

Drawing a Round Taper

By Jay Close

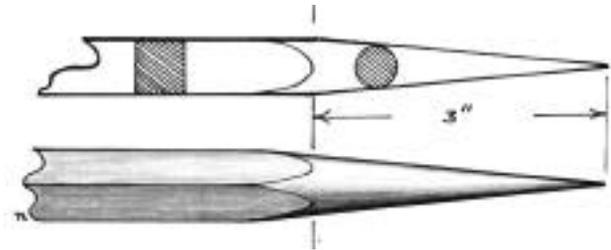
Illustrations by Tom Latané

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.

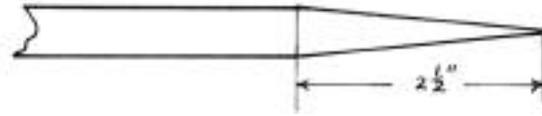
Starting at a yellow or light welding heat, forge a square taper on the end of the 1/2 inch square bar. This taper should be 2 and 1/2 inches long and hammered to a sharp point.

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



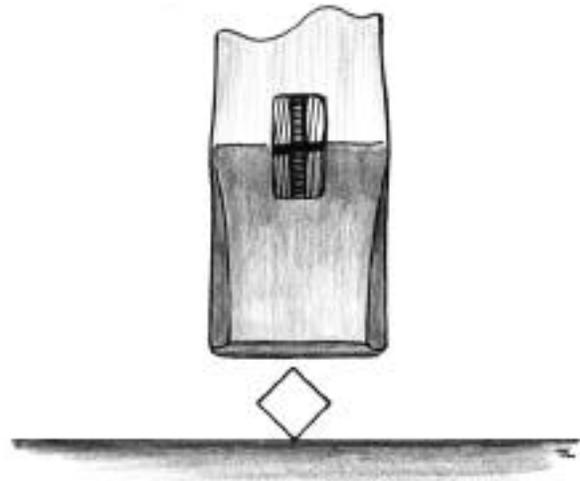
2. Needed straight taper and dimensions.

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.”



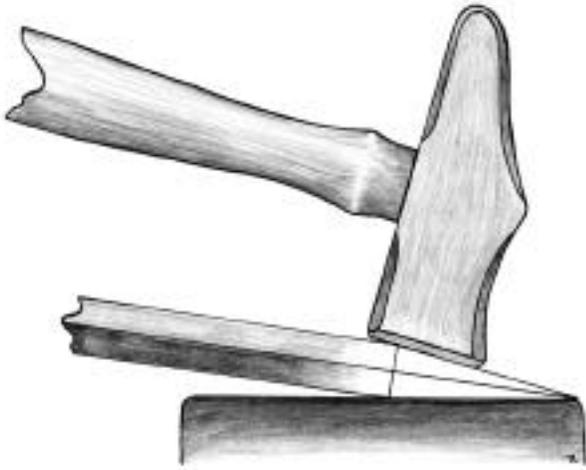
3. Corner up position.

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 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]

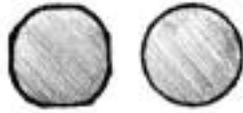
Go back and hammer down these rounded corners as facets once more. Then forge down the new corners before rolling and rounding.

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 "sugarish 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 facets before achieving a round:

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

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

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

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

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

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

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

.785 inches

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

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

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

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

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

Bending

By Jay Close

Illustrations by Tom Latané

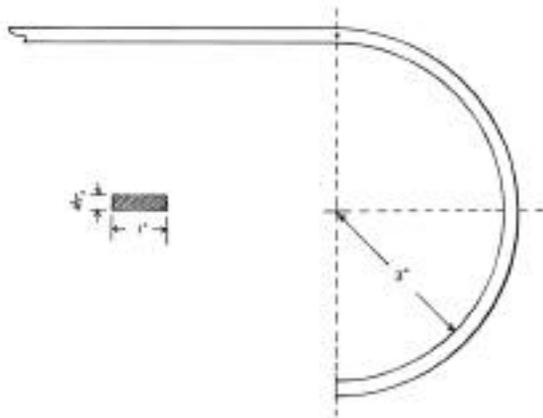
Lesson Number Four- Bending

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

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

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

Intent: The student will practice calculating the bar stock needed



1. Dimensions of the finished forging.

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

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

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

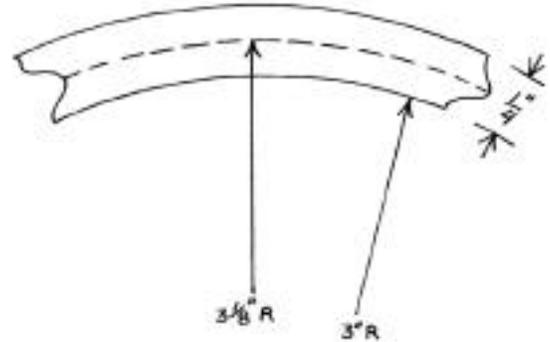
Method: After calculating the needed material to make the bend, the curve is produced by using the horn as a bending point or fulcrum. Shifting the location of the bar on the horn and changing where and how hard the bar is struck controls the needed curve.

Step One:

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

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

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



2. Material needed.

of dimensions, simple geometry yields an accurate result.

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

bar length needed = pi times radius

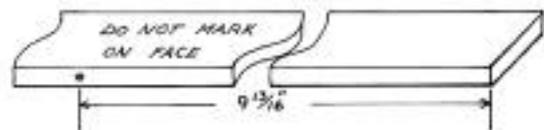
bar length needed = 3.14 times 3.125 inches or 3 and 1/8 inches

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

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

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

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



3. Material layout.

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

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

CONTROLLED HAND FORGING

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.

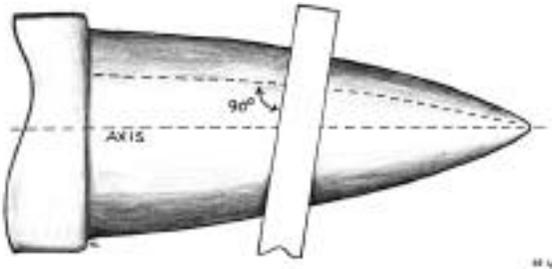
Step Two:

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 bar is unsupported by the anvil. These are also areas for experimentation.

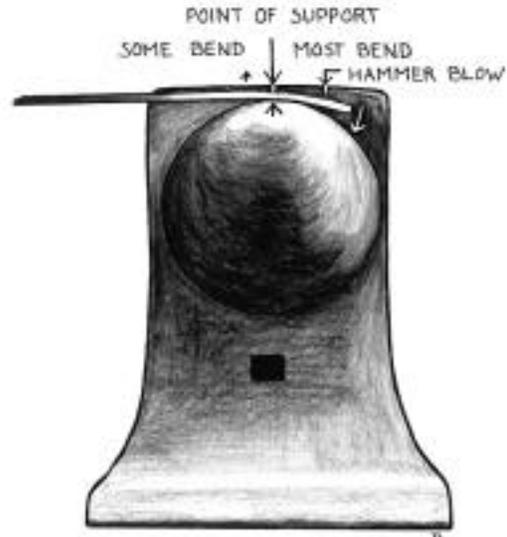
Get this first part of the curve well bent. It is often easier to straighten it later than introduce more curve.

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.

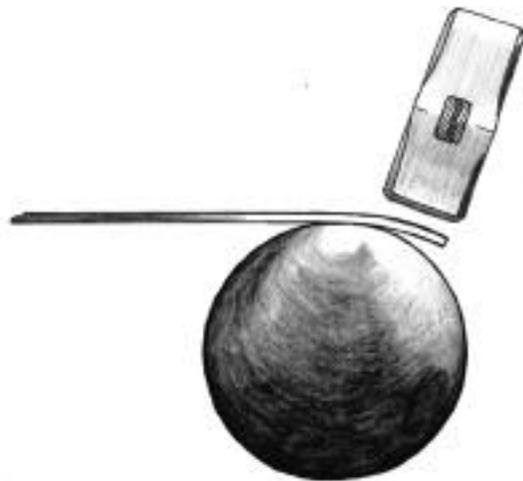
HINTS:

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.

CONTROLLED HAND FORGING

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.

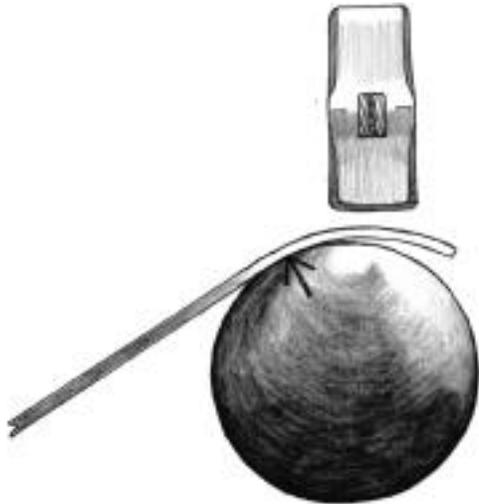
A hard blow at a high heat close to the anvil horn with a small amount of the bar unsupported will result in the tightest bend.

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 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.

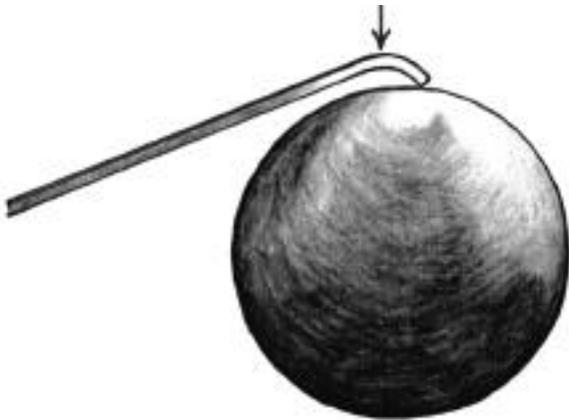
b) An under bent end of the bar, if caught soon, can be corrected by placing the end of the bar on top of the horn, lowering the holding hand down and hitting down to tighten the bend. (See drawing #7)

CONTROLLED HAND FORGING

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.



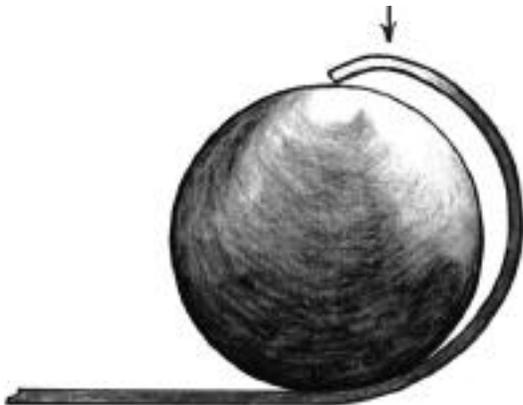
9. Straightening an overbent bar.

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 it meets the punched layout it should also hit the end of the bend.



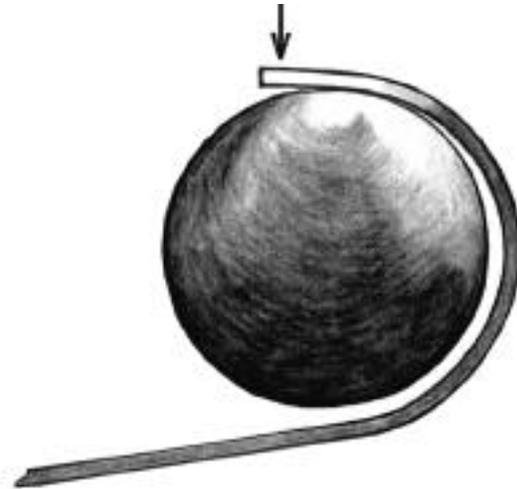
10. Another way to straighten an overbent end.

The straight section should remain straight

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

Forging Dynamics:

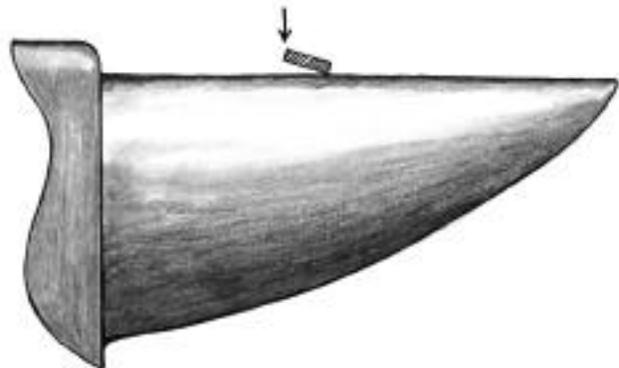
The hotter the bar, the softer it is. Therefore, the more shape change that will result when a given hammer blow is applied. In bending we apply a force to change the axis of a bar. By supporting the bar at a given point on the horn we concentrate the effect of our hammer blow to a certain length of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



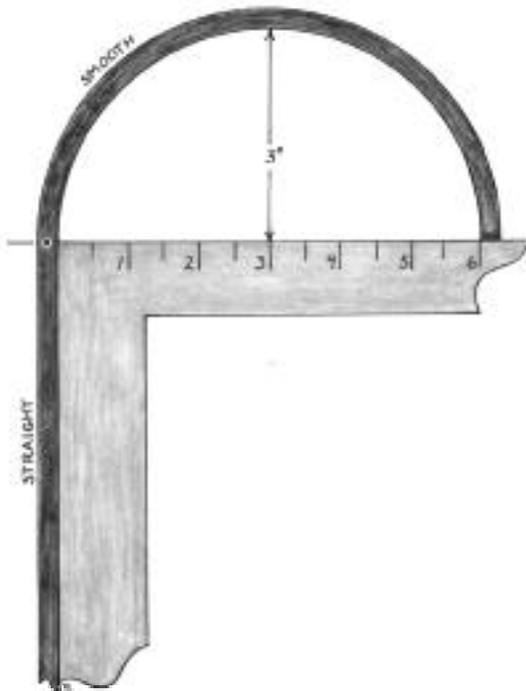
12. Correcting a spiral

CONTROLLED HAND FORGING

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.

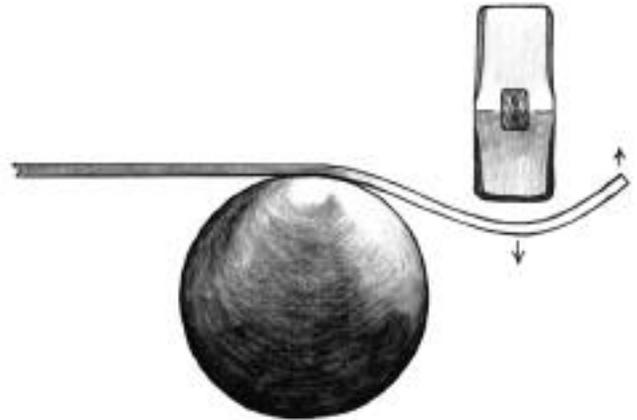
When calculating material needs for a bend of a specified radius, if you figure the lineal requirements using the outside radius, you will have too much material. If you use the inside radius you will end up short. The central axis of the bar will remain unchanged in a bend or twist, therefore, do your 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 outside. 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

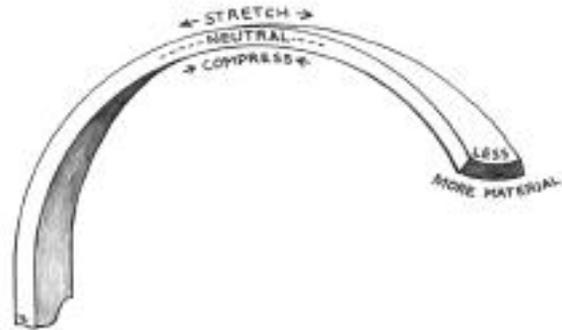
to a crack or split. In no case should you mark the face of the bar either inside or outside of a bend. Both situations, by disrupting the unbroken, bar surface will result in the concentration of



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.