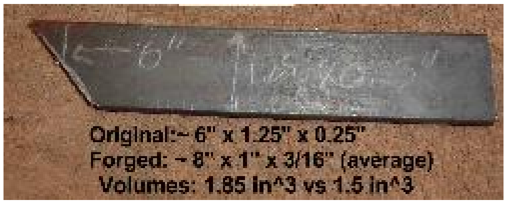
Forging & Grinding a Full Tang Blade the Ironflower Way

There are two schools of blade making – forging and stock removal. Forging is usually estimated as 10 times as fast as just grinding but there is LOTS more opportunity to foul up. The essential tools for forging are a forge (gas preferably), one or more hammers and an anvil. Cutler hammers as shown tend to decrease digs, so that's a good thing. A decent blade smith anvil is REALLY nice. And (taking a hint from the Japanese sword makers), a tub of water with baking soda in it (to cut rust) is highly recommended.

The first critical decision is the steel type. What is being used here is 5160, a nice friendly steel but any high-carbon forgeable steel is ok (L6, O1, 1095, 52100, etc.). You will want a bar slightly larger than the desired final dimensions. In this case, it's 1.25" x 0.25" while aiming for a 1" x 3/16" blade. Note the diagonal mark.



Why forge the corner back into the body to make the tip when a diagonal cut does most of the work? As shown, the blank has 1.85 in3 of volume and the projected blade needs only 1.5 in3, so there is ample "meat" for our purposes.

You can saw out the blank anyway you want but a horizontal metal cutting band saw and a pair of Vise-Grips makes this a snap. Since a nice look at the end of the tang is also a slant, you can saw out trapezoids and minimize stock waste as well as save some time at the anvil.

It is always a good idea to sketch out what you want to make to get the dimensions in the right ball park. Since a paper pattern tends to have problems when a blank at forging temperature is brought too near, cutting a pattern out of light sheet steel is not a bad approach. If you do this repeatedly, you'll eventually have a wall of patterns. In this case, the pattern was chosen to insure that the tang would be long enough for a big hand.

The first step is to delineate the break between the tang and the blade proper. For this exercise a point a near the middle is needed. You can use the edge of the anvil as shown (note – tip is in the tongs) to forge in a 900 angle. What we would like is something like a 450 to 600 depression, so the anvil is not really optimal. The edge of the depression on the blade side ought to be perpendicular to the eventual edge, but that's not possible. As the hammer blows strike towards the corner of the anvil, the tong hand is slowly brought up to drift the depression in the direction we want.

In this case, the depression is barely a suggestion. This technique works but has two drawbacks – the actual angle of the depression to the blade is not optimal and the spine of the blade will have been pushed down towards the depression – something that will have to be corrected later. There is a better solution if you happen to have available…

A treadle hammer, a striker, or a fuller. As shown, a piece of round stock is simply beaten into the blade at the delineation point. It doesn't (and actually shouldn't) have to be more than 0.5" deep.

When we are done, you get something like what is shown in the image to the right.

We can now do a preliminary shaping on the tang. The tang is placed on the anvil with the tong hand down enough to "catch" the depression on the edge of the anvil. Strike at the spine of the tong to "spread" the depression out. Do not worry about the fact that the narrowing of the tang as it meets the blade is far too fat. This is a good thing. The blade end won't flop around excessively when

you forge it because there isn't enough meat at the junction of tang and blade. We will thin it out later.

What you can do at this stage is to introduce a bit of taper in the tang and flatten it out. So what you get is something like….

this. Flip the blank around and start heating the blade section.

First, beat in the angle formed by the diagonal cut and the edge (Ok, we missed that picture, so live with it). The metal will thicken at the angle, so flip it on the side and push it back to the original thickness. Repeat until you like the curve from the main part of the edge to the tip. You now have a profile established.

Find a corner of the anvil and position the back "corner" of the blade over it. You can now stretch out the metal on the blade side of the delineation and move the angle closer to the 900 we wanted in the first place. Position the edge close to the edge of the anvil and start forging the bevel. In the image, I'm working the bevel around to the tip, so the blade has been angled to place the tip near the edge. This means you hit the hot steel and not the anvil. If there is sufficient heat, flip the blade over and repeat on the other side.

As you heat and reheat the blade, alternate the side that is initially up and try to work both sides equally (more effort will be needed on the cooler side to move the steel the same amount as was moved when it was just out of the fire). DO NOT work the steel below a red heat – it isn't good for it or you. You can work it very hot (NO – not sparking!). We'll take care of grain problems later. Your hammer ought to be sitting in the tub of water. As you come to the anvil and pick up the hammer, splash some of the water on the face of the anvil. As the steel contacts the water, the scale will tend to be blown off and you end up not driving scale into the steel. The result is that your steel will be significantly smoother for the price of a slightly cooler blade.

As the bevels form, the steel on the edge thins and will begin to cool faster than the spine (as shown to the right). You also have to be constantly adjusting the angle you hold the tongs such that the bevel is in contact with the anvil. If you hold the blade flat to the anvil, all you will be doing is chasing the bevel back and forth relative to the spine of the blade. Now, since the steel is expanding on the edge, the spine will begin to "hook" backwards. We could have hammered in a counter curve initially but that is not really necessary. Since the edge will be a whole lot cooler than the spine when you decide the edge is too cold to forge….

Flip the blade edge up and across the flat of the anvil. Hammer straight down onto the edge. Yes, it will deform but the spine will begin to straighten. If the blade is too cool to move much, just stop working on the edge a bit sooner and then follow this procedure. You want to keep an eye on the degree of "hook" and correct it when it looks like there is maybe a quarter inch or so of air.

This image shows the result of the "hook" – a curved spine. If you are making a skinner, this may be a good thing, but for us, we want the curve to go away.

So start hitting it on the edge as shown. When the spine actually starts to contact the anvil's face, the sound will change to a dull thwack – that's the signal to move to another location on the edge.

Here you can see that there is some deformation on the edge but the spine is getting close to being where it should be.

The result is a reasonably straight spine – no, not yours – the blades.

Eventually, the spine will be straight and will "thump" along its length when the edge is struck. As you can see in this image, the spine is ok again and the heat distribution between spine and edge is obvious. As you continue to forge the bevels, continue to straighten the blade as needed. Guess what technique is absolutely critical when forging a single-edged sword like a katana….

A secondary method to fixing the curve is to forge the spine near the tip and gradually decrease the amount of forging as you work back to the tang. What you are doing is simply expanding the metal at the spine and thus pushing the "hook" back. You are also messing up the bevel to some degree. Go lightly, keep the spine and edge in the correct relationships – you are not forging a chisel, so keep the edge centered on the spine throughout the length of the blade. Remember to alter the tong hand to keep the surface you want to work on in contact with the face of the anvil.

There is nothing special about the spine. You can place the edge in contact with the anvil and hit the spine to clean up hammer marks and level the spine. You can also work the tip as shown to correct the hook or to create a drop point or clip.

So…just repeat all of this until the shape, size, and finish are what you want. Don't obsess over finish at this stage – we will be coming back to the blade in a few minutes.

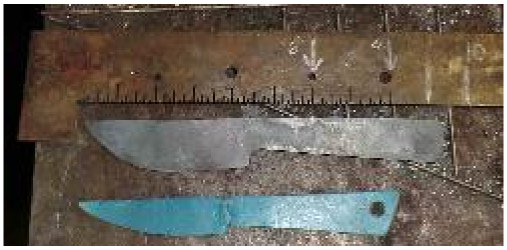
When the rough forging is completed on the blade, there ought to be an obvious taper from tip to tang as shown.

The center line of the blade also ought to be the same between the tang and the spine. As you can see here, there is a good taper but the blade is not centered. Not to worry – we'll fix that later. If you have a vise available, it's a good tool to test how well the blade is centered. You clamp the blade and check that there is about the same amount of air showing along the sides of either the tang and/or blade depending which you are checking. Or, you can hold the knife up to a decent light and sight down the length. Either way works, but it's still too early to worry about this.

What we now have is a rough blade (note – there is still a small amount of curve present), and it's time to work on the tang. The tang can be forged with a top-to-bottom taper (simplifies some grinding and improves balance while complicating fit-&-finish) or left quasi-rectangular in cross-section. It should taper from the blade to the tip.

Here the tang before significant forging is compared to the model. The tang is shorter than the model's tang.

After forging, it is longer. Note that while we started with 6” of stock, the rough forged knife is now approximately 9.5” long. This is one of the reasons I like to forge blades. Once the tang is done, so back and make a final pass on the blade. Clean up hammer marks (switching to a lighter hammer helps here), correct any problems of the bevels not being centered, and check and correct the taper of the spine relative to the center line.



This image is the spine of the knife showing the tang and blade are both tapered (and aligned as described above).

From the bottom, you can see that the blade is wedge shaped while the tang is more rectangular in cross-section.

This oblique image highlights the difference.

One feature I like to have on my knives is a drop-handle. They are easy – heat the blade and clamp in a vise as shown.

A couple of taps on the back corner of the tang drops the tang a touch and makes the blade feel better in the hand (IMHO).

The more dings in the tang, the more work in the fit-&-finish. If you have a treadle hammer and a flatter, use them. It pays off in the long run. Remember that if you do the drop handle and/or use a flatter, make sure the blade and tang are still in line and that the tapers are symmetrical to their center lines.

Grain structure is a serious concern. Large grain means weak steel. Grain grows as a function of time above critical temperature (anything usually over 15000 F but that depends on the steel alloy) and the actual excess temperature. Temperature is far worse than time, so by the end of the forging, the grain structure in your knife is pathetic. It's even worse for Damascus (2600-28000 F versus maybe 20000 F). The solution is heat-cycling or normalization. We will do this during the heat treat but there is no reason not to do it now. Run the blade up to critical temperature (the old "does a magnet stick" trick is a good way to train your eye to the correct color), then let it air cool until there is no visible color (about 10000 F). Every time this is done, the grain is reduced. After three repetitions, there is typically no more to be gained.

The last step is to anneal the blade. Run it back up to critical and then bury it in either wood ash (here in an old ammo container) or

Vermiculite (here in a cannon shell casing – got to love military surplus!). In either case, let it rest for at least an hour or more (until cool to the touch). You can also use an electrical digitally programmable oven (like a Paragon) and run a typical 13 hour program. For most of us, the ash or vermiculite is sufficient. On occasion, when dealing with O1, the industrial process may be required.

When you dig the knife out of the annealing solution, there will be a crust of carbides as well as the hammer marks you left covering the surface. Grinder belts are expensive, disks for a side-grinder are cheap, so buzz off the surfaces before starting to grind. In this image, there is a poor-man's mag chuck – a couple of big speaker magnets bolted to a section of angle iron. Drop the blade on, and grind away. Flip it over (and don't burn your fingers) and do the other side. There is a critical principal that applies here and to all other grinding (no – you ought to have those safety glasses and ear plugs in place already), the "marks" are canyons. You do not grind the canyons, you grind away all the high lands around the canyons until the surrounding surface is at the level of the bottom of the canyons. If you "dig in" to remove a mark, all you are doing is deepening the canyon and creating more work eventually. So, DO NOT do this! Buzz off the surface and don't obsess at this point.

Eventually, you'll have something like the blade in the image. It is not smooth but the crust has been removed and the surfaces have been knocked down a bit.

The next stage is to profile the blade. I typically follow the sequence shown – first the spine over the blade, then the spine over the tang (blending them as needed), then the edge, and finally the bottom and end of the tang. You are going for a surface at more or less right angles to the sides of the blade and tang.

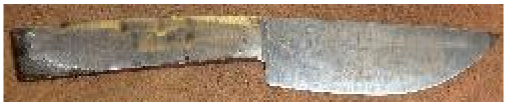
What is normally used is a 2x72 belt grinder. The unit shown here is a variable speed, 4-statiion grinder with a 1.5hp 3-phase motor controlled by a variable frequency drive (VFD). Commercial versions of these run about $2500 to $3000 or more. This one is a home-made unit and cost about $900. To do most of the grinding, you want to use a flat platen. It's nice to have a dust removal system (that's the aluminum tube with rubber ball under the grinder) or mask, safety glasses, and a dunk tank. The tank is not optional. This grinder can run from 0 to 3600 rpm and for most grinding, it is set at 2400 rpm. The belt shown is a 36-grit ceramic belt. Don't bother with aluminum oxide belts for grinding metal – ceramic is the way to go.

Grinding makes the blade hot – the older the belt, the hotter they get. In general, WAY too hot to hold. So….buy a magnet. The one shown here is a "Mighty Mag" base (useenco.com TM625-0440 $12 on sale). You can support the portion in contact with the belt with fingers on the magnet and with the other hand on the section not being ground. In some cases, having two magnets makes life easier, so live big and buy two. With proper lighting, you can look down on the belt (as shown) or even look at it from the back edge – useful for checking plunge cuts. You can use a steady rest – basically a table that bolts to the grinder – to control the angle at which the blade hits the belt. For most grinding, it is not really needed.

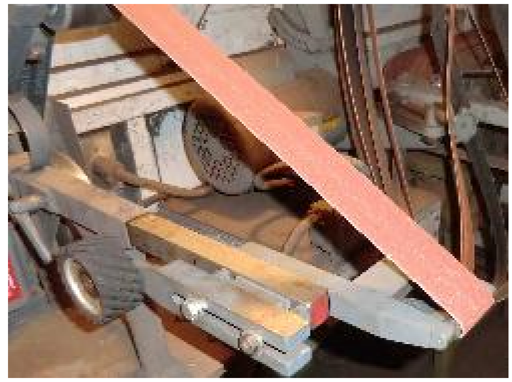
There is nothing sacred about the angle the blade makes to the belt. You can grind horizontally as shown in the previous image or vertically as shown here. In fact, by altering the grind angle a bit, you can spot areas needing grinding as you move from coarse to finer belts. Since you have forged in the bevels, that is where we start. The edge is always up, and the left side of the blade is ground with the tang to the right. The magnet is in your left hand and the tang in your right. Try to keep the blade parallel to the belt. You push the assembly towards the grinder and start making sparks. It is very easy to push more with the magnet hand and less with the tang hand. This will create a taper towards the tip, so just be aware of the problem. If your tang-to-blade transition is to be a cliff-face (the infamous plunge-cut), you have to first set the cliff-face by positioning that point just off the edge of the belt, then with the tang hand closer to the grinder, make contact and let the belt edge create the cliff. This is tricky, so practice on scrap first! Whatever you push on hardest will go away first. Keep dunking the blade and magnet when ever them seem too hot – usually every 30 seconds or so. Get use to wet boots.

Keep the blade moving over the belt. Adjust the spine to edge taper by changing the relative pressures (the magnet makes this way easier) Your goal is to have a flat surface from the tang to the tip, spine to edge. Eventually you will be done or give up. Typically, if doing a plunge cut, you will have the situation shown here. The "steps" are created by grinding the bevels such that the width of the blade's spine at the blade-tang junction is less than the width of the tang (which has yet to be ground). All of this assumes that the blade cross-section is a wedge. There are other profiles – multi-faceted, hollow ground, etc. I happen to think that the wedge is optimal in that the weight is minimized while strength is preserved. It especially works well for Damascus.

The tang is then ground – either in a taper spine-to-bottom or a quasi-rectangle. You want the sides to be flat and symmetrical side-to-side.



To clean up the integral finger guard (that's the ragged back of the blade as it meets the tang's bottom surface), we can use a round file, the broken edge of a flat platen, or the fork wheel (as shown here). The fork wheel is a 2" wide, 0.5" diameter contact wheel with very tiny bearings. Those bearings go away if the wheel turns at too fast a speed.



So, we turn the speed down to something like 900 rpm. This is one of the great things about having a variable speed grinder. So, set the speed, place the fork wheel arm in place and tension the belt. Turn on the grinder and approach the wheel with the blade held vertically, point up and the sides perpendicular to the wheel. Ease forward and make contact. If you look at the previous image, the upper belt surface runs at an angle to the floor, so the blade will generally be held with the tang end closer to the grinder than the point. Grind until all the forge marks are gone and you like the shape.

It ought to look something like this. Note the slight bite taken out of the bottom of the tang (just to the rear of the plunge cut). Put the 4-sttaion head back on the grinder and give the bottom of the tang a lick or two to remove metal so that the bottom of the tang smoothly meets the top of the curve left by the fork wheel.

It's now time to locate the pins that will hold the scales to the tang. I like to use 5 pins (4 to hold and one for the mosaic pin). I eyeball the location of the first and last pins. You want these about ½" to ¾" back from the end of the tang and the plunge cut. Too close and the pins will be ovals due to shaping the scales. Too close to the center and the scales are not well supported. The other pins need to be equally spaced between the first two. You can measure, use dividers, or cheat using a printed aid like the one shown. Mark the locations.

You also want the pins to be in line and centered on the tang. You can (as above) use measurement, dividers, or -- you're right-- another toy – a center scribe. The scribe is simply two pins inset into a block with a pointed pin just showing above the surface of the block and exactly half way between the flanking pins. I find it convenient to place the tool in a vise as shown.

Lay the blade between the flanking pins and draw the blade between then while maintaining downward pressure. In this image, the spine is being pressed to the left pin, it is drawn forward, and makes a counter-clockwise movement. To compensate for the asymmetry of the profile of the tang,

you can shift the pressure to the other pin and draw it again. What you get is

a scribed line. Use a center punch to mark the locations of the holes. If there are two scribed lines, just split the difference when making the punch marks.

Drill the holes on the drill press. The holes need to be a touch bigger than the pin stock, so here they are made with a #30 drill bit (0.128") for use with 1/8" stock. Remember to compensate for the tapers spine-to-bottom, front-to-back when locking the tang in the drill press vise. The image here shows the balance point is about right, the holes are done, and the tang surface needs a touch more grinding (the little extension of the cliff wall forward onto the blade surface).

Finally, we can look at the dimensions. The lengths are 4.375” and 4.75” for blade and tang respectively. Relative to the thicknesses at the buzz-off to the end of the rough grind, the tip went from 0.125” to 0.098”, the edge from 0.128” to 0.045”, the spine at the start of the tang went from 0.288” to 0.149” and the end of the tang dropped from ~0.120” to ~ 0.10”. So, there was a loss of near 30% due to grinding. This is why you should not be too concerned if the blade seems a bit chunky when the forging is finished. The general rule holds – it is a lot easier to remove than add material.   Time wise, there is something like 15 minutes in the forging and a little bit more than that in the grinding. The next step is the heat treat.