of a general purpose, forging hammer. Although a round-faced hammer like a ball peen may be used in a pinch, a hammer with a square or octagonal face will be most useful. Closeup photos of the author's hammer accompany this lesson.

Material:

1/4" x 1" mild steel cut to approximately 24 inches in length (or any convenient hand-holding length).

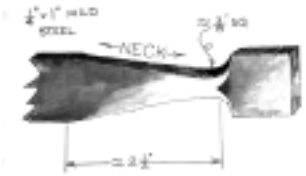


Figure 1.

Figure 1 shows the target shape. Unlike many discussions in this lesson series, target dimensions are less important here than control of the form. Consider for this lesson the accompanying dimensions are suggestions.

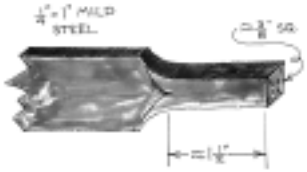


Figure 2.

More important than a particular measurement are forged shoulders opposite each other and in alignment. The shoulders should be sharp and distinct.

The extension created on the end of the bar is square in cross-section, centered along the axis of the bar and it can be allowed to grow thicker than the parent bar dimension of 1/4".

The almost inevitable slight pucker where the shoulders meet the extension should be minimal. The form must be straight and without twist.

Step #1

Cut a length of 1/4" x 1" bar approximately 24 inches long– or any length convenient to hand-hold. (A shorter bar held in well-fitting tongs is also acceptable.)

Heat two or three inches of the end of the bar to a yellow or lightly sparkling heat.

Step #2

Place the bar flat on the near-edge anvil so that a square of material lies on the anvil face as in Photo 7. Use a part of your anvil that has a well-rounded edge.

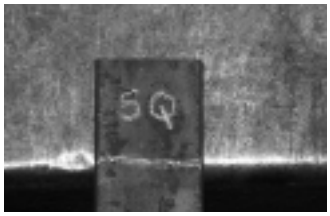


Photo 7.

Then, neither moving the bar forward nor back, rotate it so that it is on edge with the same material supported by the anvil. See Photo 8.

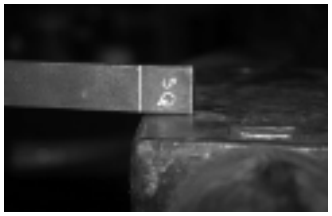


Photo 8.

Tip: A chalk or soapstone mark on the anvil one inch from the edge will also position the bar for this exercise. However, thinking of shape as opposed to dimension is a useful skill to develop. Here is an opportunity to judge ratio and proportion "at heat."

Keep the work-holding hand and arm relaxed and the bar horizontal. Only then will you create the sharpest set of shoulders. Any tendency to lower the holding hand so the anvil corner bites more into the work will result in an angled shoulder.

Step #3

With the target shape well in mind, the first hammer blows must be quick and hard to make full use of the available heat. Ideally, the hammer blows will exactly align with the near edge of the anvil and begin the needed shoulders. However, do not attempt to exactly match the hammer to the anvil edge with the first blow. Rather, approach the target shape through *successive approximation*.

Start with a confident blow near the end of the bar. Take the second blow a little closer to the desired shoulder and the third a little closer still. Creep up on the desired match of the hammer to the anvil edge.

Photo 9.

Photos 9, 10 and 11 show this series of hammer blows.

After three hammer blows (maximum), stop and rotate the bar so the other edge is uppermost. Feel for light contact between the shoulder you started and the rounded edge of the anvil.

Photo 10.

Note: Even hammer blows that were significantly short of matching the anvil edge will begin to make a slight shoulder on the opposite side of the bar (Photo 12). Take advantage of this when repositioning the bar and as a target for your hammer blows.

Photo 11.

Forging Dynamic: For every action there is an opposite and equal reaction. The force of the downward striking hammer causes the anvil in effect to strike up. But while a hammer blow's effect is concentrated in the area of contact between hammer face and workpiece, the anvil makes much broader contact. That is why a hammer blow that is not perfectly aligned with the edge of the anvil can still begin to create a shoulder on the underneath surface of the bar.

Repeat the series of hammer blows on this other vertical edge of the bar. All of this needs to happen very fast and very confidently.

Photo 12.

Troubleshooting:

Early and continuous correction is key to success.

If the bar begins to become parallelogram in section, put the long cross-sectional axis vertical and forge it down. See *Controlled Hand Forging "Lesson One: Drawing Out"* by Peter Ross and Doug Wilson for guidance (*Hammer's Blow*, Winter 2003).

If the bar begins to cup or collapse in one direction, this must be corrected by flattening before proceeding. Persisting with a bar that has started to cup in that way will only make the problem worse and increasingly hard to correct.

Photo 13.

Another related problem is a "pucker" or fold developing along the length of the bar. Photo 13 shows this clearly. While almost unavoidable to a small extent at the shoulder transition, if uncorrected it can become a lengthy cold shut.

If this pucker or cold shut plagues you, it is a good indication that you are working too cold and/or not hitting hard enough.

Forging Dynamic: When the bar is cool or the hammer blow light, the shaping force of the hammer is not transmitted into the middle of the bar. The shaping is, therefore, superficial and limited to the bar surface. The metal will always move in the path of least resistance. In the case of a bar on edge, as in this exercise, the path of least resistance is to the sides: the edges flare out leaving the shape of the middle of the bar relatively unaffected. The result will be a pucker or fold.

Step #4

High heat and hard hammer blows are so important to the success of this exercise, little is gained working below an orange heat. When the bar has reached an orange heat, get it back in the fire.

Photo 14.

Likely a second or third heat will be necessary to complete this exercise. Start with the same yellow or lightly sparking heat. You should have the beginnings of shoulders on both edges of the bar. See Photo 14.

The bottom shoulder will allow you to accurately position the bar on the edge of anvil; the upper shoulder will make a visual reference for your sequence of hammer blows. You may even be able to start closer to the shoulder and more confidently place the hammer face in relation to the anvil edge.

Again, hit hard and with intent, but take no more than three blows before rotating the bar to address the opposite edge.

Troubleshooting:

By now your shoulders will be definite enough that a new problem may develop: the extension may not be centered on the axis of the bar. This is usually the result of not working both of the edges equally.

This is corrected by placing the shallow shoulder down and against the edge of the anvil as in Photo 15. Keep the bar horizontal. Then, hit a blow on the upper shoulder to drive the extension back on center.

Photo 15.

Sometimes a misplaced blow or a bar not held touching the edge of the anvil will result in shoulders of equal depth but one forward of the other. This is a more challenging correction. See Photo 16.

Photo 16.

The short shoulder must be reset farther back to match the other. First, blunt the sharp corner of the shoulder (Photo 17). This will help avoid a cold shut as the metal moves into the path of least resistance.

Photo 17.

Forging Dynamic: When struck with a hammer, the heated bar will move in the path of least resistance. A sharp shoulder that is struck vertically with a hammer will move forward and begin to fold over. Low heats and/or light hammer blows aggravate this effect. If the movement is not anticipated or not corrected, a cold shut may result.

Photo 18.

Next, place that shoulder down on the edge as in Photo 18. Hit one corrective blow. This will produce a shallow mark, the beginnings of a shoulder at an accurate location opposite its mate on the other edge of the bar.

Rotate the bar so the shallow shoulder mark is uppermost and work progressively into the newly positioned shoulder.

Targets:

Forge the shape including all corrections in three heats. Photo 1 and the drawing illustrate the target shape. Pay particular attention to the following points:

1. The extension must be centered visually on the centerline of the parent bar.

2. Any pucker at the base of the shoulders is not to extend more than about 1/2 inch up the extension.

3. Shoulders are of the same depth and positioned the same distance from the end of the extension.

4. The cross-section of extension is square– neither rectangular nor a parallelogram. Outside calipers can help determine this.

5. The form is visually straight and without twist.

Forging Two-Sided Shoulders

By Jay Close and the CHF Committee

Photos by Jane Gulden and Jay Close

Charleston, South Carolina

Lesson #26B.

Part Two: Forging Two-sided Shoulders on the Far Edge of the Anvil

Editors Note: In the last issue of the Hammer's Blow*, the first part of this lesson was published with an incorrect headline. The editor regrets the error.*

Intent: The student will learn to forge two-sided shoulders on the far, rounded edge of the anvil, using only the forging hammer to control the location and dimension of the shoulders.

Introduction: Forging two-sided shoulders on the far edge of the anvil is challenging. Where the hammer is being placed on the work is often obscured by the hammer head itself and one must hold the bar at an increasing angle to the anvil face as the shouldering progresses. Figure 2 below shows the desired final form: an approximate square of material centered on a tapered "neck." While the sketch below includes suggested dimensions, as in the previous exercise, controlling the form is more important than meeting a set of prescribed measurements.

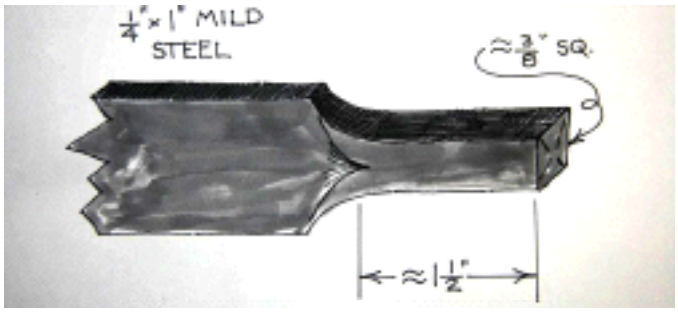


Figure 2.

As in the earlier exercise, smiths tend to be partial to a particular stance and presentation of the workpiece to the hammer and anvil. Either can be effective.

Tools Needed:

Basic forging tools only. See references in Part One concerning the general forging hammer, its selection and shape, and anvil set up.

Material:

1/4" x 1" mild steel, cut to approximately 24" in length (or any convenient hand-holding size). A shorter length held in well-fitting tongs is also acceptable.

Step #1

Heat two or three inches of the end of the bar to a yellow or lightly sparking heat. Place the flat of the heated bar on the anvil in an area with a rounded edge. A square of material 1-inch by 1-inch should project off the far edge of the anvil surface (See Photo 20).

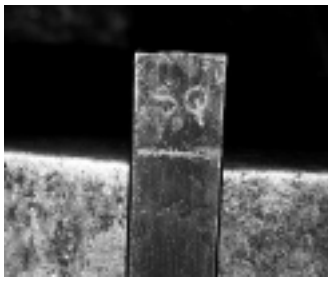


Photo 20.

Keep the bar horizontal as you rotate it on edge. Shift neither forward nor back. One inch of the stock should remain off the anvil as in Photo 21.

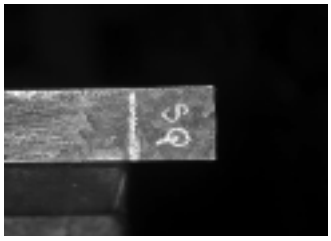


Photo 21.

The first hammer blows must come confidently: three blows, each one progressively closer to the desired alignment with the anvil edge– better to be short of the perfect alignment than hit too far forward.

Depending on which forging stance you decide to use, different parts of the hammer head do most of the shaping of the shoulders. This is parallel to your experience in the first lesson.

After <u>three</u> blows (<u>no more</u>!), rotate the bar so the edge once against the anvil is now uppermost. Reposition the workpiece so that the desired one-inch square of material is still off the anvil as in Photo 22. Adjust the angle of the bar so the just-forged edge is in contact with the anvil face.

Take two or three more blows working up to the edge of the anvil, then rotate the bar and work up to the other shoulder of the bar again. This is the same rhythm, forging and rotating, that you practiced in Part One.

Photo 22.

At an orange heat, the bar goes back in the fire. Working hot minimizes problems.

Note: As the shoulders develop, you must angle the bar on the anvil and cant the hammer into the shoulder. Have the tapered neck fully supported by the anvil at all times.

Step #2

Reheat the bar to a yellow heat and continue to draw down the neck. Hit hard but aim your first hammer blow confidently away from the edge of the anvil. The second and third hammer blow will move progressively closer to accurate alignment with the far rounded edge of the anvil.

Take no more than three hammer blows before rotating the bar, so the edge once against the anvil is now uppermost. Achieve the desired form by successive approximation.

Troubleshooting

Comments made in reference to the first exercise apply here. The sooner a problem is corrected, the better.

Watch for hint of a fold or pucker developing in the neck where it transitions into the square of material on the end. If one should begin, flatten it out before going further.

An off-center mass on the end of the bar (Photo 23) is adjusted by placing the shallow shoulder on the rounded edge of the anvil. Then, apply gentle pulling force to hold the shoulder tight to the anvil edge, and with a sharp blow as shown in Photo 24, drive the mass on center. In effect, you are creating a shearing force focused at the transition where neck meets square to push the square into alignment. The shoulder must be in contact with the edge of the anvil for this to be effective.

Photo 23.

Shoulders that are different distances from the end of the bar can be improved by positioning the long shoulder as in Photo 25. A hammer blow directed through the diagonal of the bar by striking the upper corner will drive the shoulder forward into better relationship with its partner. Often it helps to cool the corner that is to receive the corrective hammer blow.

If the mass on the neck is centered, but the neck itself is not in alignment with the axis of the bar, as in Photo 26, this too can be corrected. At a light orange heat, place the "neck" with the shallower angle uppermost as shown in Photo 27. A single blow should drive it on center.

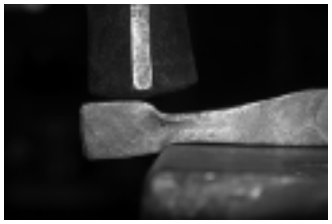


Photo 24.

Photo 25.

Targets

Forge the shape, including all corrections, in four heats.

Work toward a shape resembling Figure Two.

Pay attention to the following points:

1. The neck is evenly tapered, straight sided and centered on the axis of the bar.

2. The neck should be square in section at the point of transition into the square on the end. Expect the neck to grow thicker than the parent bar. This is okay for this exercise and often desirable in a finished forging, too.

3. The square on the end is approximately one inch square.

4. The square on the end is centered on the neck.

5. The shoulders are even depth.

6. The form is straight and without twist.

7. There is little or no hint of a fold along the neck.

Photo 26.

Photo 27.

Acknowledgments: Thanks to the Controlled Hand Forging Committee for many useful comments on this lesson. Thanks to Jane Gulden for taking a Saturday morning to help with the photography. And thanks to the American College of the Building Arts (www.buildingartscollege.us) for supporting my involvement in this lesson series.

Controlled Hand Forging Lessons
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Lesson #5 & #6	Twisting & Drawing, Punching and Bending
Lesson #7	Upsetting
Lesson #8	Splitting
Lesson #9	Mortise and Tenon Joinery
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Lesson # 26-1	Forging Two-Sided Shoulders – Part 1
Lesson # 26-2	Forging Two-Sided Shoulders – Part 2