Improving the Horizontal Position[1] Accuracy of a 4 x 6 Horizontal/Vertical Bandsaw, Version 1.1

By R. G. Sparber

Background

Almost anything you need to know about the 4 x 6 Horizontal/Vertical bandsaw can be found on the 4x6bandsaw group located at groups.io. My education was greatly improved through several conversations with John Vreede, a leading expert on this machine. John is a member of this group and generously offered his insights. John, I am exceedingly grateful for your help.

Scope

I have two audiences. The first group just wants to get their saw to cut more accurately. Then we have the group that must be convinced the effort will pay off. They want to know the theory behind the procedure.

I am not addressing how to run the saw. Blade speed, feedrate, and wear on the blade all affect accuracy. I'll leave that topic for another day.

[1] When this saw is in the vertical position, precise cuts depend on erecting a fence that is parallel to the saw cut[1]. One way to do this can be found at https://rick.sparber.org/FenceAlignmentTool.pdf

Contents

Be Reasonable!

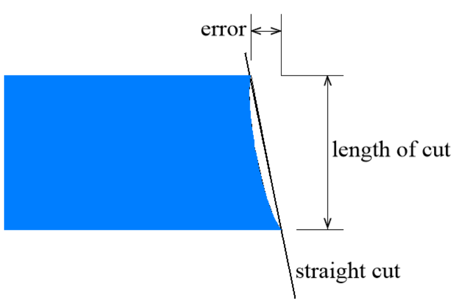
Your 4x6 costs a lot less than a commercial saw. The main reason for this is that these saws are, essentially, a partially completed kit. Their accuracy can be significantly improved, but be prepared to do some re-machining.

These saws are adjustable. Too adjustable. Some suggested modifications will limit adjustability, so they become more predictable. These changes are optional but will help you avoid frustration as you chase your desired accuracy.

If your saw is heavily worn, you may find that various errors change from cut to cut. This will limit how accurately you can set up the saw.

Accuracy

It is all about *your* expectations.



At one extreme, you may expect the saw to reliably cut in a straight line with an error of less than ± 0.0005-inches per inch of cut. Or, maybe you would be happy if it could do ± 0.05-inches per inch of cut and wander a little from straight.

The smaller the error, the larger the effort that will be needed to both align your saw and operate it. My goal is to help you achieve an error of less than ± 0.002-inches per inch of cut. Deviation from a straight cut is less than 0.003-inches.

Measurement Tools

- Two 1-2-3 block.
- A machinist square at least 4-inches by 4-inches.
- A selection of shims.

All other tools will be assembled from bits of scrap metal.

Consumables

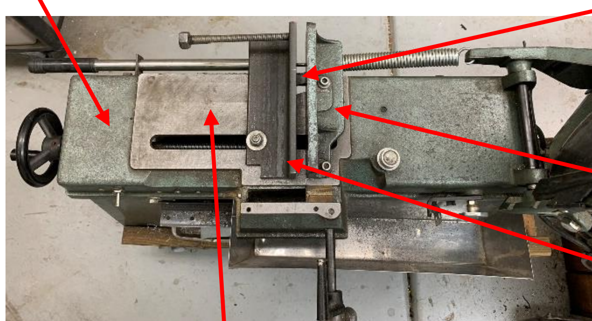
- A 1 x 4 S4S pine joinery timber about 1-foot long. An alternate is a 2 x 4 softwood construction lumber.
- 5/8-inch thick 4-inches wide at least 6-inches long piece of mild steel
- ¾ x ¾ x 6-inch bar of mild steel. Cold rolled is preferred.
- 1/8-inch thick mild steel plate. See page 16.
- Misc. screws.

Nomenclature

Naming the parts of the 4 x 6 is essential to any discussion. My goal was to choose names that are descriptive, short, and memorable.

Frame – it carries the **saw blade**, **drive wheel**, and **idler wheel**.

Base – it sits on the floor and supports the rest of the saw



Vise – holds the stock to be cut. It consists of a **fixed jaw** and a **movable jaw**[3].

The vise sits on the **vise table**, a machined surface on the top of the base.

[3] This is a custom movable jaw.

Pivot Shaft – it turns in journals that are part of the base.

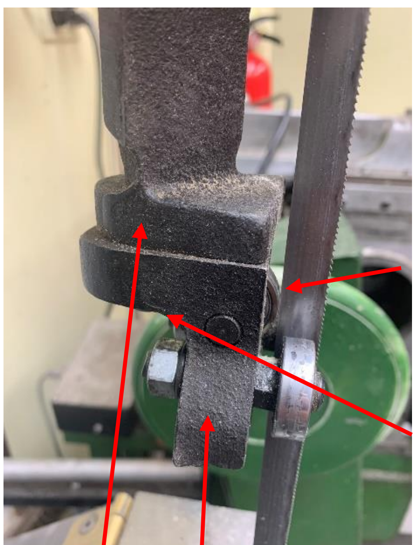
The left end of the pivot shaft is captured by the **support arm**.

The **Upper Blade Guide Assembly**

consists of the

inner guide wheel and the

outer guide wheel.



This side view reveals the

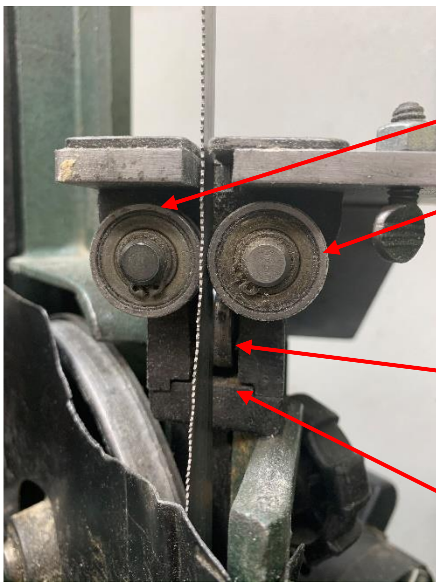
back support wheel and the

blade twist adjustment (a locking bolt is behind the back support wheel)

The blade moves from top to bottom in these pictures.

These three wheels are held within the **guide wheel carrier** and is bolted to the **blade guide bar**.

The Lower Blade Guide Assembly



consists of the

inner guide wheel**,** the

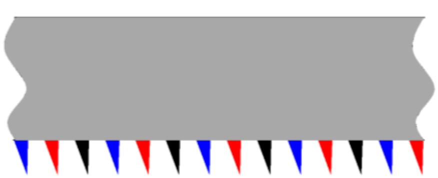
outer guide wheel,

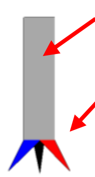
and the
back support wheel**.**

You can see a front view of the
blade twist adjustment.

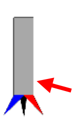
Notice how the blade enters the lower blade guide from the top, passes through the three guide wheels, and then twists about 45° before coming in contact with the drive wheel.

My blade consists of a





back,
and
teeth.



Ideally, the blade cuts a slot parallel to the **blade flank**. In reality, it cuts, well, where it cuts. I'll call that the **blade cut**. I will define **blade path** on page 25.

We just covered a lot of terms, and it is easy to forget one or two. You may want to print out this page as a memory jogger.

Nomenclature Summary

frame
saw blade
drive wheel
idler wheel
base
vise
fixed jaw
movable jaw
vise table
pivot shaft
support arm
upper blade guide assembly
inner guide wheel
outer guide wheel
back support wheel
blade twist adjustment
guide wheel carrier
blade guide bar
blade flank
blade cut
blade path

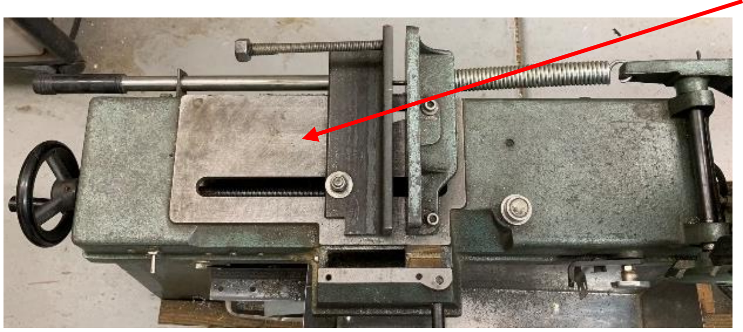
The Alignment Procedure

To those readers that just want to get this task done, read on. If you want to know ***why*** you are doing the following steps, jump to page 24 and read to the end. Then come back here.

In most cases, you will cycle between testing and adjustment until you are happy with the test results. No matter how careful you are with these adjustments, you will reach a point where the error varies over time. This is at the limit of the saw's accuracy. On a good day, you might have an error of 0.001-inches off per inch of cut. Trying for better may drive you crazy.

The alignment process must be performed in order. All adjustments depend on other adjustments, so you can get poor results if you jump around.

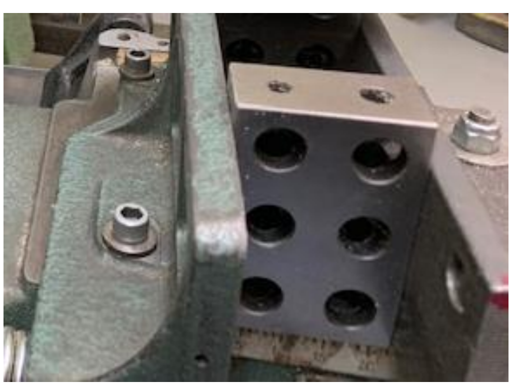
Vise Table Flatness



Ideally, the vise table is machined flat. But sometimes, the cast iron then warps. We need to at least see how bad it is. Lay the edge of a machinist square on this surface in various orientations and look for light leaking out. If you find a high spot, make a note, and avoid the area during the rest of the alignment procedure.

Machining or scraping the vise table flat is beyond the scope of this article.

Fixed Jaw Vertical Alignment to the Vise Table



The fixed jaw's vertical face should be perpendicular to the vise table or slightly tipped towards the movable jaw. If it is not, stock clamped in the vise may be squeezed up from the vise table.

Preparation

1. Clean surface of the fixed jaw and of the vise table.
2. Verify the mounting screws are tight.

Test

1. Place a 1-2-3 block or machinist square against the fixed jaw and vise table.
2. The block or square should be a snug fit on these two surfaces. An intense light behind the block or square will help you see any gap.

Remediation

You can mill the bottom of the fixed jaw, so it is perpendicular to the vertical face of the fixed jaw. I do not recommend placing shims under the jaw to tilt it because it will cause the jaw casting to bend and crack.

Fixed Jaw Alignment to the Pivot Shaft

We are going to align the fixed jaw parallel to the pivot shaft.

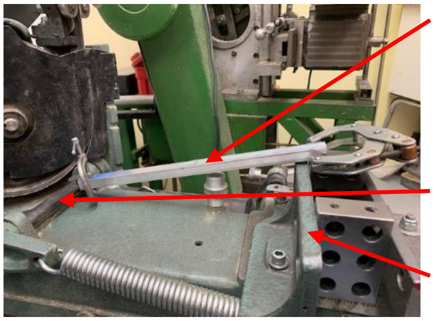
Preparation

After you've aligned the fixed jaw by this procedure, you need to do this all again every time you move the it to do an angle cut. To save time in future, pin the square position when you complete this procedure. Then the jaw can be quickly moved from any angle back to true. I recommend that you bring the fixed jaw to a drill press and drill a hole for a pin that is perpendicular to the bottom of the jaw. Mine was drilled with a #32. At this preparation stage, drill through the fixed jaw only.

Once the fixed jaw is aligned, use a handheld electric drill to go through this hole and drilled through the vise table. Then use a 1/8-inch reamer through both holes at the same time, so they perfectly line up.

When you have set up for your next 45° cut, drill through the hole in the fixed jaw with a 1/8-inch drill[4] and into the vise table. Then the return from miter cut to true is a piece of cake.

[4] Since the hole in the fixed jaw was already drilled and reamed 1/8-inch, you cannot use the #32 followed by the reamer and expect it to be centered.



1. Deburr the ends of a bar that can reach from the

pivot shaft to

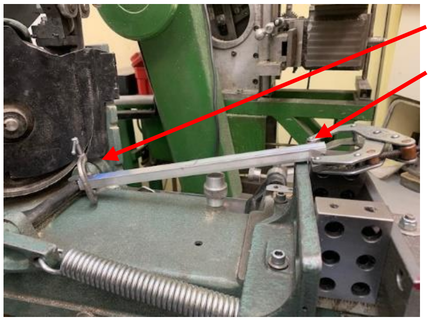
beyond the fixed jaw.

2. Clamp a small bit of deburred metal on top of the bar at one end. It should be able to rest on the top of the pivot shaft without touching anything else.

3. Put down a ½-inch thick parallel on the vise table

4. Place a 1-2-3 block on the parallel and against the fixed jaw near the right bolt.
5. Place a second 1-2-3 block to its left approximately aligned with the left bolt.

6. Place an approximately 0.1-inch spacer between the bar and the top edge of the fixed jaw. I chose something flat, so it would not roll off of the top of the fixed jaw.



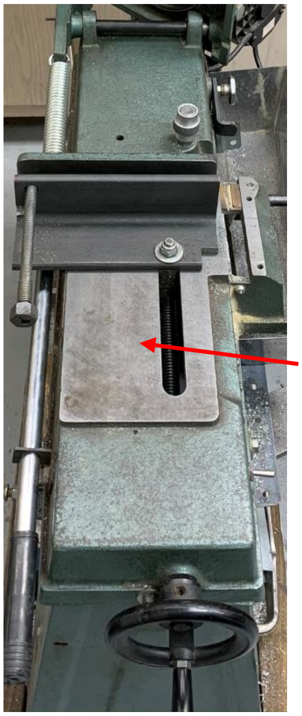
7. Press the bar against the pivot shaft while pressing the other end of the bar against the side of the 1-2-3 block. Be sure the end of the bar is only in contact with the pivot pin's outside diameter and is clear of the right journal.

8. Clamp the bar to the block. Using a Kant Twist will avoid any shifting.
9. Loosen the movable jaw.
10. Carefully lift up on the bar/block assembly without bumping it and remove the 0.1-inch spacer.

Procedure

1. Slide the bar/block assembly on the parallel over to the left until the far end of the bar almost touches the left journal.
2. Loosen the two fixed jaw mounting screws enough that you can just move the jaw.
3. Pivot the fixed jaw until it is snug against the block while the bar is contacting the pivot shaft.
4. Tighten the two screws to secure the fixed jaw.
5. Slide your alignment tool back to near the right journal.
6. Repeat Preparation steps 6 through 10 above.
7. Repeat Procedure step 1.
8. If there is not a snug fit to the pivot shaft and the vertical face of the fixed jaw, repeat the entire Fixed Jaw Alignment to the Pivot Shaft task.
9. If the test passes, continue on to testing the vise table.

Vise Table Alignment

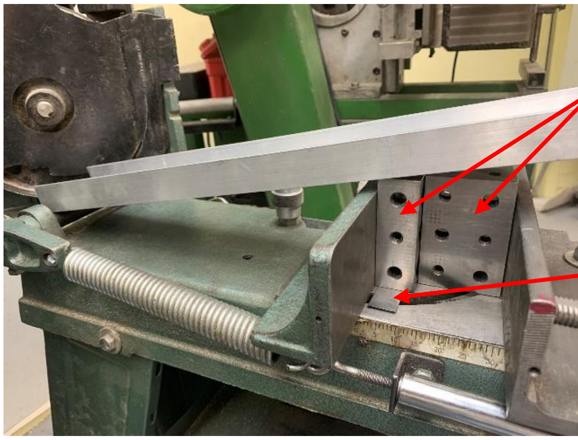


I am only concerned about the side to side tilt of the vise table with respect to the pivot shaft, although you must avoid known areas that warped after machining.

There is no Set-up for this alignment other than to clean the surface.

Test

1. Locate a bar that is about 3-inches wide and long enough to go from the pivot shaft to 6-inches beyond the movable jaw when fully retracted. This bar must be dead flat. If you have access to a surface plate, the bar must not rock as it is pressed onto this plate in various spots.



2. Clamp two 1-2-3 block in the center of the vise as shown, being sure that they are flat down on the vise table.

This spacer is installed later.

3. The bar is pressed against the pivot shaft and perpendicular to it as set by eye.
4. Push down on the bar right over the point it contacts the 1-2-3 block. Push on the right side and also the left side over the block.

5. If you hear any clicking, it means the vise table is not on a plane that is parallel to the pivot shaft. Add shims to the edge of the block until the clicking stops. The shims may be needed on the left or right sides of the block.
6. If you didn't need any shims, congratulation! Move on to the next task. For the rest of us, this error must be addressed in order to align the rest of the saw. The thickness of the shim stack is not that important, but its placement relative to the block tells us how the vise table slopes.

Remediation

I built a sine bar from a piece of ¾ x ¾ x 6-inch hot-rolled steel. With this cross-section, it will not have a tendency to fall over or to flex. Cold-rolled steel would have been better, but I didn't have any. So, I used my belt sander to make the top surface flat. I also radiused the bottom edge on one end. I chose to do this so the corner would not distort under load. If filed to a sharp corner, it would soon flatten in an uncontrolled manor. This radius must be as uniform as possible, so the bar does not rock side to side when the bar is resting on this edge and is pressed against the fixed jaw.

I drilled and taped a ¼-20 hole in one end, so a screw head would grab the edge of the vise table to prevent the bar from sliding to the left when the stock being cut is pushed down.

I drilled and tapped a ¼-20 hole at the other end of the bar about ¾-inch in, and fitted it with a setscrew.

With a hex wrench controlling the setscrew, I adjusted the bar's height on the left end until my bar no longer clicked as I pushed on it. Then I fed in a second setscrew to prevent further rotation.

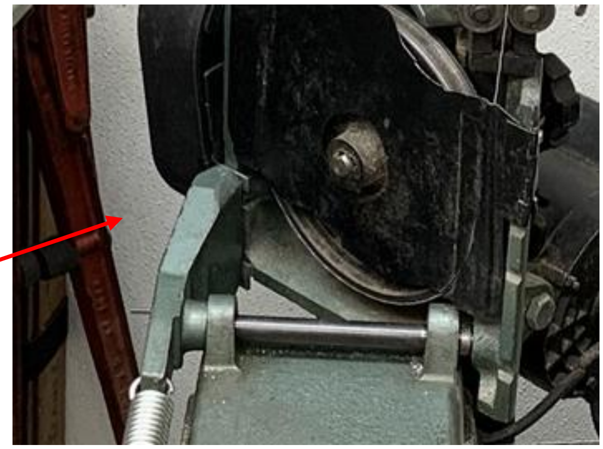
If your vise table was tilted the other way as indicated by the shim stack being on the right side of the 1-2-3 block, turn the sine bar end for end and hook the screw head over the left side of the vise base.

From now on, when I need to make a precise cut, I will place the stock on this sine bar.

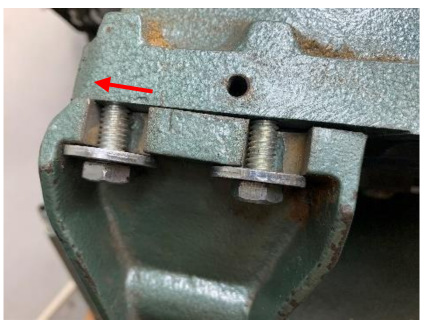
For the rest of this article, I assume you have made a sine bar.

Frame Alignment

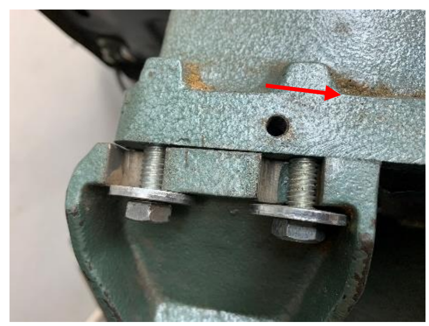
Now that the fixed jaw and vice table has been made parallel to the pivot shaft, we can align the frame.



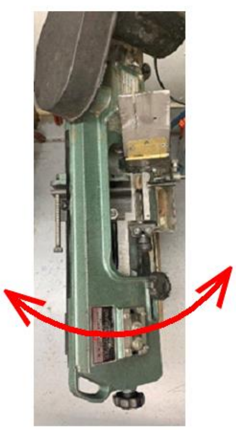
On the left side of the pivot shaft, we have the support arm which bolts to the frame.



Looking at the joint between the support arm and the frame, two bolts are visible. I can shift the support arm, so the bolts are all the way to the left,



or all the way to the right.



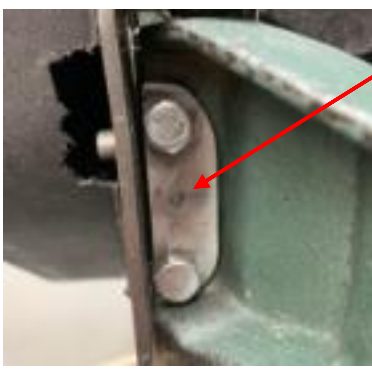
This movement of the frame relative to the support arm causes the frame to pivot side to side.

The alignment is correct when the blade is perpendicular to the pivot shaft.

Preparation

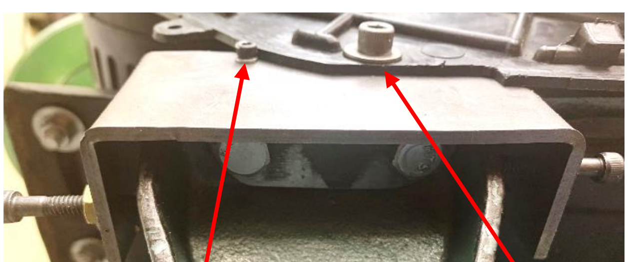
Unplug the saw! Bandsaws were invented for use by butchers. They cut meat very efficiently. Any meat.

On my saw, when I loosened the bolts, the frame sprang away from the support arm by about 1/8-inch. This tension stresses the frame. I filled the gap with a spacer made from 1-inch wide steel strap. Here you see the spacer before I trimmed off the excess.



I replaced the two washers with a plate. The force as the bolts are tightened is now distributed over a larger area.

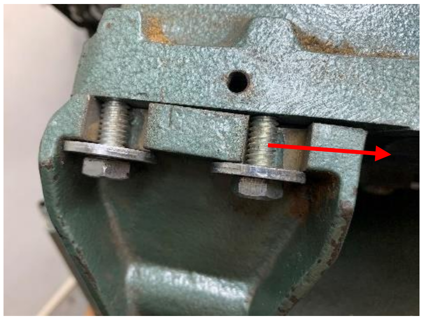
You can use a dead-blow hammer to tap the arm during the alignment Preparation, but building a frame makes well-controlled movements possible.



I used an existing tapped hole that secures the belt cover, plus I added a small screw to prevent the frame from rotating. Not visible is a strip of sheet metal that goes around the back of the support arm. It attaches to the side supports and keeps them from bending as the 10-24 adjustment screws are tightened.

Preparation

1. Verify that the saw is unplugged.



2. Loosen the two bolts.
3. Move the support arm all the way to the right.
4. Tighten the two bolts.

By starting at one extreme, in most cases, there will be no question about which way we must move to get to alignment.

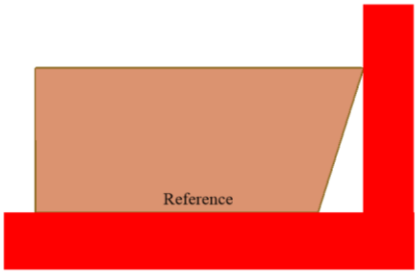
Note: this picture was taken without the spacer installed.

Test

The best material for this testing is 1 x 4 S4S[5] pine joinery timber. Second best is 2 x 4 softwood construction lumber. If your wood is not smooth, flat, and straight on one edge, plane or sand an edge to this condition. Mark this edge, “Reference.”

For this test, you do not need the sine bar.

1. Plug in the saw.
2. Place the wood flat in the vise with the reference edge against the fixed jaw.
3. Slide the wood over such that a ¼-inch slab is cut off.
4. Tighten the movable jaw.
5. Make the cut and discard the slab.
6. Remove the wood block and brush off any splinters.

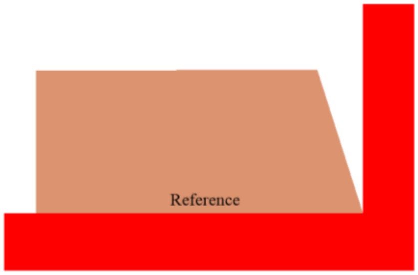


7. Place the wood against a square with the Reference surface touching the square.
8. Record which way the cut differs from square plus, roughly, the size of the gap.

9. Unplug the saw.

[5] This wood has parallel edges and has no warp. You can make a cut, flip it over, make a second cut, and then use the thickness variation of the resulting sliver to indicate twice the error.

10. Loosen the two bolts.
11. Move the support arm to the left relative to the frame until the bolts are approximately centered in their slots.
12. Repeat steps 1 through 9.
13. The gap should be smaller and might even reverse, so you see the gap at the top.
14. If the gap moved between top and bottom, move the support arm halfway back to the previous position.



15. If the gap did not reverse, as described above, between the top and bottom, move the support arm all the way to the left.
16. Repeat steps 12 through 14.
17. If the gap still did not reverse between the top and bottom, it is time to widen the cut-outs in the support arm. The metal is cast iron, so files easily. I removed a lot of metal with my 1-inch wide belt sander. Be sure to remove material from both cut-outs.
18. Repeat steps 12 through 17. Eventually, you will get to the point where the gap is "acceptably small." Only you can judge what that means. Don't go crazy trying to make this perfect. You will soon make cuts in steel and do your fine-tuning.
19. If you did not install an adjustment frame, scribe a line across the frame and support arm to indicate the position. You do not want to loosen those bolts and find that you have to repeat the above alignment Preparation.

20. Locate a piece of mild steel ideally 5/8-inch thick and 4-inches wide. It should be at least 4 inches long. Machine one edge flat and define it as your Reference edge.

The picture shows my sine bar installed, but it was not necessary for this test.

21. Place the steel bar flat on the vice table with the reference edge against the fixed jaw. It should extend about 1/8-inch beyond the blade.

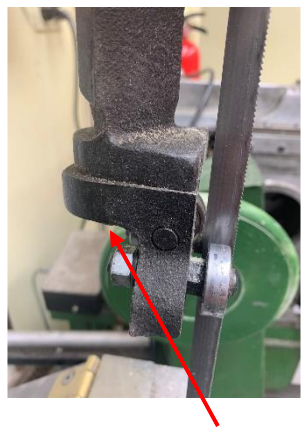
22. Saw off a strip of steel[6].
23. Deburr the bar and test it with your square. If necessary, adjust the frame until you are satisfied with the squareness of the cut.

When you can "accurately" cut steel, softer metals will cut as well as long as you use the correct down-feed rate. Feed rate? Oh, and the blade must also be tensioned correctly. I'll leave these topics for another day.

Blade Guide Alignment

Preparation

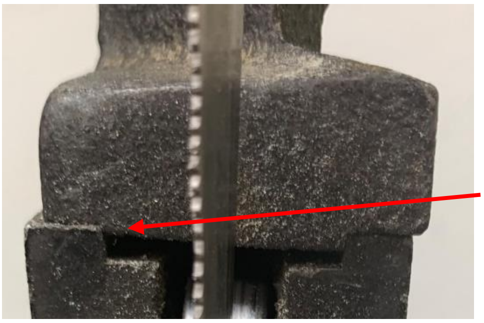
The upper and lower blade guides aim the blade.

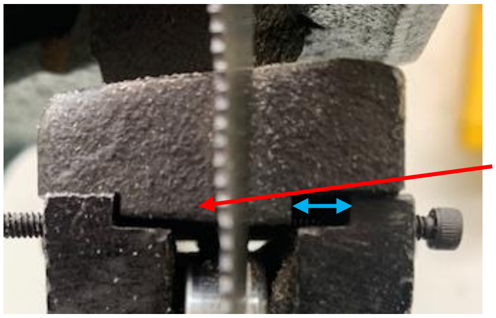


Sure, you can adjust where the blade points by loosening the bolt, shifting the guide wheel carrier, and tightening the bolt. Frustration creeps in when you need to make small changes in the alignment. That is when you will appreciate adding five screws to each blade guide.

[6] If you are using cold rolled steel and the edges are parallel, you can make a cut, flip the stock over, and make a second cut. Then measure the difference in thickness at the ends of the sliver to read twice the error.

I tapped two 4-40 holes on each side of the guide wheel carrier.

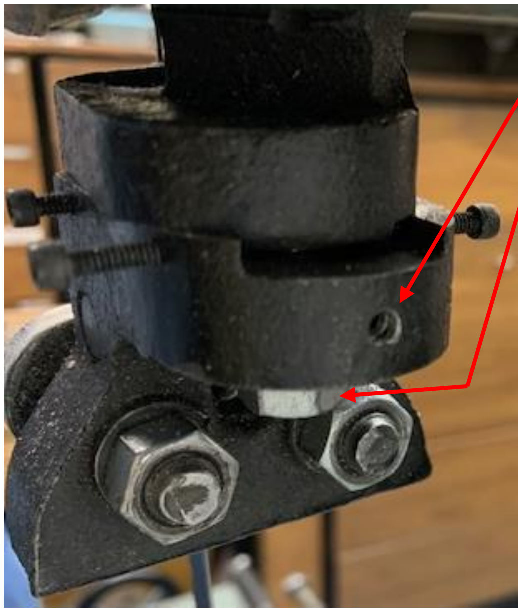




The job got a bit more involved when I discovered that the tongue was not machined deep enough. As shown, the screw cannot push on the side of the tongue. I had to mill around the tongue, so it extended deeper into the mating groove.

I also reduced the width of the tongue, so there is more room for the guide wheel carrier to rotate relative to the blade guide bar (blue arrows).

At first, I used 4-40 set-screws but quickly realized that my hex wrench was rounding off due to the needed torque. I then changed to Socket Head Cap Screws, which accept a larger hex wrench. One of them broke off as it hit a feature on the base. I have since replaced it with a shorter screw.

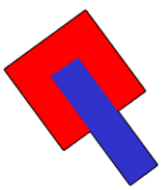


I tapped a 10-24 hole in the back of the guide wheel carrier. It was fitted with a setscrew that presses on the bolt. As I'm tightening
the bolt, I press the guide wheel carrier towards the blade until it hits this stop. The position of the back support wheel is thereby set relative to the frame.

Preparation

1. Unplug the saw.

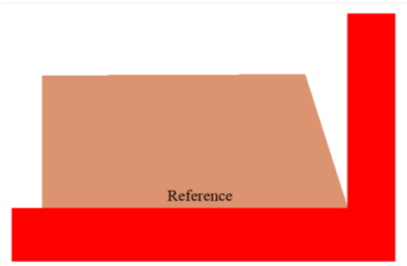
2. Pivot the frame to the vertical position.



3. Looking down on the upper guide wheel carriers as you stand in front of the blade, rotate it counterclockwise, so the flank of the blade points away from the vise. The blade will experience the maximum amount of twist while in this position.
4. Rotate the lower guide wheel carrier the same way.

Test

1. Place your sine bar down on the vise table. Then place your test wood, reference edge down, in the vise.
2. Plug in the saw.
3. Saw off a ¼-inch slab. Discard.



4. Brush off any splinters and place the wood block on a square. The gap should be on the top.

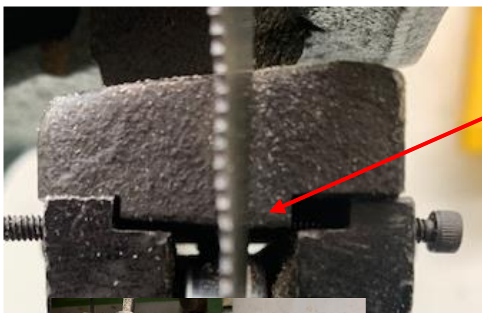
If it is on the bottom, you will need to

a. Unplug the saw.

b. File off more of the upper blade guide bar's tongue so the upper guide wheel carrier can rotate more.

If the cut is close enough to meet your expectations, move on to the next test.

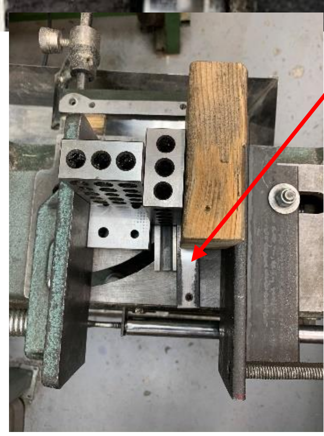
5. Assuming the gap is on the top,



a. Unplug the saw.

b. Rotate the upper guide wheel carriers, so the tongue is centered.

Repeat steps 1 through 4 until you are happy with the test cut.



6. Crank the movable vise jaw to full open.
7. Using 1-2-3 blocks and parallels, align the sine bar with the fixed jaw.
8. Clamp the test piece of wood between the 1-2-3 block and the movable jaw. The idea is to have the wood parallel to the fixed jaw, sitting on the sine bar, and as close to the lower guide assembly as possible.
9. Repeat steps 1 through 5.

The blade now cuts wood square when the stock is on the sine bar. It is time to cut steel!

10. Locate your steel test bar.
11. Place it on your sine bar, up against the fixed jaw. My steel test bar was thinner than the sine bar, so I added a packing plate in front of it.
12. Saw off a 1/8-inch strip of steel and discard[7].
13. Deburr and test the cut against your machinist square.
14. If needed, adjust your lower blade guide until you are happy with the squareness of the cut.
15. Repeat the process specified on page 22 using the steel plate.
16. If needed, adjust the upper blade guide until you are happy with the squareness of the cut.

Congratulations! You have (*temporarily*) aligned your saw.

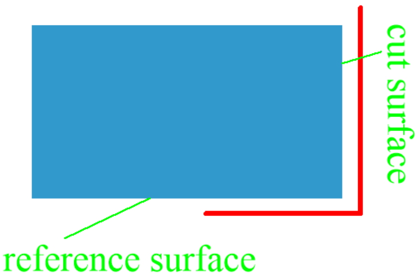
Check every saw cut. Blade wear can cause the saw to cut out of square. Repeat the Blade Guide Alignment to restore accuracy. When you replace the blade, this alignment will likely be necessary.

[7] If your test steel has parallel edges, you can make the cut, flip over the steel, and make a second cut. The difference in thickness at the ends of this sliver is twice the error.

The Theory

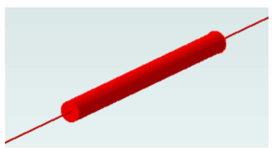
The last section told you *what* to do in order to improve the accuracy of your saw. If you are interested, here is *why* those procedures are necessary.

Ideal Blade Movement

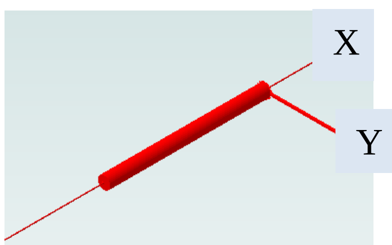


When the saw is perfectly aligned, the angle between the stock's reference surface and the cut surface is exactly 90°. OK, you knew this. But what is going on here?

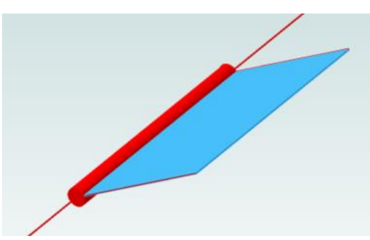
It all starts with the pivot shaft.



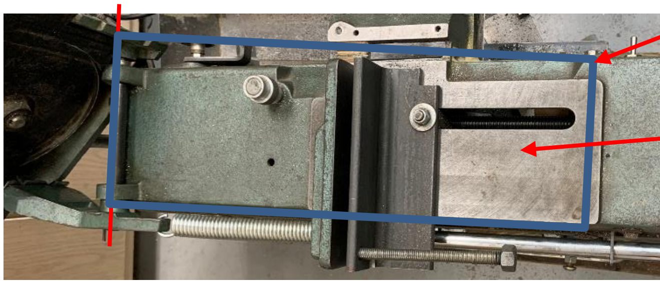
Ideally, this is a perfect cylinder with its major axis running axially. Call this the **X-axis**.



The **Y-axis** is perpendicular to the X-axis.

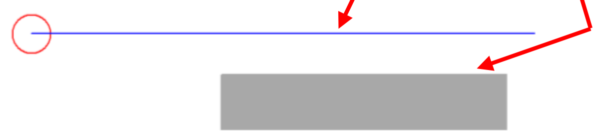


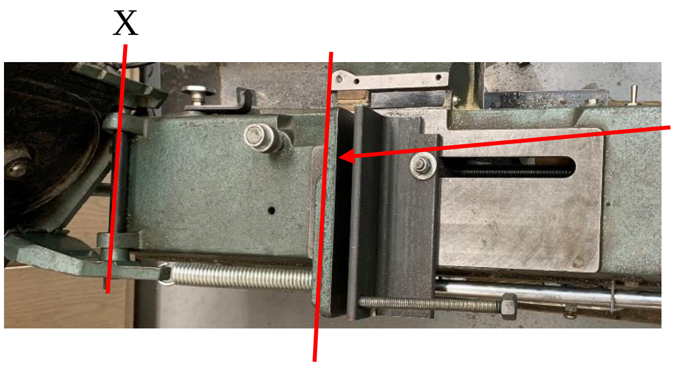
The **XY-plane** is defined by our X and Y axes. Notice that it is free to spin around the X-axis like a flag in a stiff wind.



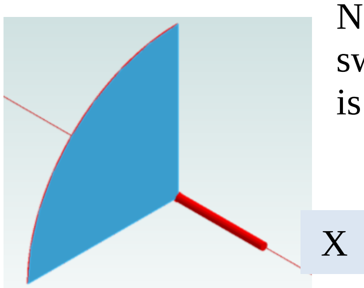
This blue rectangle is my XY-plane set to be parallel to the vise table.

Looking from the side, if my saw was ideal, the vise table would be parallel to the XY-plane.

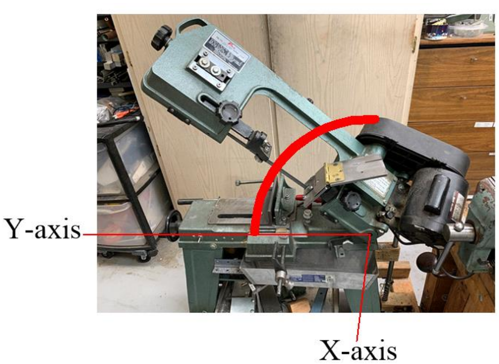




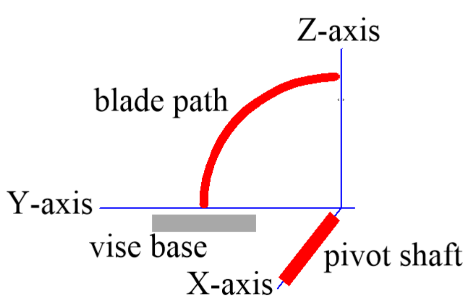
My ideal saw would have a fixed jaw that is parallel to the X-axis.



Now picture a line perpendicular to the X-axis that I swing through 90°. It would trace out a quarter circle and is my ideal **blade path**.



With the XY-plane parallel to the vise table, where does this quarter circle live? I need to add a third axis.

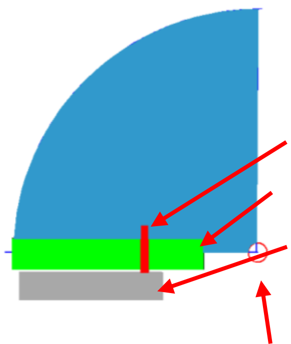


The Z-axis is perpendicular to both the X and Y axes. I can then say that the blade path is in the YZ-plane.

To recap, the X-axis is at the center of my pivot shaft. The Y-axis is parallel to the ideal vise table. The blade path traces a quarter circle centered around the X-axis on the YZ-plane.

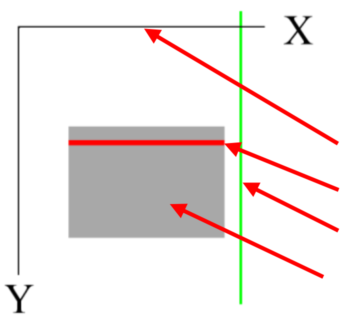
Making An Ideal Cut

Consider what happens when the blade path, fixed jaw, and vise table are in perfect alignment.

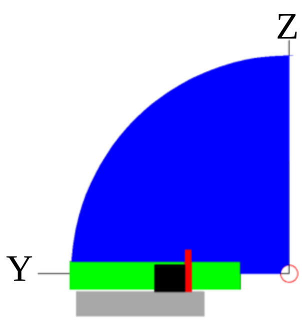


This is a side elevation view (YZ-plane) of the with the
fixed jaw,
the blade, and the
vise table.

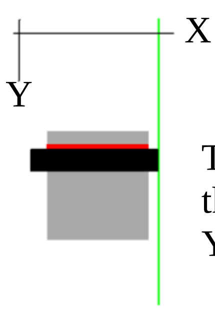
The pivot shaft is here, so the X-axis is point straight at you.



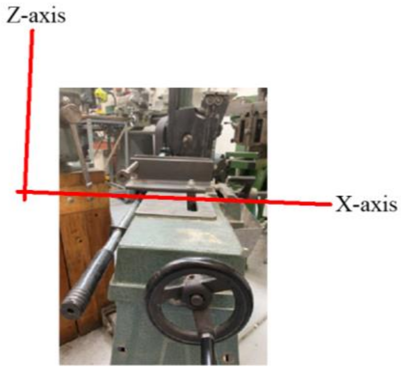
Here is a top view (XY-plane) of
the pivot shaft (X-axis),
fixed jaw,
the blade path, and the
vise table.



Back to the YZ-plane, I place some stock against both the fixed jaw and vise table and then rotate the blade down.



The blade cuts the end of the stock perpendicular to the fixed jaw and the vise table. In other words, the end of the stock is parallel to the YZ-plane.



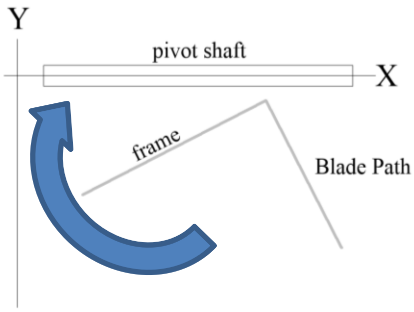
When I crouch down and look towards the vise, I see the XZ-plane.

The blade cuts parallel to the Z-axis.

Misalignments

What happens when things are not ideal?

Blade Path Not Perpendicular to the X-axis on the XY-Plane



If I rotate the frame in the XY plane, the blade path will follow.

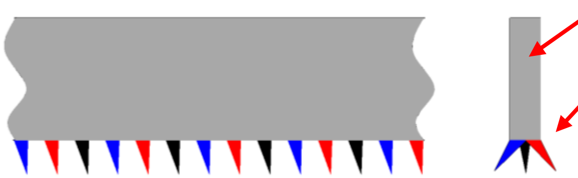
As the frame rotates clockwise, so does the blade path. The right end of the frame at the pivot shaft doesn't move much. The left end at the pivot shaft can be moved forward and back at the joint between the support arm and the frame (see page 15.

Blade cut not aligned with the blade path

Remember those blade guide assemblies? They let me adjust the twist of the blade. We set that as near as possible to ideal on page 19.

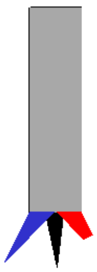
But there is another way the blade can misalign.

You may recall that my blade consists of a

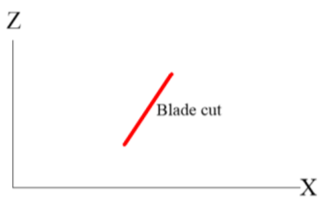


back,
and
teeth.

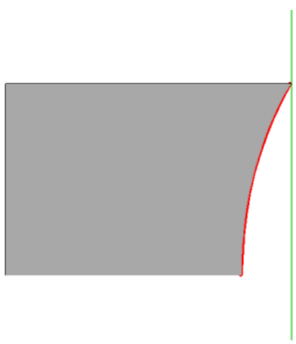
Ideally, the teeth set to the right cut exactly as much as the teeth set to the left. In this case, the blade cut is parallel to the flank of the blade.



In reality, often there is an imbalance, through wear or damage. Teeth on one side are not as sharp as teeth on the other, and then the blade will not cut parallel to the blade's flank. It is, therefore, more useful to talk about the blade cut than the blade flank. In this picture, the ends of the red teeth are blunt while the blue teeth are sharp. This blade will cut to the left.



Viewed on the XZ-plane, my blade cut is the red line. Ideally, it is aligned with the Z-axis. In this exaggerated example, it is out by about 30°.



The green line is how the blade moves in the air as the frame is pivoted from vertical to horizontal. Ideally, this line is parallel to the Z-axis.

As the blade tries to follow its 30° path, it departs from the green line that is parallel to the Z-axis. The misaligned or worn blade does its own thing and digs itself deeper into the stock. There is a tug-of-war between the cutting action pulling to the left and the blade's tension, pulling it back to the green line. After the cut has completed, the blade springs back to the green line.

In summary, I have identified two misalignments that cause out of square cuts:

1. Blade path not perpendicular to the X-axis on the XY-plane
2. Blade cut not aligned with the blade path

Other causes, involving the operation of the saw, are beyond the scope of this article.

Acknowledgments
John Vreede opened my eyes to the complexity of, and the remedies for, the 4 x 6 Horizontal/Vertical bandsaw. In his honor, I hope that readers will gain understanding through this article and thank John for his wisdom and generosity.

I welcome your comments and questions.

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