# 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).

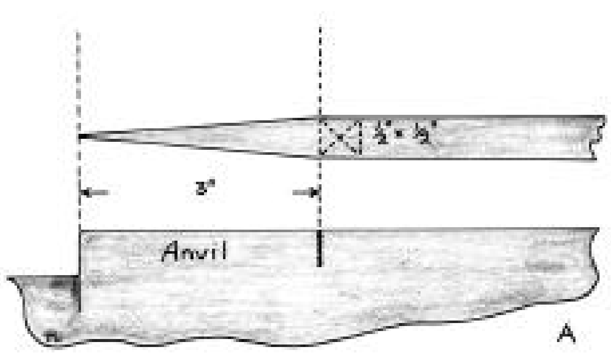
*Method:*

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

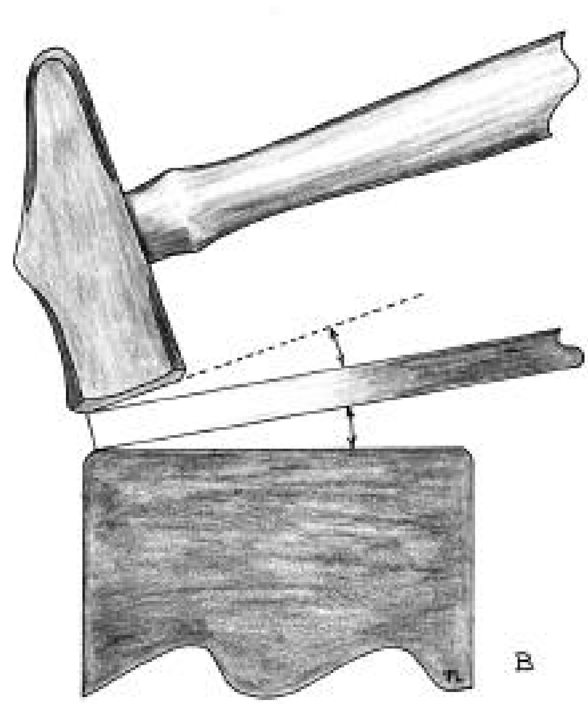



*The measured piece held over the anvil.*

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.

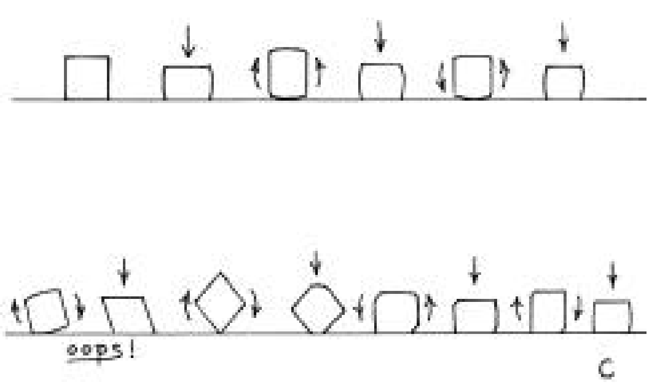
*Hint*:

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

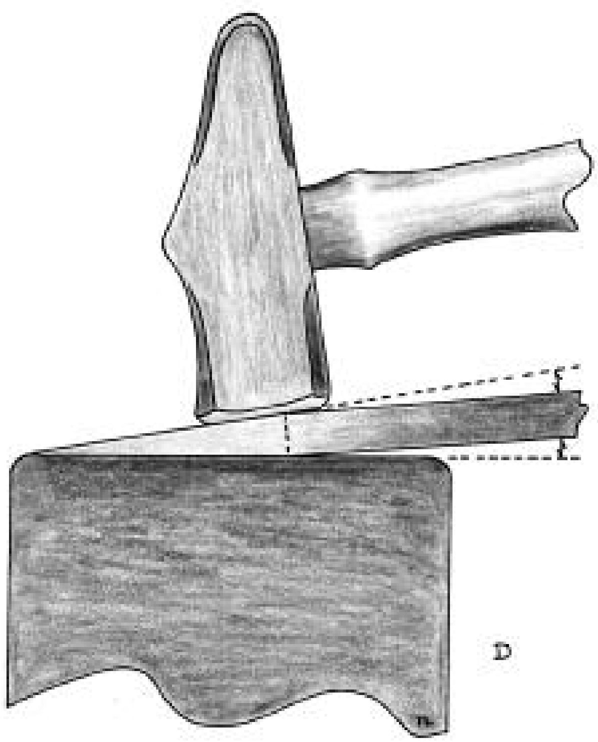



*Rotation and deformation of the bar by the hammer, and correcting a parralellogram.*

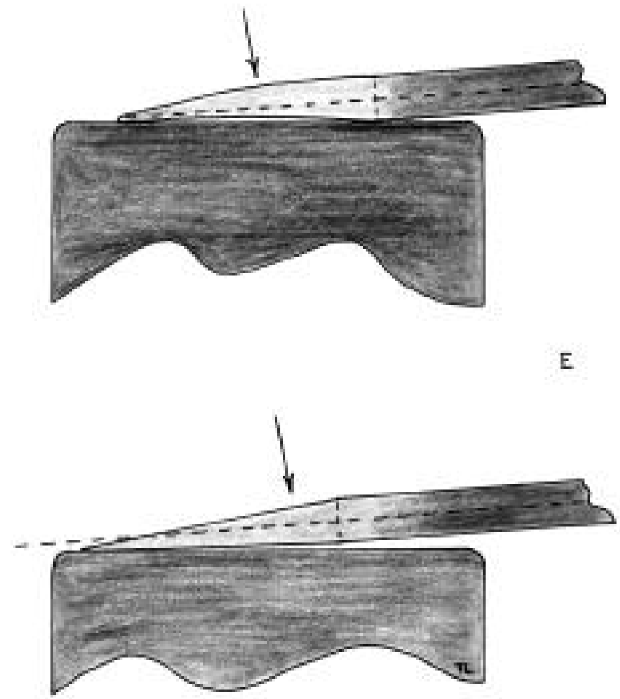
until the taper is 1/4 " short of the desired length . Work with heavy hammer blows at a bright heat while you are reducing the cross section. Lighter hammer blows at lower heats will help you refine the shape of your taper and smooth the surface. Establish a clear and well-defined beginning of your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

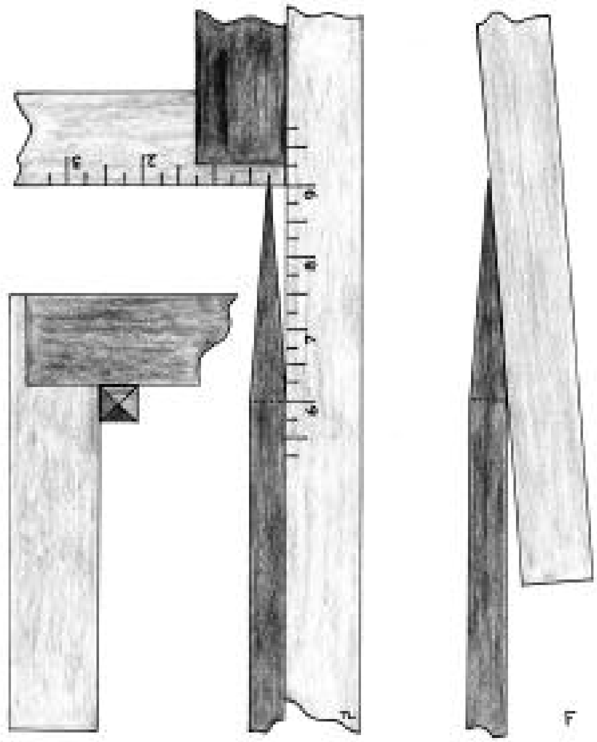
Hammer-finish with smooth surfaces and without discernable hammer marks.

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.

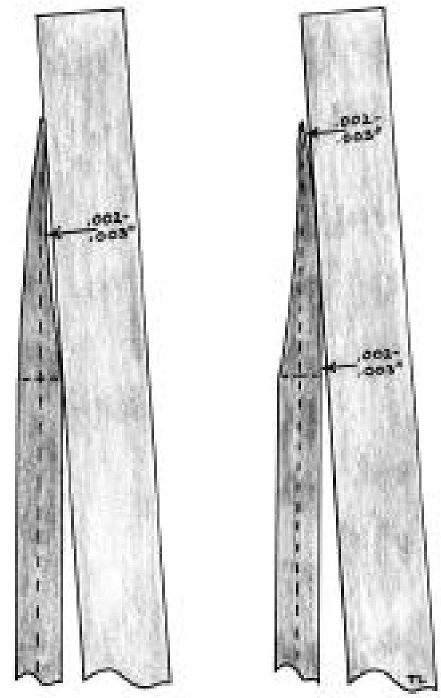
Measure your results using a square and a rule. The four flats of your taper should be straight within two or three thousandths of an inch, length within 1/16" and square in cross section. With practice you should be able to forge to this accuracy by eye. Repeating this exercise with care and attention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

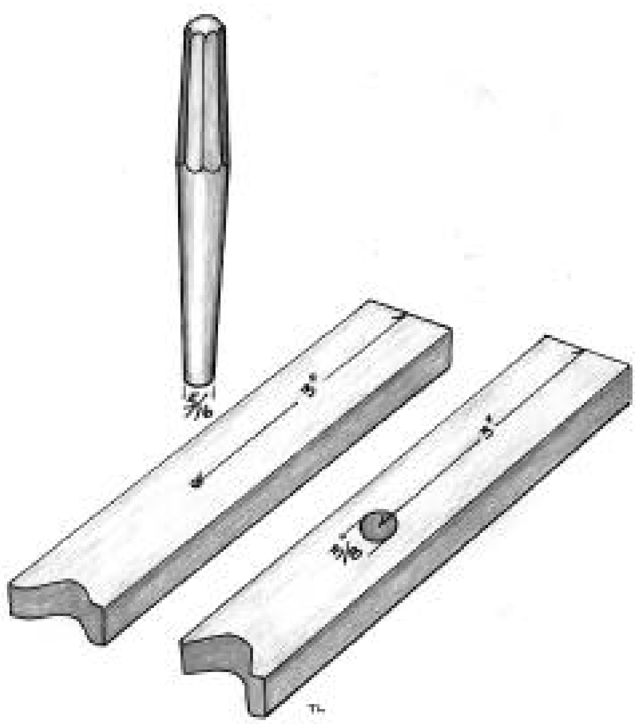
# Lesson Two: Hot Punching

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.

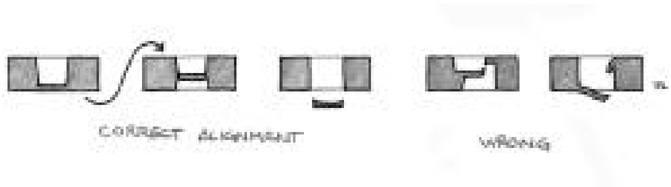
The top end should be tapered slightly to reduce mushrooming in use.

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

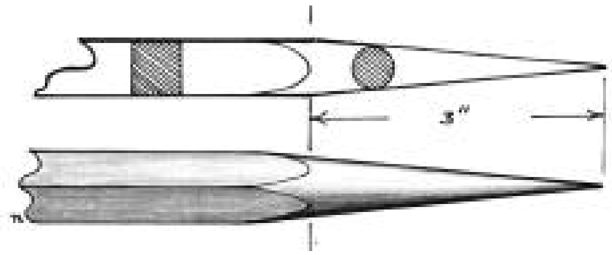
By Jay Close
Illustrations by Tom Latané

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.

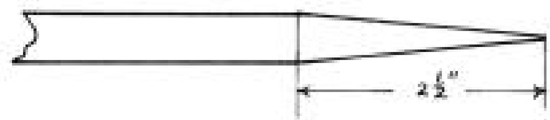
Starting at a yellow or light welding heat , forge a square taper on the end of the 1/2 inch square bar. This taper should be 2 and 1/2 inches long and hammered to a sharp point.

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



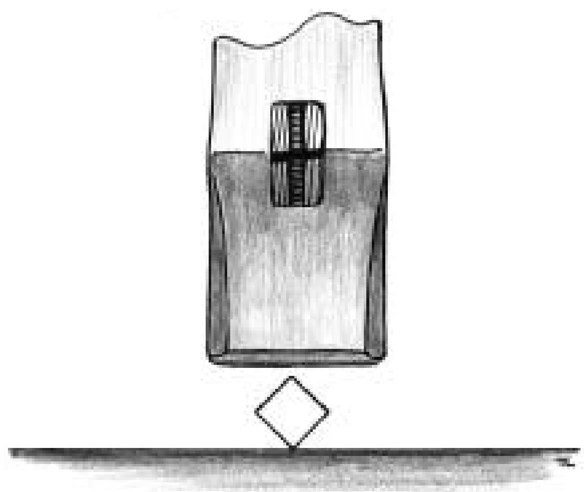

*2. Needed straight taper and dimensions.*

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.”



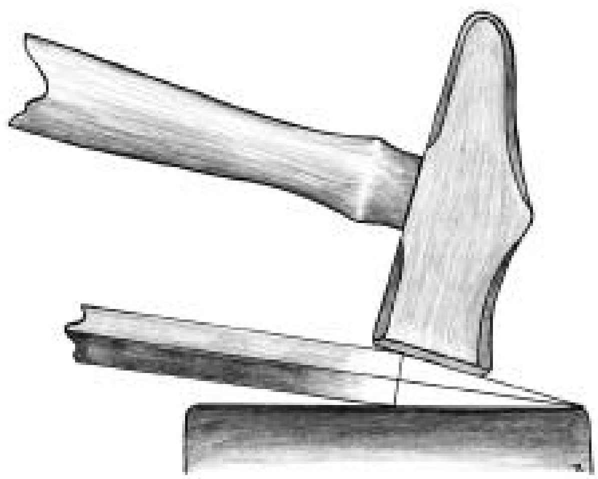
*3. Corner up position.*

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]

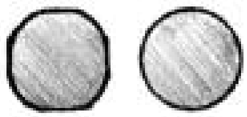
Go back and hammer down these rounded corners as facets once more. Then forge down the new corners before rolling and rounding.

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

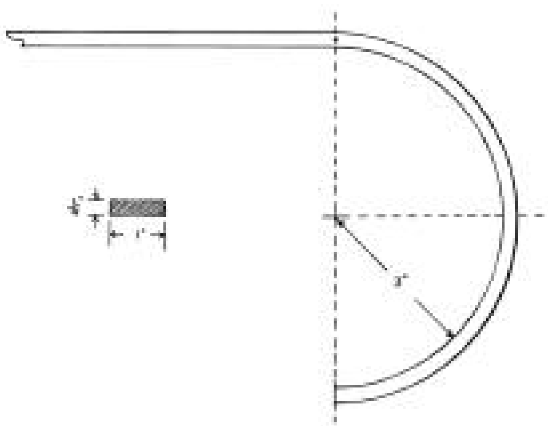
Lesson Number Four– Bending

*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 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.



*1. Dimensions of the finished forging.*

*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.

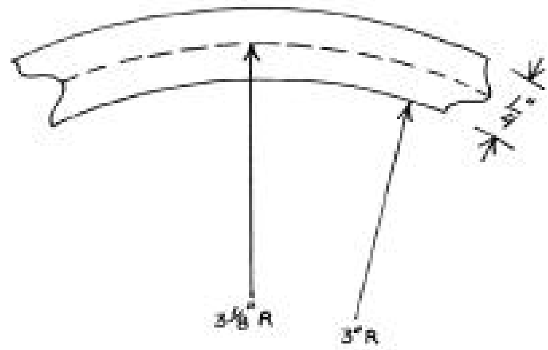
*Method*: After calculating the needed material to make the bend, the curve is produced by using the horn as a bending point or fulcrum. Shifting the location of the bar on the horn and changing where and how hard the bar is struck controls the needed curve.

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 of dimensions, simple geometry yields an accurate result.




*2. Material needed.*

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*

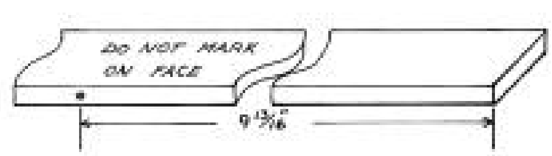
*bar length needed = 3.14 times 3.125 inches or 3 and 1/8 inches*

*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.

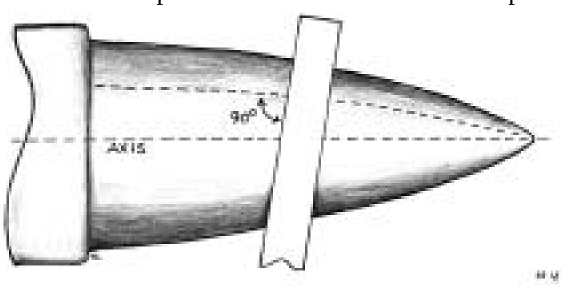
Step Two:

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.

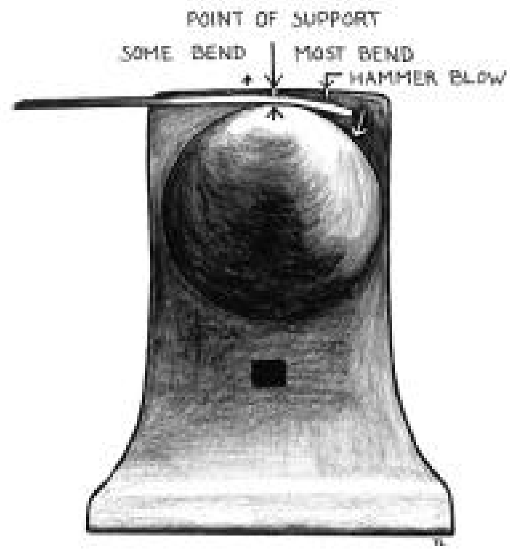
Get this first part of the curve well bent. It is often easier to straighten it later than introduce more curve.

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.

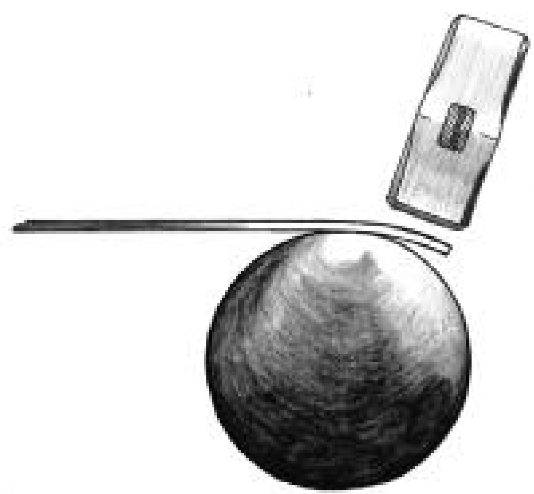
*HINTS:*

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.

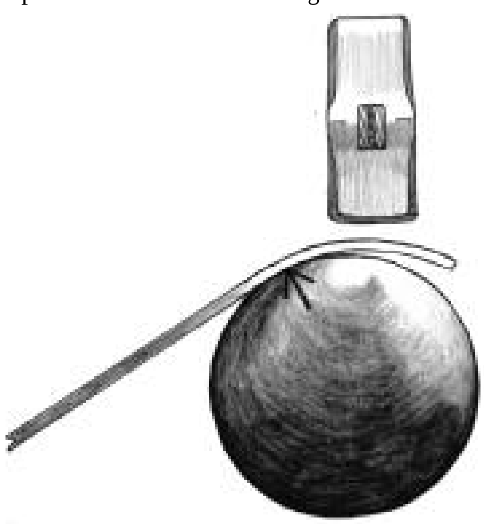
A hard blow at a high heat close to the anvil horn with a small amount of the bar unsupported will result in the tightest bend.

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.

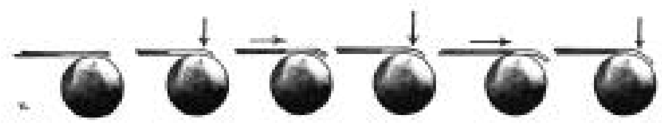
At a light orange to yellow heat repeat the sequence of Step Two to continue the bend. Keep track of your punch mark and visualize the complete curve as you work.

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.

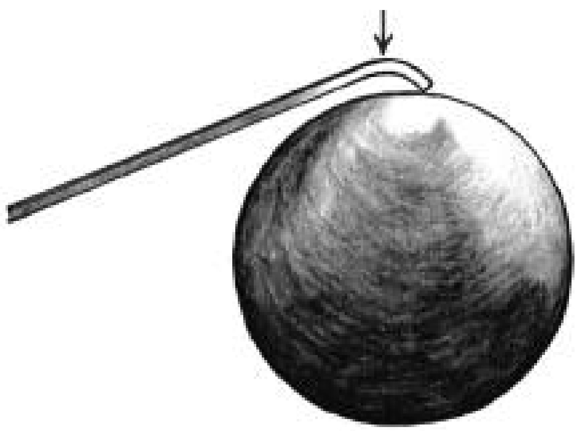
If, on the other hand, the over bend is not noticed until most of the curve is already completed, then the bar is best flipped so the curve reaches under the horn and the end comes on top. Support the end and hit to the far side of the point of support.

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.



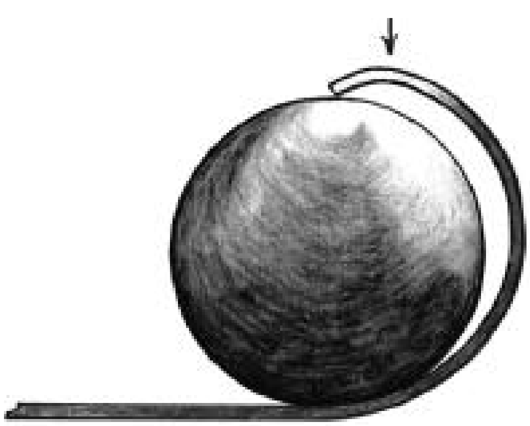
*9. Straightening an overbent bar.*

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.



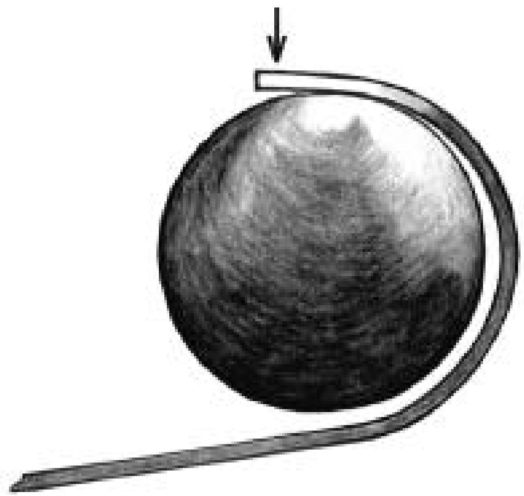
*10. Another way to straighten an overbent end.*

The straight section should remain straight

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

Forging Dynamics:

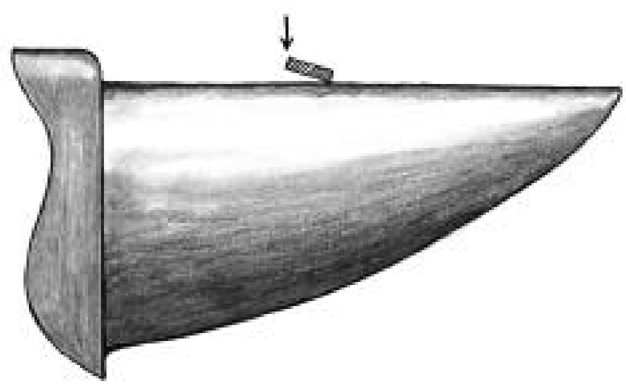
The hotter the bar, the softer it is. Therefore, the more shape change that will result when a given hammer blow is applied. In bending we apply a force to change the axis of a bar. By supporting the bar at a given point on the horn we concentrate the effect of our hammer blow to a certain length of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

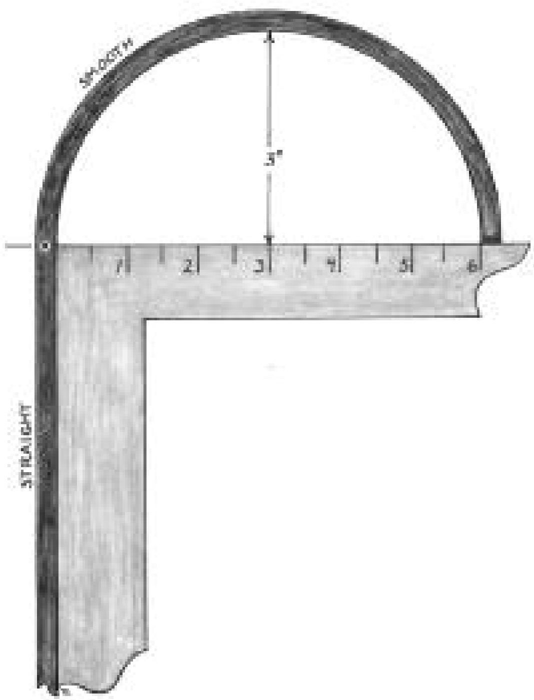


*12. Correcting a spiral*

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.



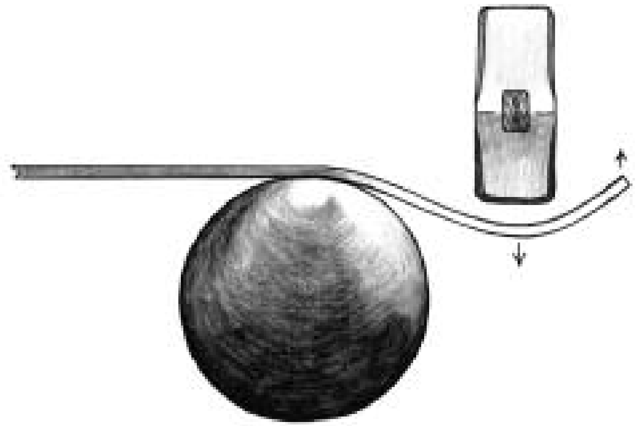

*13. Checking your work.*

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.

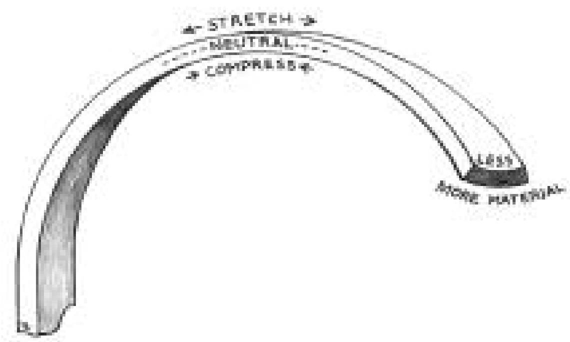
(4) When marking out for a bend, use only a round centerpunch mark, not a chisel cut or something similar. This will minimize the potential for concentration of stress in the bar that could lead to a crack or split. In no case should you mark the face of the bar either inside or outside of a bend. Both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



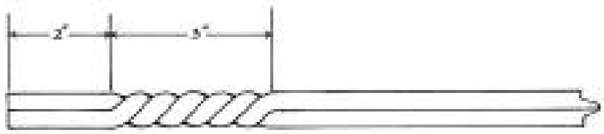

*15. Forging dynamics– “cupping” of the metal within the curve.*

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:*

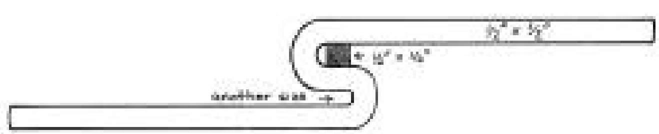
The student will twist a 1/2"square bar one and one-half turns.

*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.

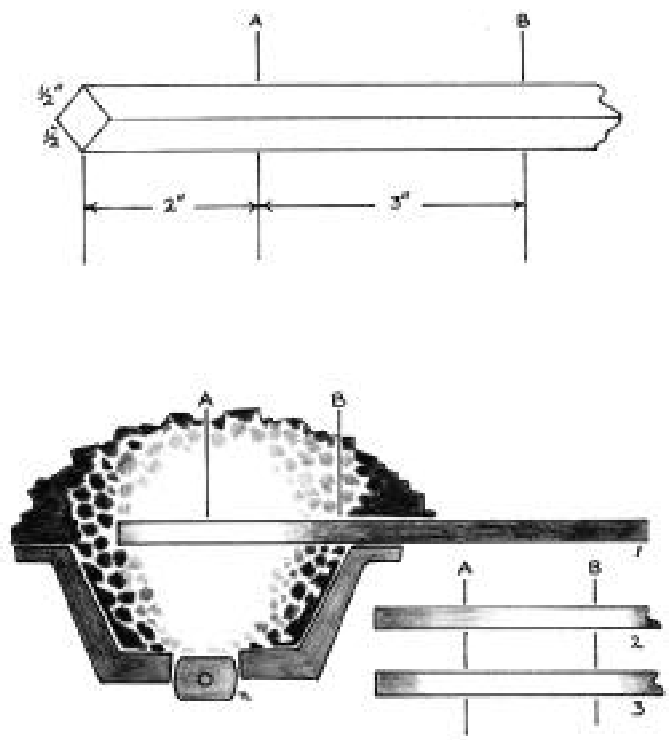
The exact size of these bars is not critical. Bars in the area of 1/4"x 1/2"x10", or slightly shorter, work well. The idea is to use straight, lightweight bars.

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.*

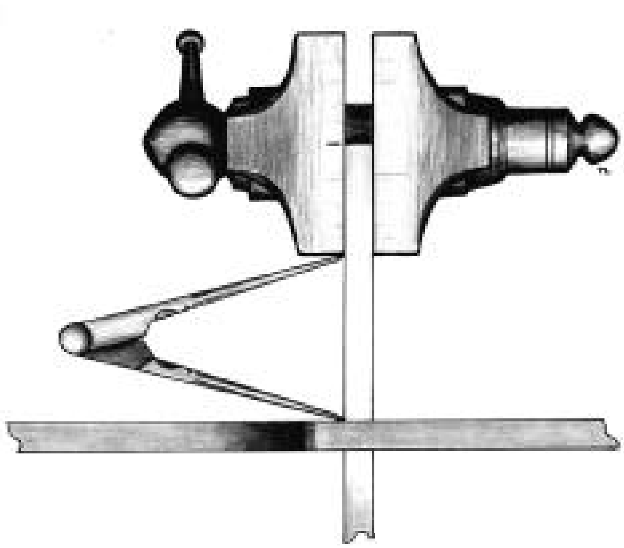
Step One:

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.

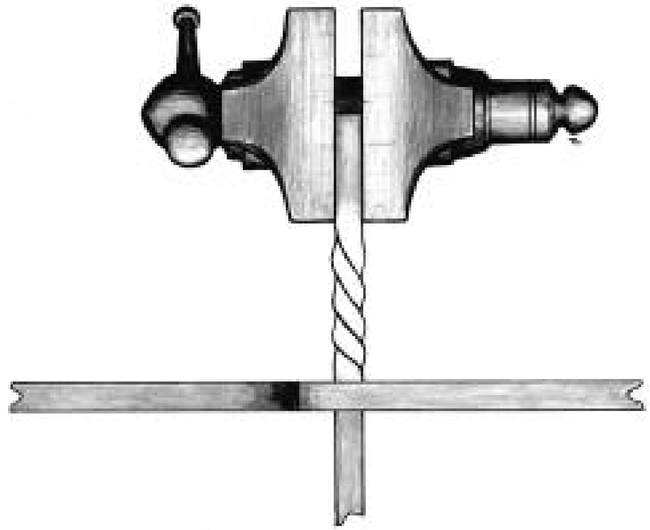
Use the dividers pre-set at 3" to determine the location of the twisting wrench and place the twisting wrench on the bar.

*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.

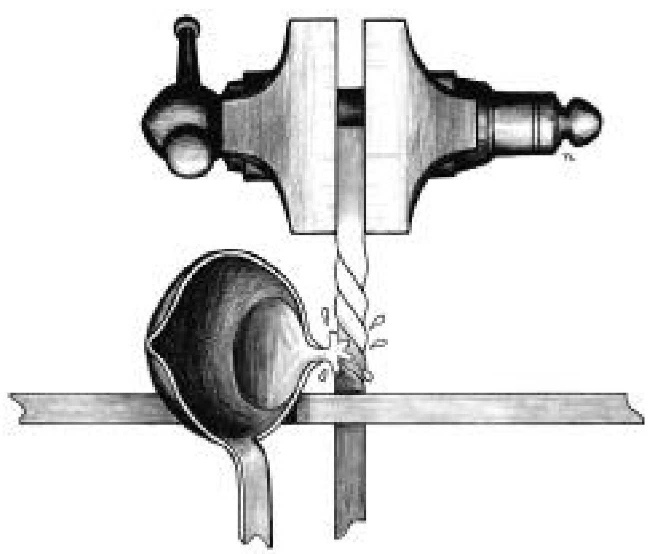
Some twists call for multiple twists in the opposite direction. Always make the first twist in the same direction to avoid forgetting which way to twist. (This may be either clockwise or counter clockwise.) It is well to develop the habit of always twisting in the same direction, except when the design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

Step Four:

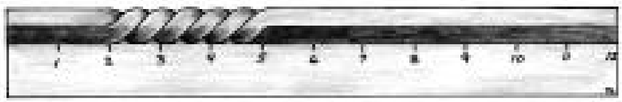
Quickly brush off the scale and inspect the twist. If part of the twist is tighter that the rest, cool it with water. Continue twisting to finish with exactly one and one-half turns.

*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.

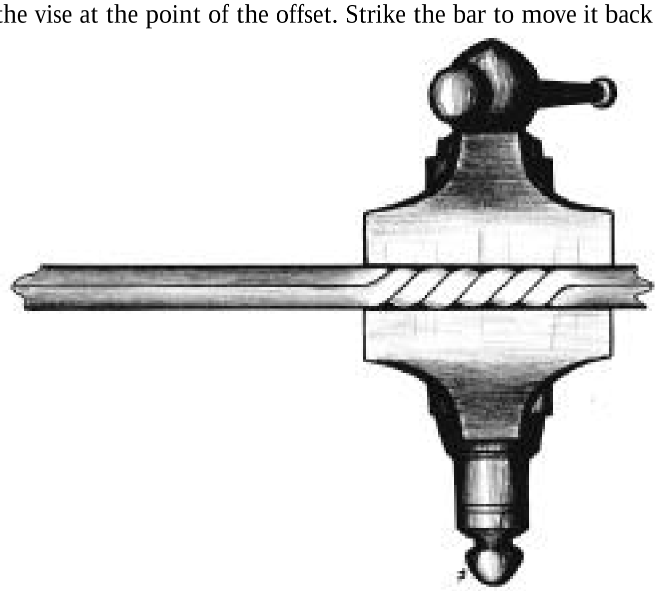
Beginners may need to use the following procedure to check for straightness: Place a straightedge lengthwise along the bar on a corner covering the twist and both untwisted parts. Do this on all four corners. The straightedge is to make contact with the untwisted corners and the corners of the twist.

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

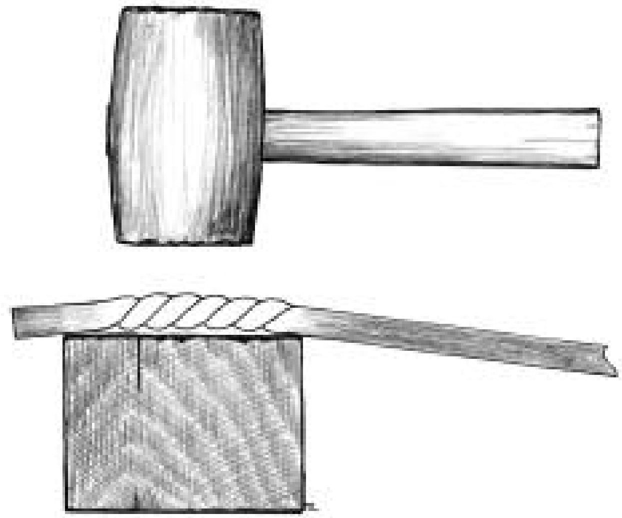
Step Six:

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.*

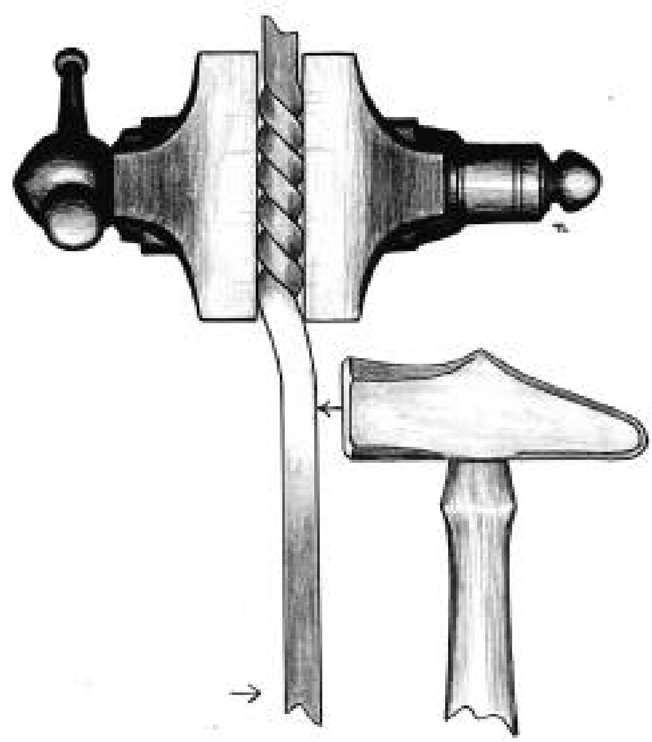


*9. Another method for correcting a simple bend.*

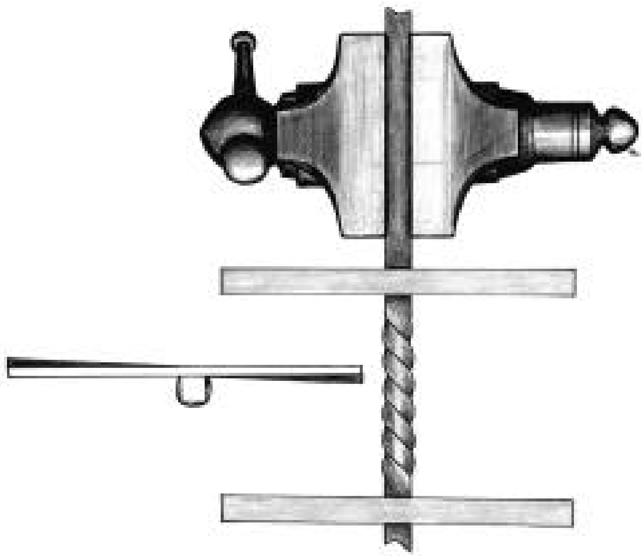
into alignment. At the same time apply pressure in the opposite direction at the end of the bar to avoid bending the bar.

*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.

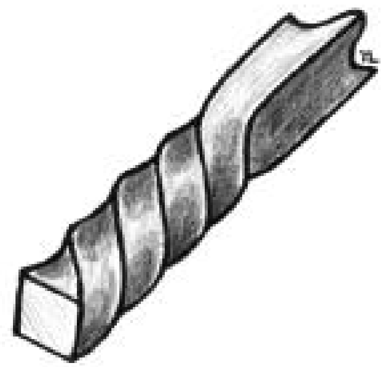
5. The entire bar is straight. A good test for straightness of the twist is to place a straightedge along the twist and check for contact with each of the corners of the twist. Also, sight lengthwise along the bar—there is to be no detectable crookedness for the entire length of the bar.

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.

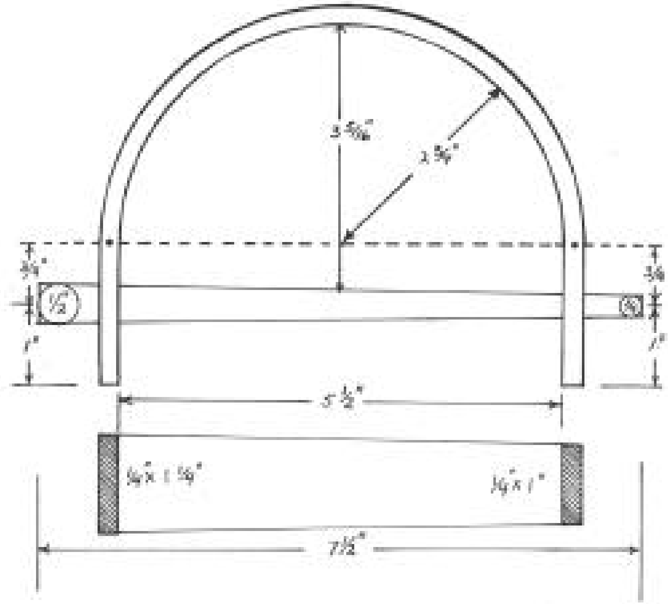


11. *Forging dynamics of twisting.*

# 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.

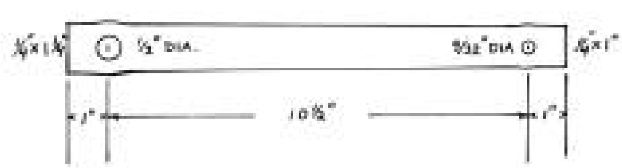
Step One:

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.

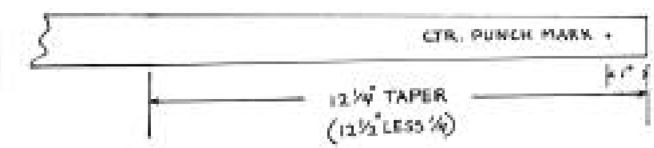
Refer to the drawing of this project for dimensions and calculate the length of the flat bar before bending. Also determine the distance between holes. Review this procedure in Lesson Four (Bending) if necessary.

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.

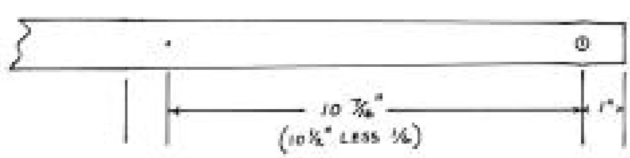
Drift the hole to 9/32" diameter using the punch.

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:*

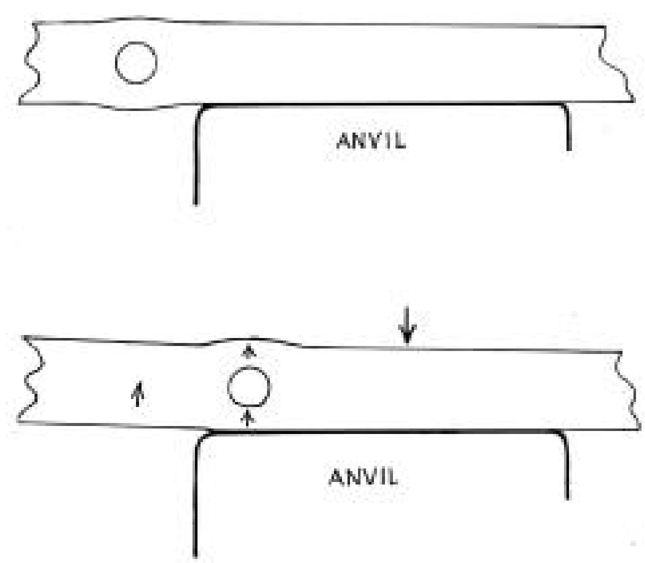
Rather than center punching the exact location, make the mark approximately 1/16" too close to the first hole. This will allow for inevitable stretching, and decrease the chance of the holes being too far apart. If there is any error to correct, it will be much easier to stretch the bar a little than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

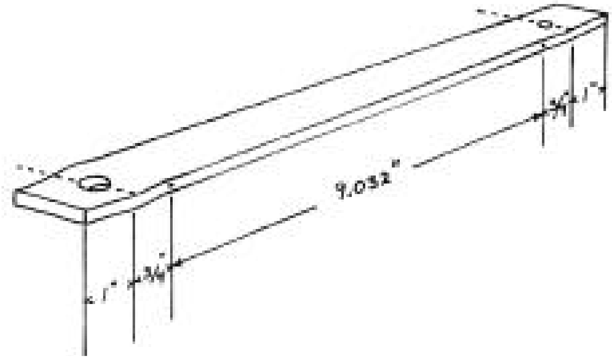
Second, cutting would deform the bend if it were already done. We would have to do the work all over again.

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 undo-




*7. The bar with punch marks on edge.*

ing the accurate dimensions already achieved.

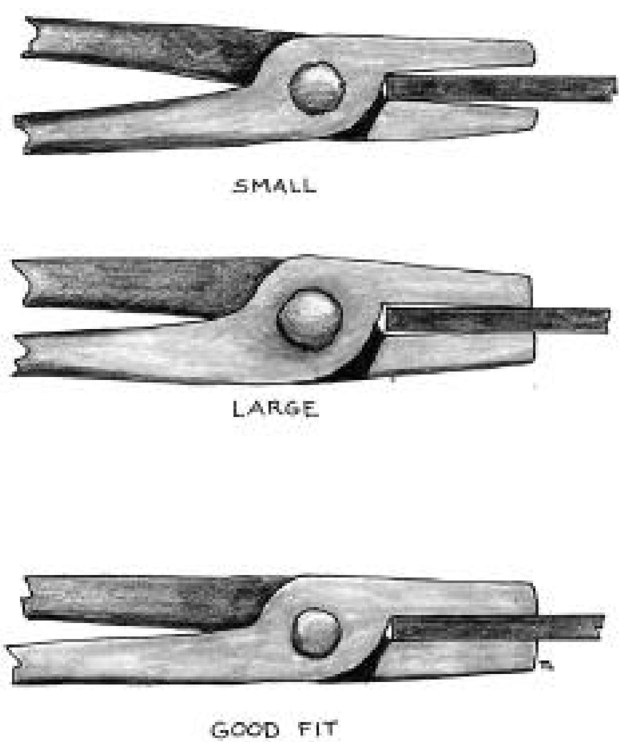
In preparation for the final step, it may be helpful to mark the limits of the bend (see Lesson 4, Bending) on the edge of the bar.

Step Six:

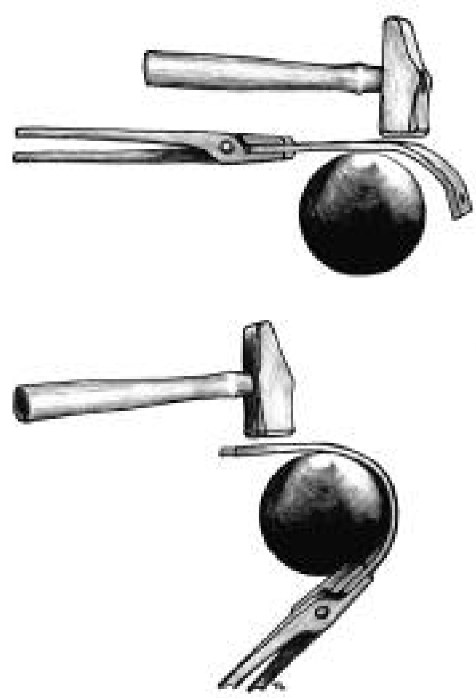
Bend the piece to match the given dimensions. Heat approximately one half the length of the bar and bend while holding the cold end in the tongs. Once done, switch grip to the bent end, heat the second half, and finish the bending. Switch grip as often as necessary to make corrections and adjustments.

*Hints:*

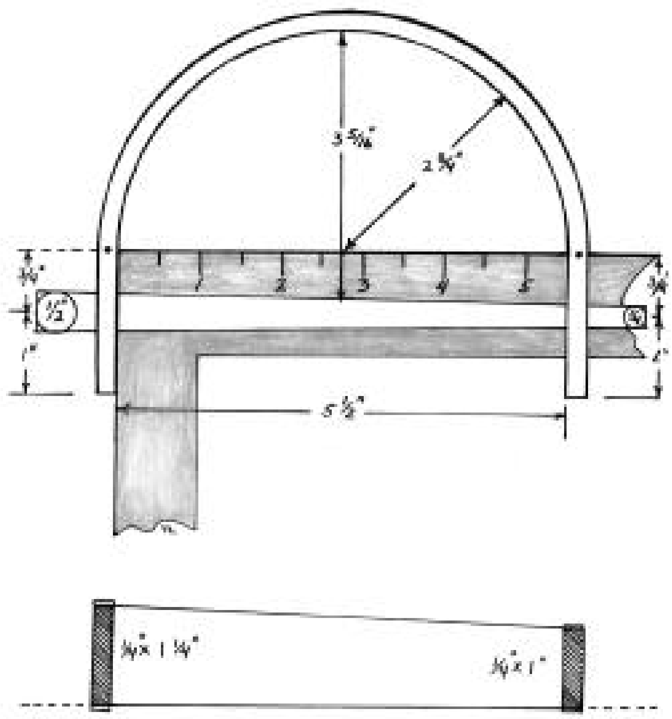
Since the bar is tapered, care must be used to get an even bend (it will bend more easily where it is smaller). If you have chosen to center punch the edges of the bar for reference it should be easy to determine if the bends start and stop at the correct places.




*6. Proper and improper tong fit.*



*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.

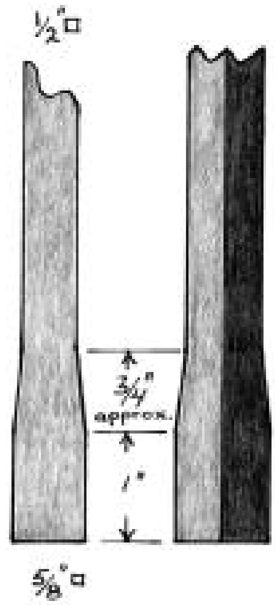
Check all given dimensions.

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.

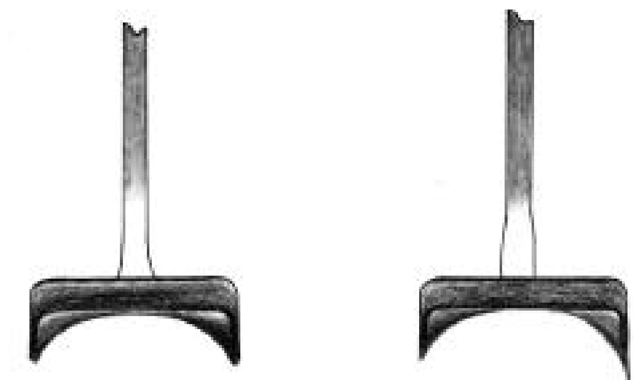
In order to work efficiently, the following conditions must be met:

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:

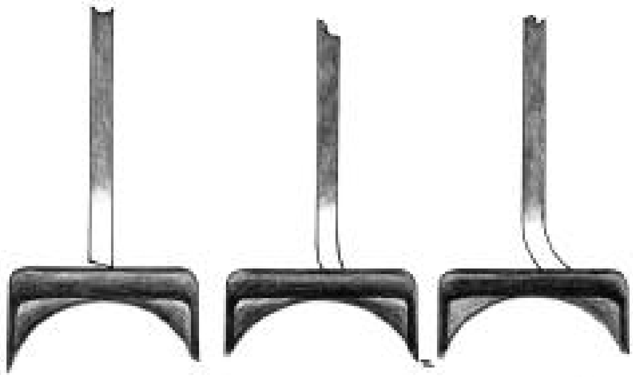
1. The size of the hammer affects the results. A light hammer can be used faster, but since it has less mass, the blows work only the very end of the bar.

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.

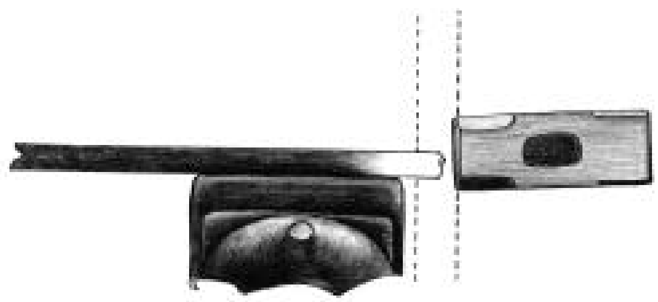
5. You have the choice of holding a short bar with hot end up or down. If down, the length of the bar absorbs some of the blow, so less is accomplished. If the hot end is up, the blows fall directly on the heated end, which is good. However, it's much harder to hold the upper end steady if you grip at 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.*

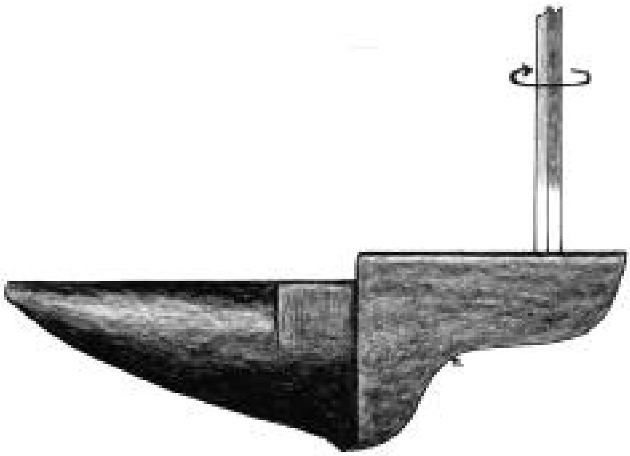
Now for the real work. Take a near welding heat on the end of the bar. It is important to heat only 1 –2 inches. Even with the best of intentions, the heat is sometimes too long. In this case, quickly quench all but the area to be upset. The fastest method is to submerge the long end of the bar (along 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.

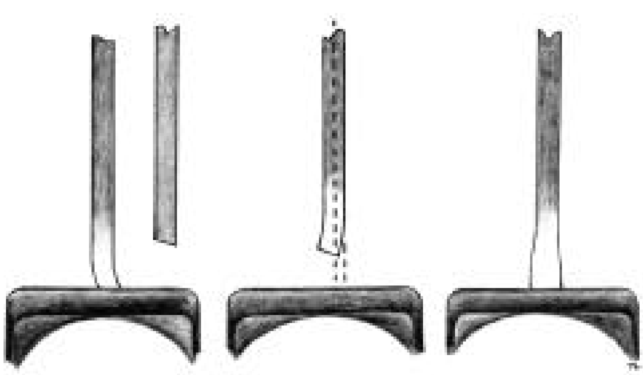
As soon as possible, return the bar to upright and strike two or three more upsetting blows. Continue in this manner until you have slightly exceeded the target dimension, taking additional heats if the bar cools below a medium orange.

*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

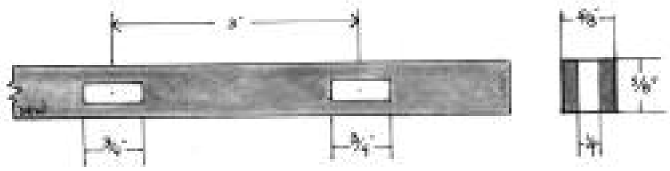
*A coffee table by Doug Wilson using the techniques described*

## 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.



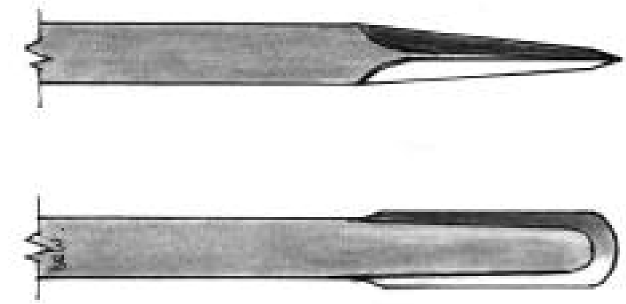
*The finished practice piece with dimensions*

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.

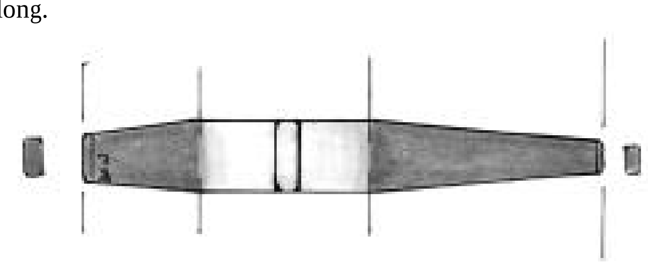
*Tools:*

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.

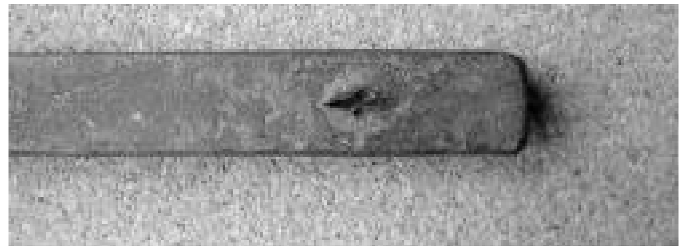
Steady the end of the bar you have been holding against your thigh. Pick up the hammer.

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.

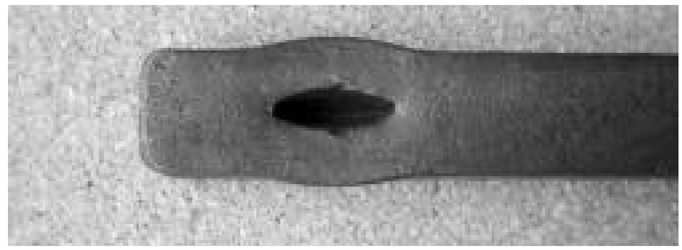
Hold the chisel vertically. Hit the chisel vertically, and you will cut vertically.

*Jay Close steadies the bar against his thigh.*



*A "witness mark" centered on the centerpunch mark*

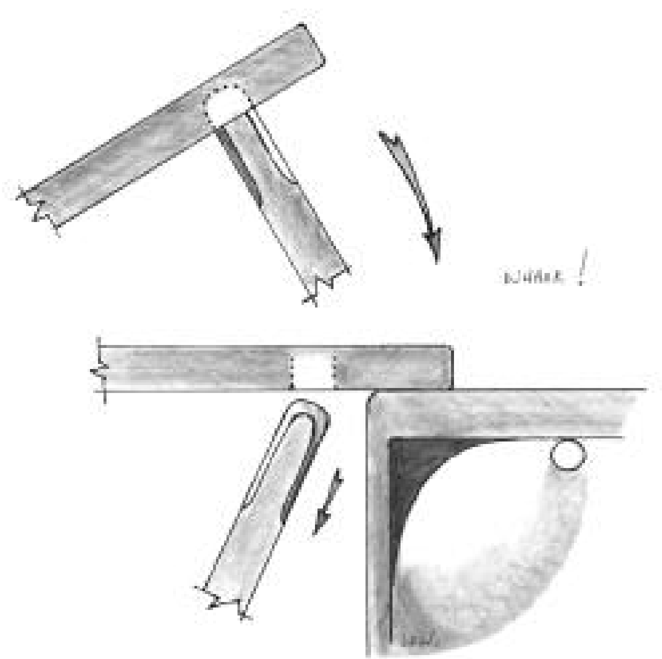
Do not allow the chisel to stay in the cut! If it softens in use, it stops cutting and begins to deform. As a starting point, three quick hammer blows to the chisel and then get it out of the cut.



*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.

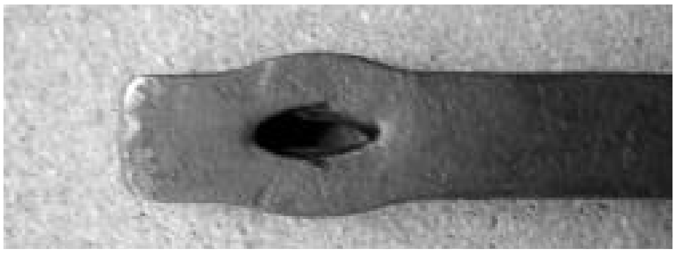


*Removing a sticky chisel*

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.

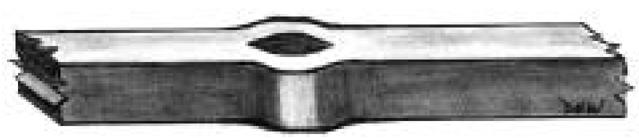
When the bar is red, remove the drift, forge in the unwanted stretch in width and get it back in the fire.

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.

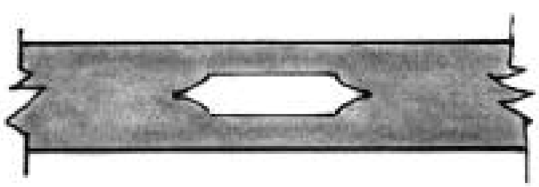
For example, say you started with 10 inches of bar. After you made the first mortise the bar grew to 10 and 1/2 inches. From the mortise center, the mortise pushed the bar 1/4 inch forward and another 1/4 inch back. If you want a second mortise a specified distance from the first, you must anticipate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

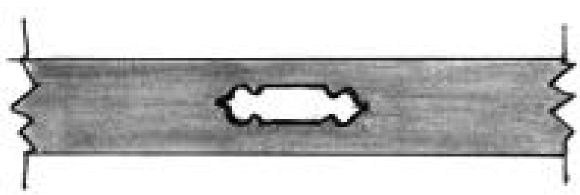
Troubleshooting:

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.



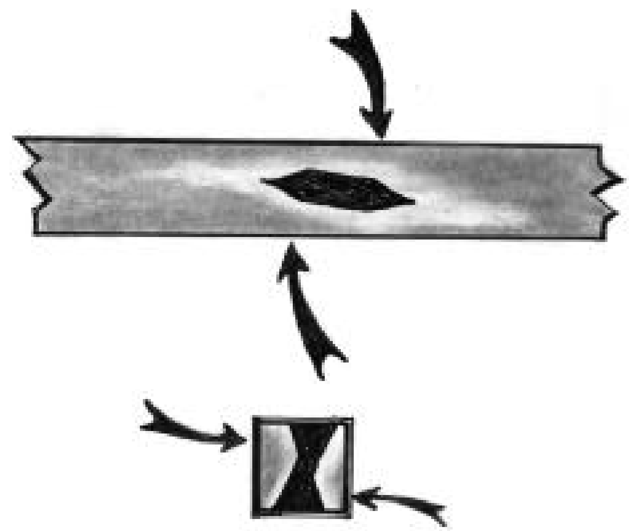
*Results of overstretched sides*

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.

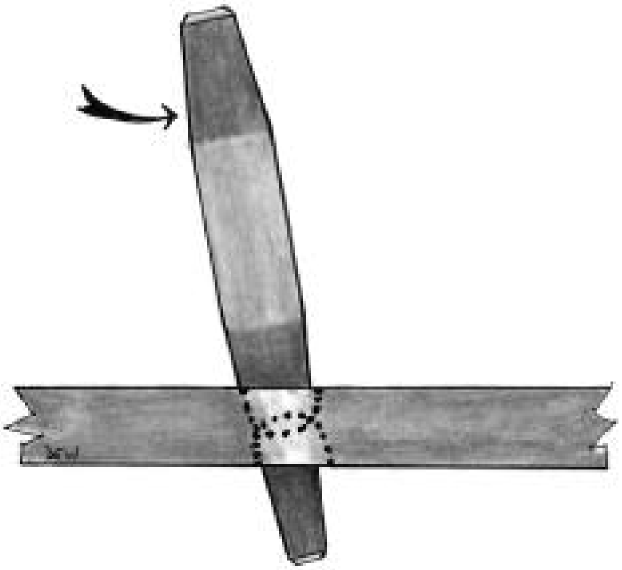
If your mortises are not 3 inches apart, you will need to adjust them—hopefully, just slightly. For greatest accuracy, remember to make your assessment when the bar is at room temperature. For your own interest, record the measurement both while the bar is red and when it is at room temperature and note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

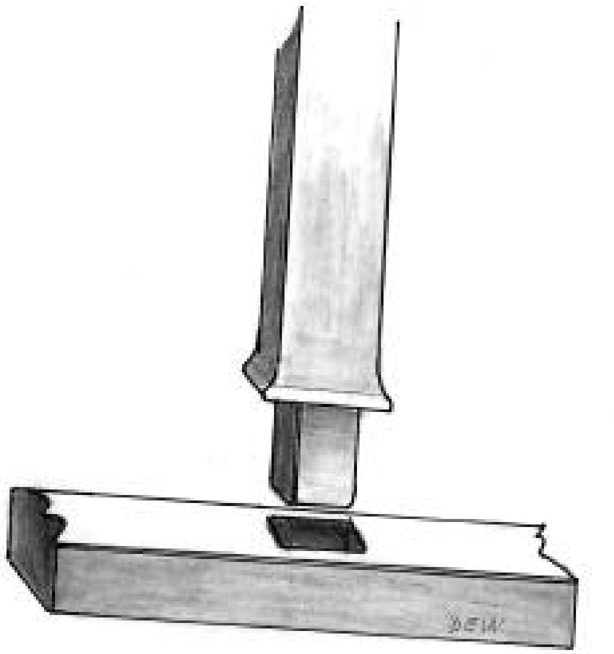
If you upset or drew out the bar between the slots to achieve the proper dimension, any dimensional change in the bar should be spread over as wide an area as possible and not be immediately obvious. The bar should be straight along its axis.

Skipjack

Striker

# Mortise and Tenon Joinery

Text and Illustrations by Doug Wilson



*#1. Example of technique*

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

*#2. A top and bottom side set*

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)

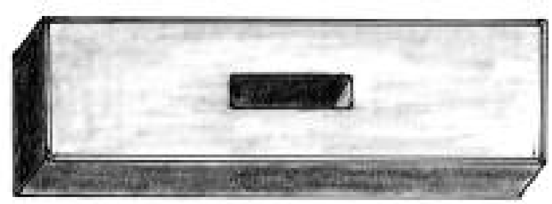
Repeat and cut the remaining two corners and sides with light blows.

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

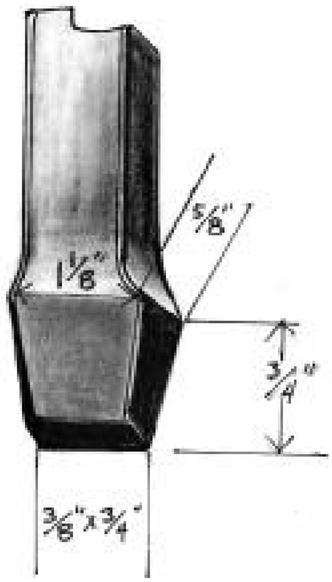
Misaligned cuts or double cuts cause hot shuts, then cracks. Proper tool alignment is critical here. Any mis-cuts should be filed out immediately.

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*

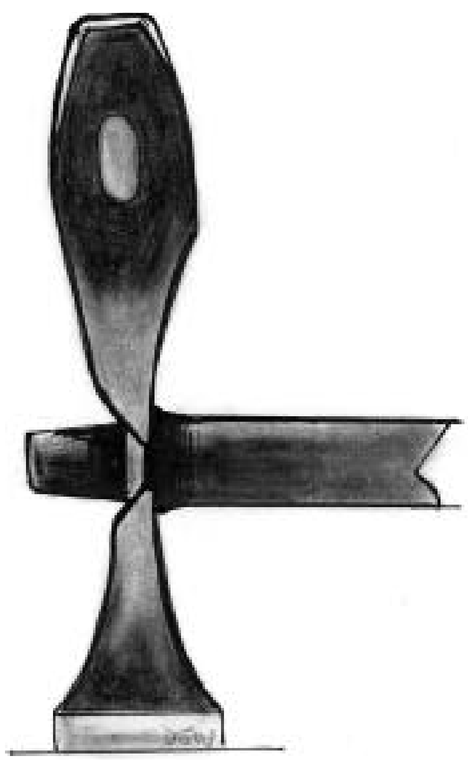
Notes: If the tenon is a bit too fat that's ok. Too thin won't do.

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.

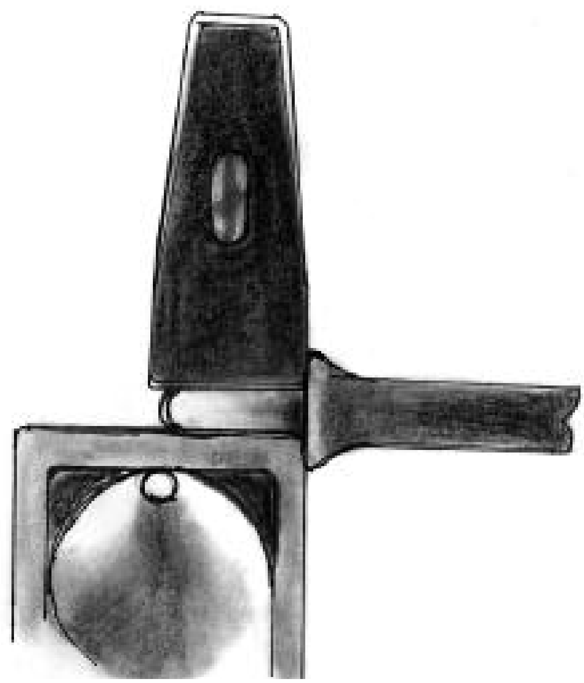
Pull the bar from the fire. Set bolster over the hardie hole. Insert tenon. Upset and square by hitting hard on top end of bar. (drawing #7)

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.



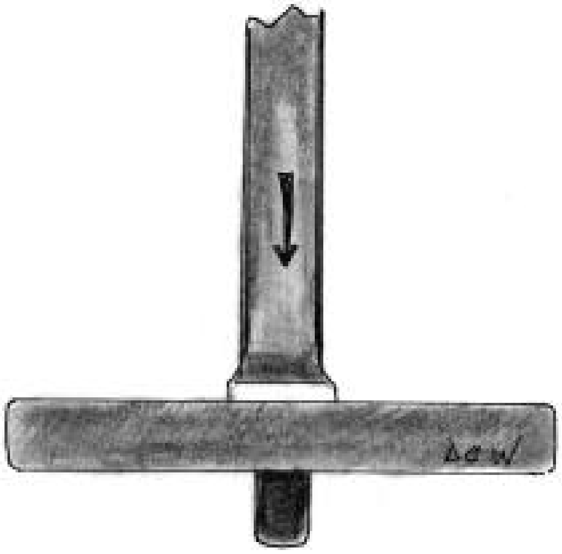
*#6. Using the set hammer*

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.

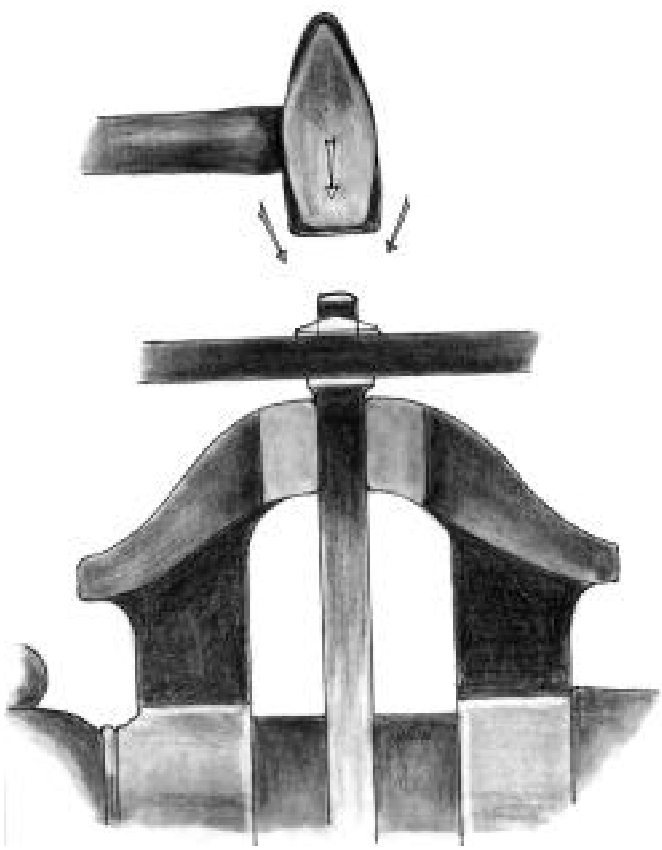
Quickly set bar in vise. Set mortise onto it. Tap it down so it sits firmly on tenon shoulders. With rapid hammer blows, upset the tenon. (drawing #8) First hammer blows are straight down. Finish with angled blows.



*#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

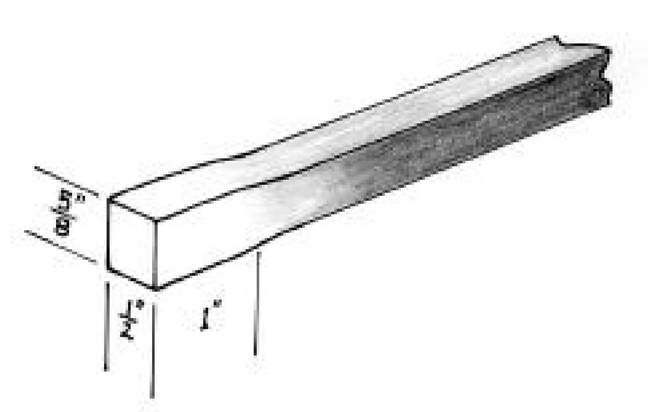



*Figure 1: Upset end preparation*

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*

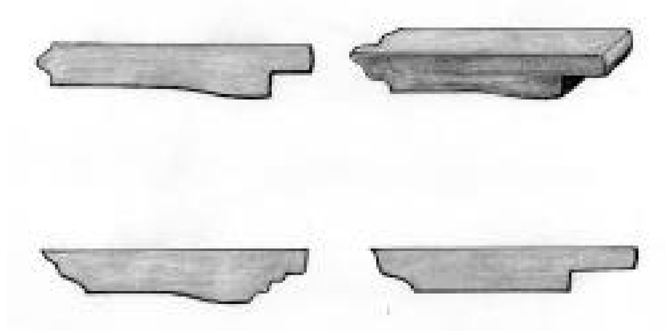


*Figure 3:Above, correct. Below, incorrect. Left– initial shoulder backed off anvil too soon. Right– no upset remains for scarf to be laid upon during weld.*

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*

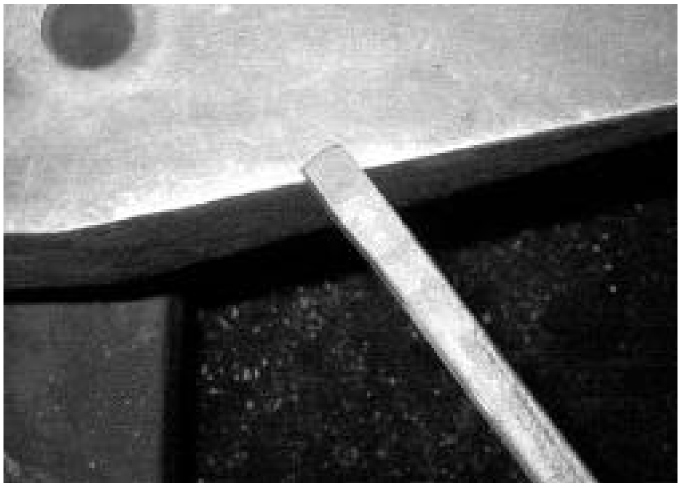


*Figure 5*

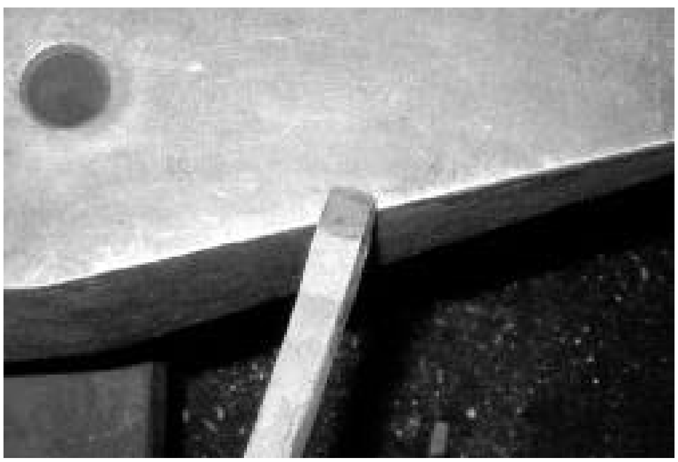


*Figure 6*

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.

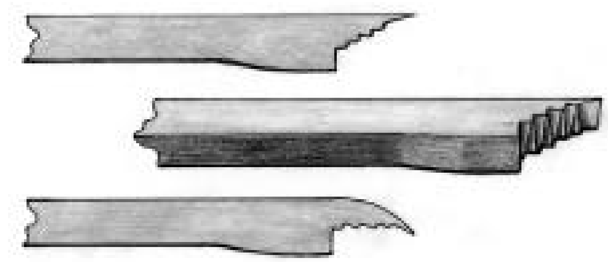


*Figure 7:Top– shouldered and stepped scarf. Bottom– Curved tip. Shoulder prevents scarf from overlapping beyond upset area when scarfs are quickly placed together.*

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.

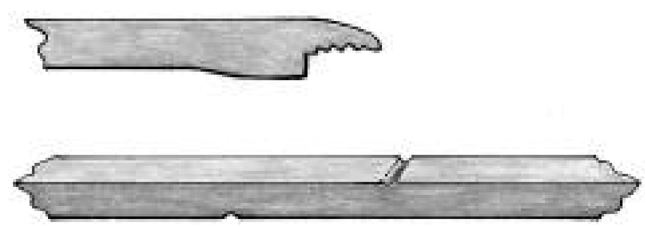


*Figure 8: Blunt scarf makes seam difficult to blend*

*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.

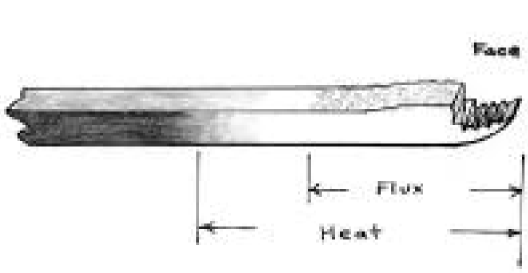



*Figure 9:Fluxed face heated from below.*

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.

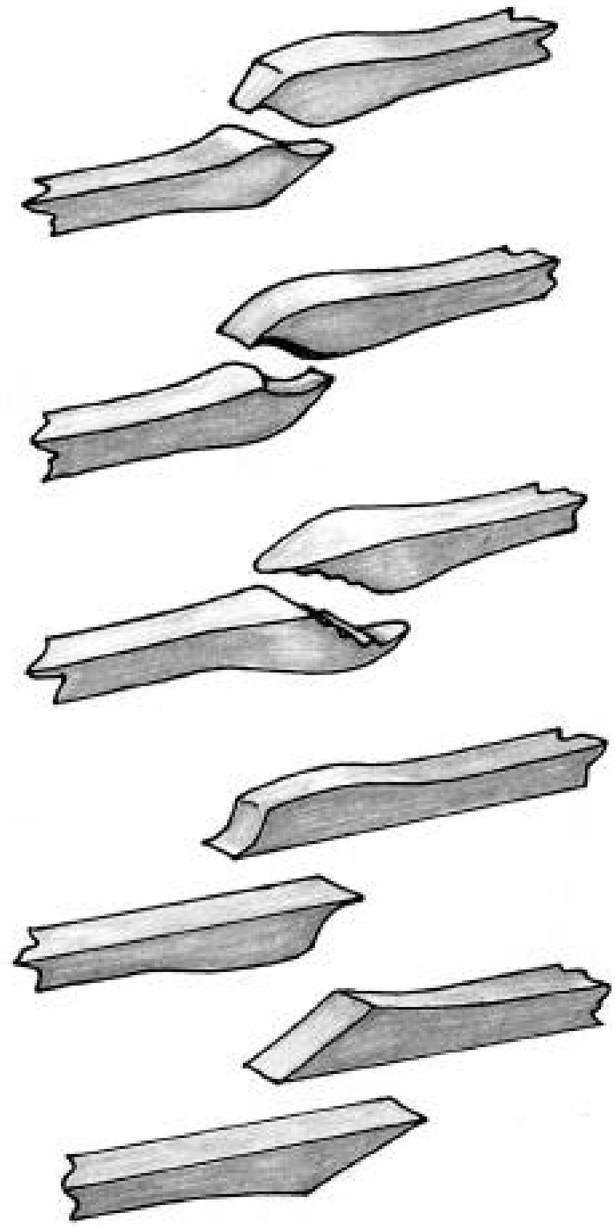
*Tip*: Rub soapstone or chalk on the face side of the bar to indicate direction of the scarf face when pulling the bars from the fire.

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

*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.*

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.

*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

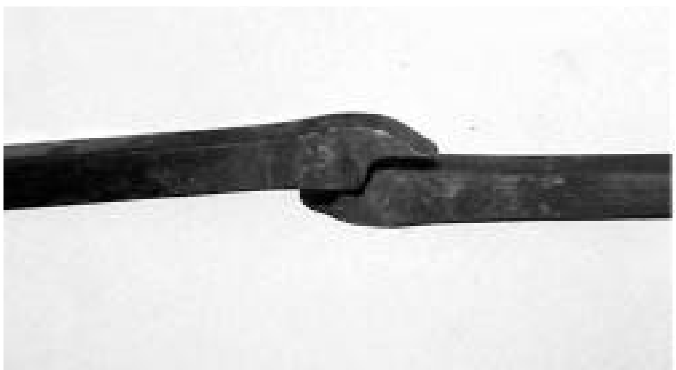


Figure 12

*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

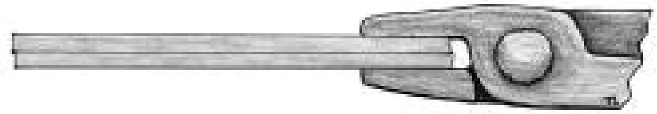


*Figure 13: Bars for practice weld– no alignment of scarfs.*

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

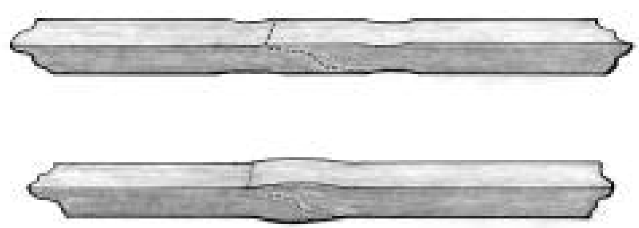


*Figure 14: Top– thin areas due to loss of material from burning, too little upset, or over-hammering, must be upset. Bottom– remaining bulge must be drawn down to dimension.*

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*

Teaching Tapes

NC Tool

# Drawing Down- Part One

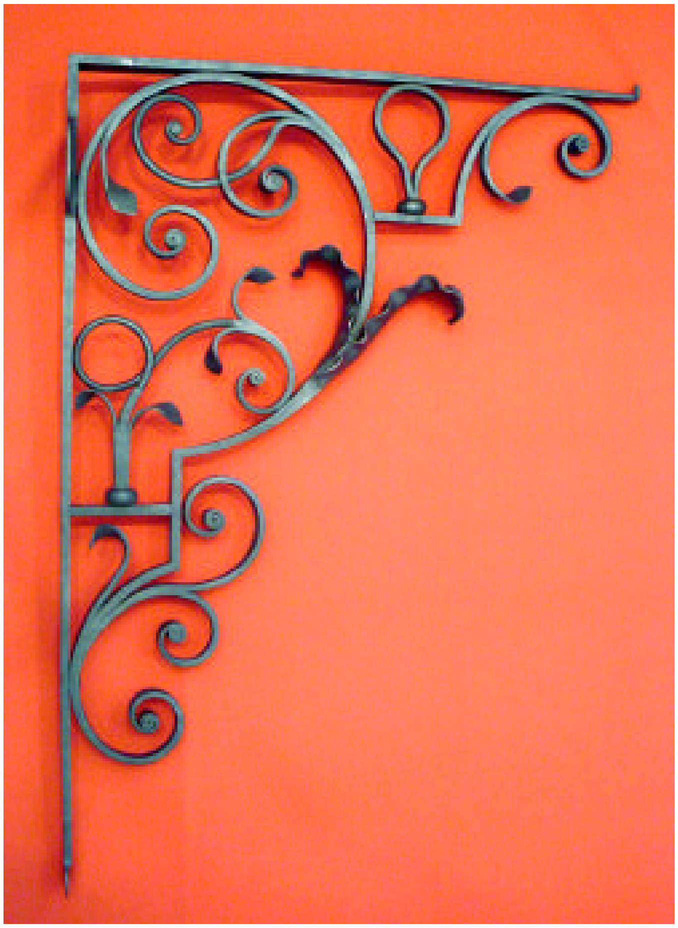


*Table bracket by Jay Close. Every bar was resized from larger stock.*

## by Jay Close

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

**Lesson # 11- Drawing D own- 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.

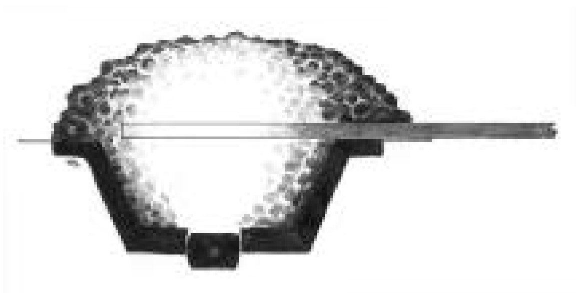
*Method*: The bar is heated in sections and each section resized by hammering flat on the bar face. Each section is finished before moving to the next. Corrections to the bar are carried out as needed. When half of the bar is resized, it is turned end-for-end and the resizing continued from the middle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

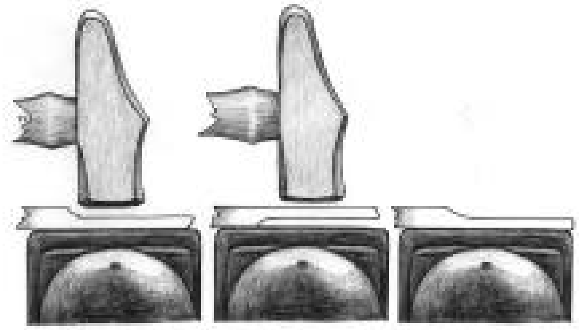
The first blow inevitably creates an offset or step in the bar on one side. Keep the bar horizontal.

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:

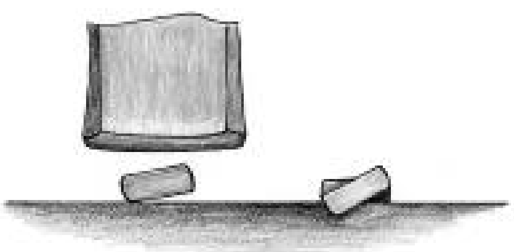
hit HARD on the bar face four or five times.
roll the bar and hit HARD on the opposite face.
forge the edge, dressing it straight.
roll the bar and forge the opposite edge, and repeat as needed.

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*

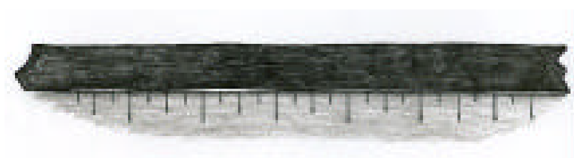
The bar must be straight. Without experience it is difficult to judge this by eye. Use the straightedge as an eye-training tool.

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.

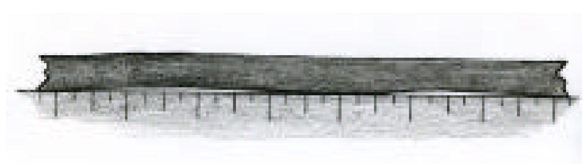
Sometimes the straightedge rocks or pivots on a high spot. If a corresponding low spot exists opposite, then you have identified a bend in the bar.

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.

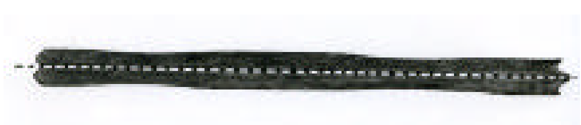
Take note of the width of any gaps between the straightedge and the bar. The eye can see light through an opening as small as a thousandth of an inch. A gap that is more than 4 or 5 thou-



*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.

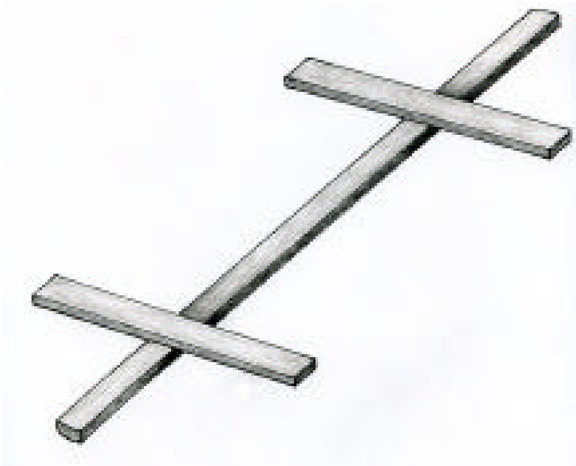
Bends and twists are first cousins. Some bends are localized twists and a twist in the bar can easily deceive the eye into "seeing" a bend. Eliminate twist before doing your final corrections for straightness. The goal is to learn to see twist without aids, but until that time make use of a pair of "winding 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*

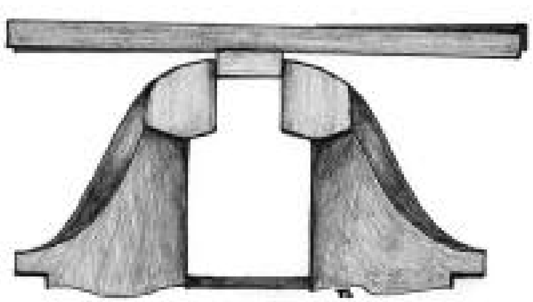
In a simple resizing exercise such as this, you should be able to work to plus or minus 1/64" in width and thickness of the bar. In other words, there could be as much as 1/32" of an inch dif-

*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

**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.

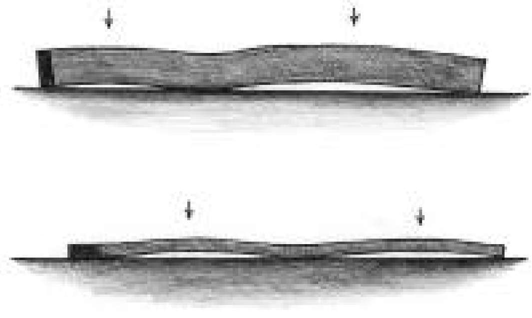
If you have kept the bar relatively straight as you worked it, little additional attention to this is needed at the end of reshaping. That needed attention can be done at room temperature.

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

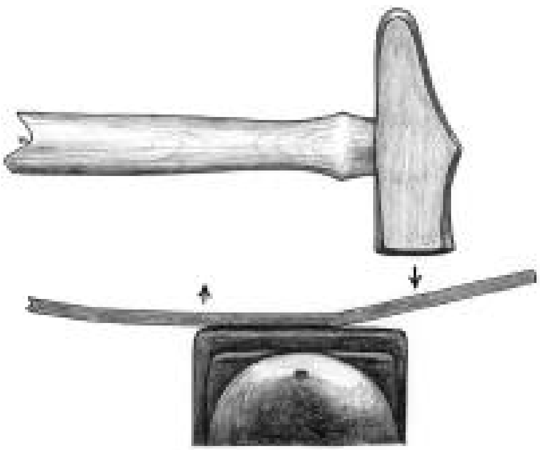
Approach straightening with a strategy. Some work from one end of the bar to the other. Some start in the middle and "chase" any crookedness out to the ends. These approaches work well for subtle correction.

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.



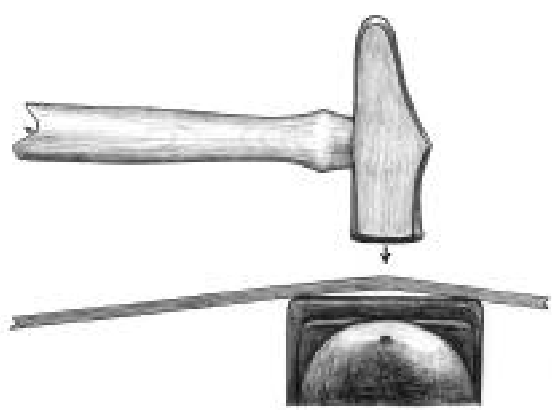
*Areas to address for straightening.*



*Ineffective approach to straightening*

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.



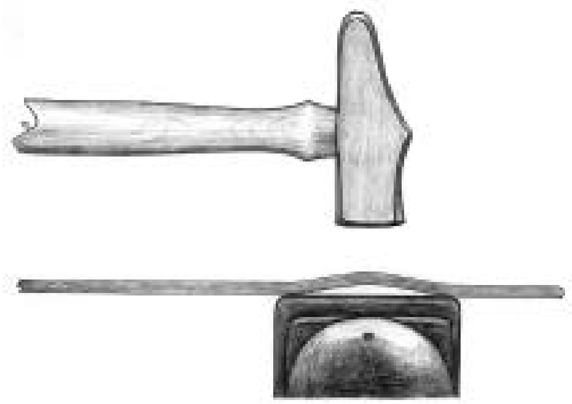
*Proper approach to straightening*

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.

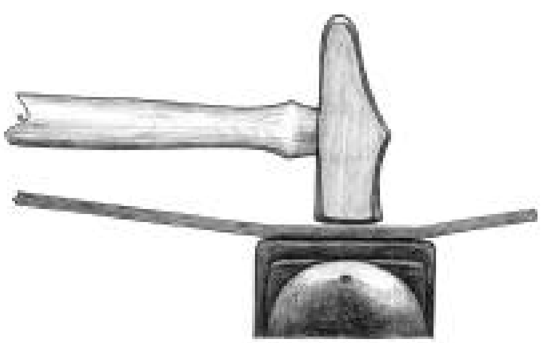
Experiment making your correction different places and orientations on the anvil face. One correction might need to be angled across the face to support a long, gentle curve. A more "spot" correction can be made with a sharp blow over the hardie hole.

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.

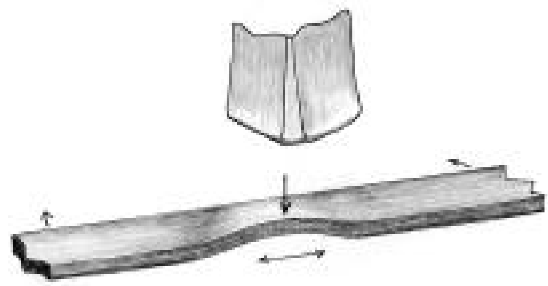
Once the bar is fairly straight along one plane, repeat the straightening on the other. Recheck the bar for straightness and start to work on more subtle problems. To accommodate the inevitable thick and thin places, and wide and narrow areas, keep in mind that the goal is the mass of the bar evenly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

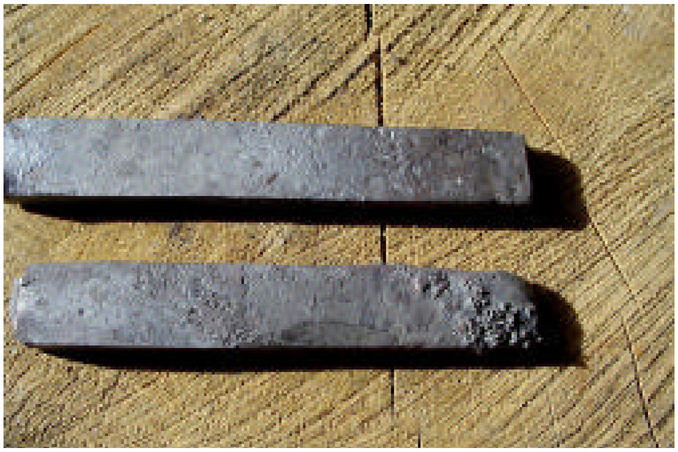


*Photo 12: The bottom bar has been burned. The top bar has been burned then slightly up set and reworked– alas, the damage has been done.*

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–

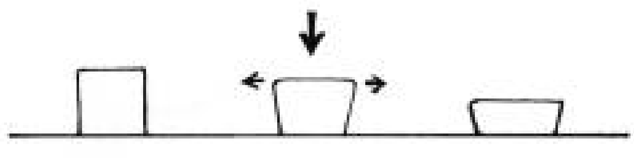
1/2-inch times 1/2-inch equals 1/4-inch

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.*

## *CanIRON V*

Registration is now being accepted for CanIRON V, Annapolis Royal, Nova Scotia, Canada. August 30 - September 2, 2005. Please check out our website at www.caniron.ca for full information. Scheduled participants include:

-Fred Crist, United States - demonstrations/lecture
-Christoph Friedrich, Switzerland - demonstrations/lecture
-David James, United Kingdom - demonstrations/lecture
-Adrian Legge, United Kingdom - teaching station/lecture
-John & Becky Little, Canada - demonstrations/lecture
-Doug Newell, Canada - design workshops
-Henry Pomfret, United Kingdom - teaching station
-Brad Silberberg, United States - demonstrations/lecture
-Kellysmyth, United States - lecture
-Paul & Heiner Zimmermann, Germany - demonstrations/lecture
-Clare Yellin, United States - lecture
-Dark Ages Re-creation Company: Darrell Markewitz, David Cox, Kevin Jarbeau, Canada
-Viking age smelt and interpretation

As well as demonstrations, lectures and workshops there will be a Viking-age smelt and forging competition, outdoor auction, oxen pull, vendor area, virtual gallery, CanIRON gallery exhibit (see below), and a closing night seafood dinner. All in the beautiful coastal community of Annapolis Royal.
(For more information, contact: info@caniron.ca)

## *Ironwork Exhibition Call for Submissions*

In association with the CanIRON V international blacksmithing conference in Annapolis Royal, Nova Scotia, August 30-September 2, 2005, ArtsPlace Gallery in Annapolis Royal will be hosting an exhibition of contemporary ironwork from August 14- September 11, 2005. We are soliciting submissions from all interested blacksmiths who will be attending the conference. Anyone interested in participating in this exhibition must have his/her work (3 pieces maximum) at the ArtsPlace Gallery by August 7, 2005. Please include an artist statement.

ArtsPlace Gallery
P.O. Box 543
Annapolis Royal, NS
B0S 1A0
Canada

We are also hoping to present this exhibition in Halifax, Nova Scotia, in the fall 2005. The venue would be the Mary Black Gallery operated by the Nova Scotia Designer Crafts Council.

For information about the conference see:www.caniron.ca

# Cutting a Bar

## by Dan Nauman

## Illustrations by Doug Wilson

**Lesson #13**

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

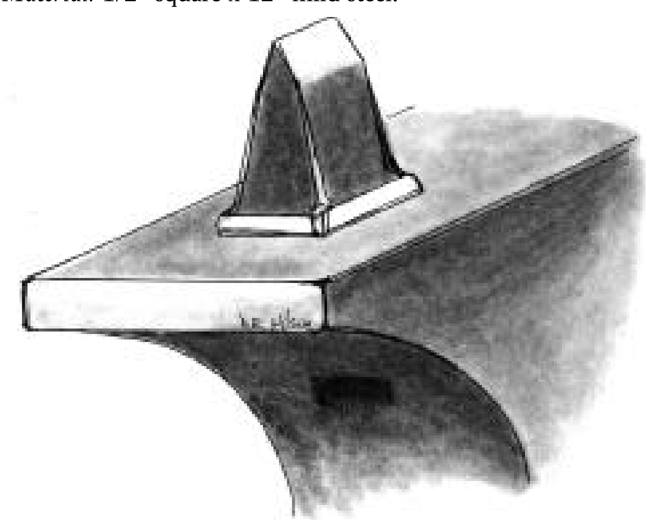
Note: A hot cut hardy has a cutting edge of about 25 to 30 degrees. A cold cut hardy has a cutting edge of about 60 degrees.

*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**

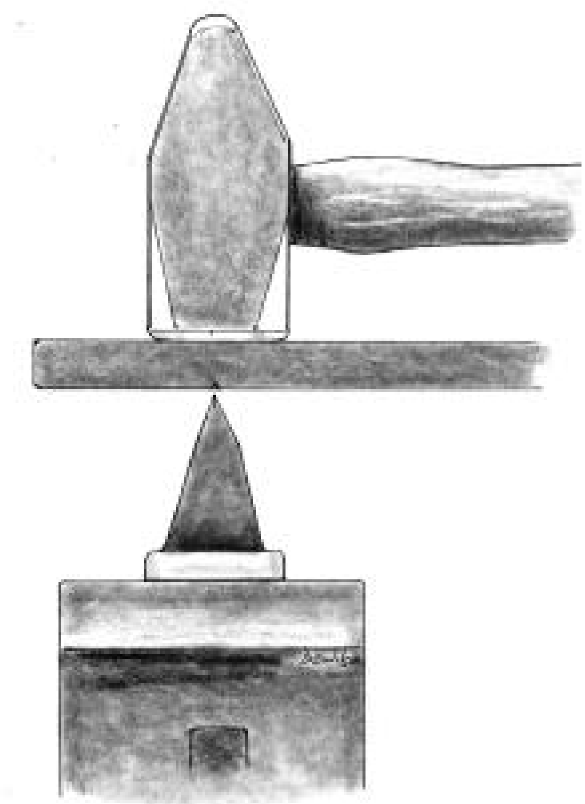
Measure 2" from the end of the bar and mark that distance with soapstone on the bar. Place the cold bar on top of the hot cut hardy edge, with the 2" mark directly above the cutting edge. Turn the bar up onto its corner, With your hammer, strike the bar down onto the hardy, hard enough to make a good 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.

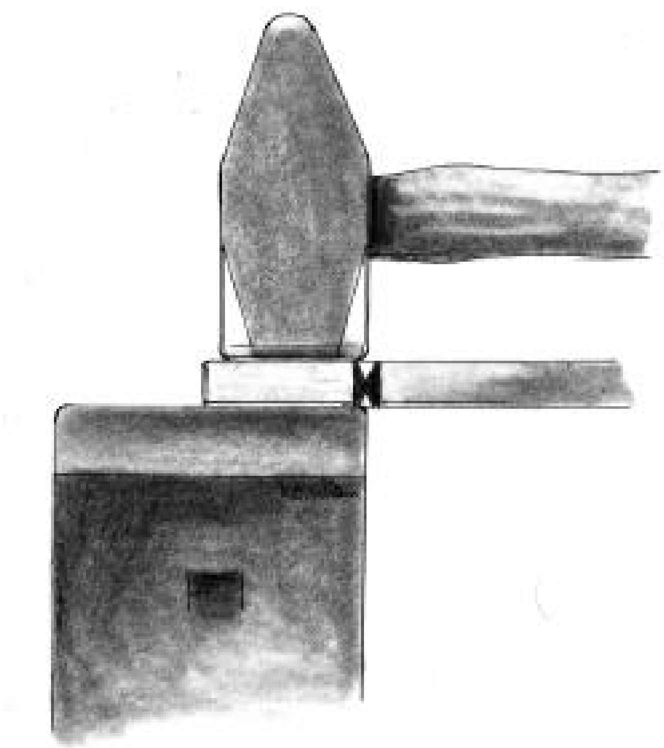
Turn the bar 45 degrees (right or left), and strike again lightly to mark the corner. Continue to turn the bar in the same direction to mark the next face with a sharp blow.

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.

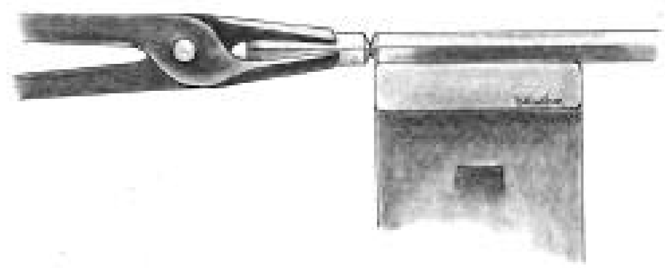


*Weighting one end of the bar with the hammer to twist the bar.*

**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:*

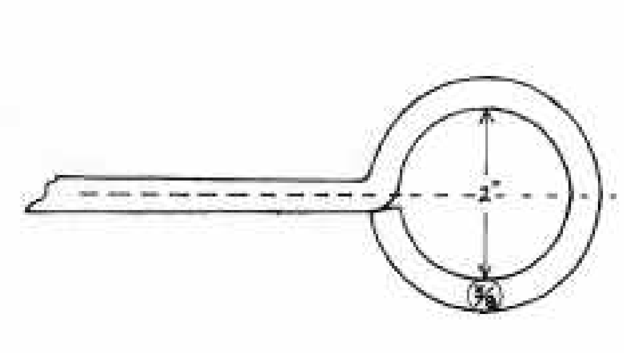
Some alternatives to nicking the bar on the hardy to mark where the bar is to be cut:

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, soap-stone, 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 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 $\pi$ = 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 $\pi$ 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.

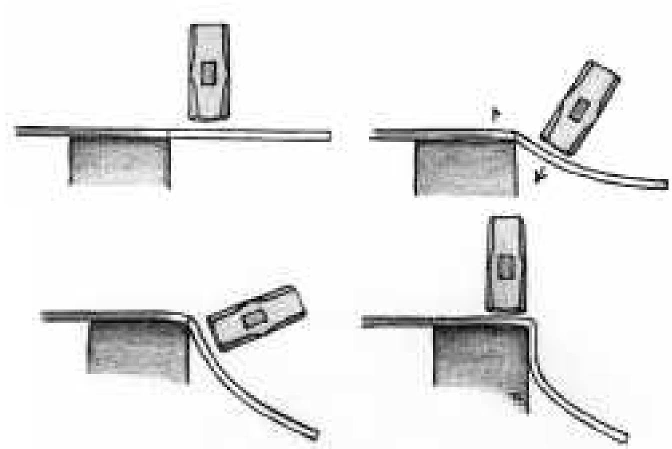
**Step Two**

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.

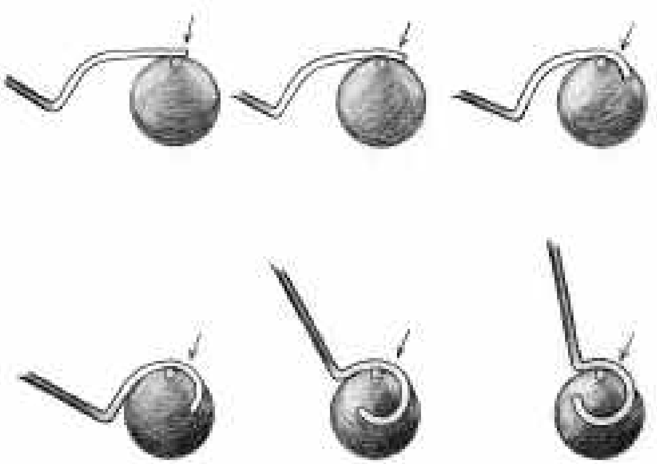
Flip the bar over with the bent portion pointing up.

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



*Progressive bends form the eye.*

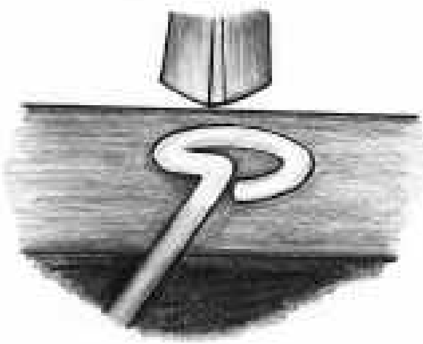
Two.

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.

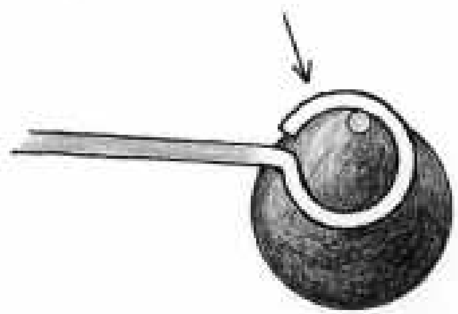
Sometimes the eye seems to spiral like a coil. Pay attention to how it contacts the horn and how you hit it. Remove the coil effect with a flattening blow or two on the anvil face.

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



*Returning the eye to the proper plane.*



*Eye flipped to an area of insufficient bend.*

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.

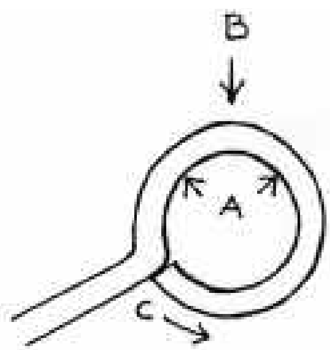
Note- Making such a bend is really a matter of approximations and on-going corrections.

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

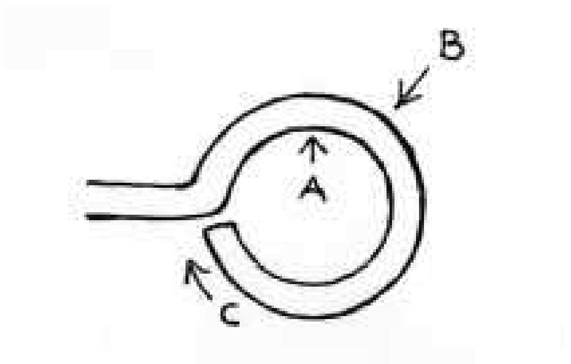



*Opening a kink– eye contacts horn at points A, struck at point B, resulting in movement at C.*

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.



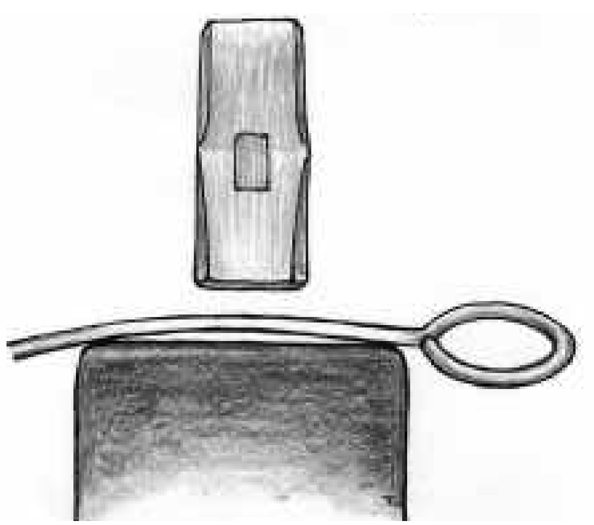

*Removing a flat spot– eye contacts horn at point A, struck at point B, resulting in movement at C.*

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.

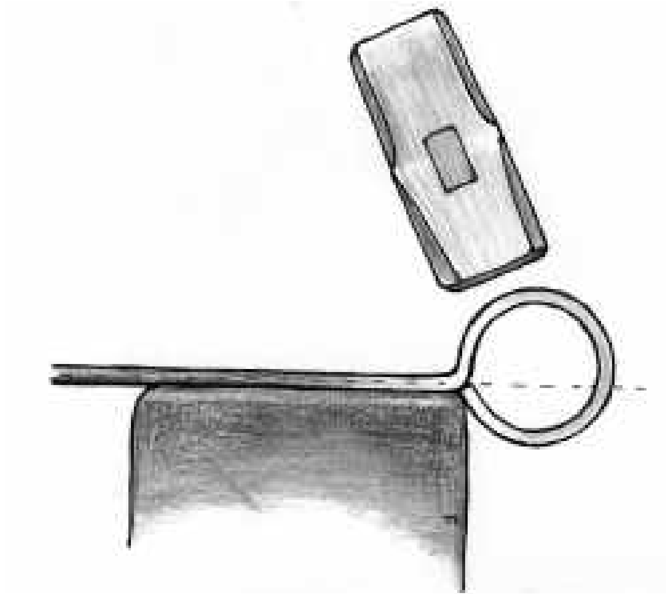
-The handle and its alignment with the eye may need correction. If so, first straighten the handle so you can accurately read its



*Straightening the "handle" portion of the bar.*

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.

-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



*Aligning the eye to be centered on the bar.*

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.

**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.