

Woodturning Tool Geometry/Physics

Or everything you REALLY wanted/needed to know about turning, but no one has ever explained it.....

By Lyndal Anthony

"Insanity is doing the same thing over and over again but expecting different results."

Quote first appears in the book "Sudden Death" by Rita Mae Brown

Problem solving comes from collecting bits of information into a carefully formulated theory, just like a detective collects bits of evidence to form a complete picture of a crime to identify the suspect. I have collected bits of information from my life and have added them up to present the following information.

I learned about woodturning with a hand plane as a freshman in high school. Our class was not allowed anything other than hand tools. Our first project was to take a block of wood and make it flat, square and parallel. I learned how to take thin cuts which would cut right through a knot. Heavy cuts were a lot of work and caused a rough finish. I learned to go with the grain in order to avoid tear out. I learned how hard it was to cut end grain. I also learned how to control the hand plane, in other words, I learned muscle control to get a consistent and smooth surface.

What is tear-out and what causes it?

Tear-out happens when the fiber is levered up, chipped or torn out of wood surface in front of the blade before the blade/gouge actually cuts/slices it.

I was turning a dry box elder bowl with a lot of curly figure in it. I kept getting tear-out and I tried all of my usual tricks; sharpening, re-sharpening, wetting the wood, different tools etc. to get rid of it. Figuring that doing the same thing over and over again and getting the same results, I went back to my grinder and sharpened my bowl gouge with a broader nose radius and this time instead of cutting with the flute half open, I closed the flute almost completely and found that the tear out was gone! That revelation started me on my quest to understand how a turning tool actually cuts the wood fibers and what the variables were and to question "expert" advice.

At this point my ninth grade shop training started to help. With this reference I tried all of the cuts/tool angles/tool grinds and techniques that the experts have always recommended.

What I found:

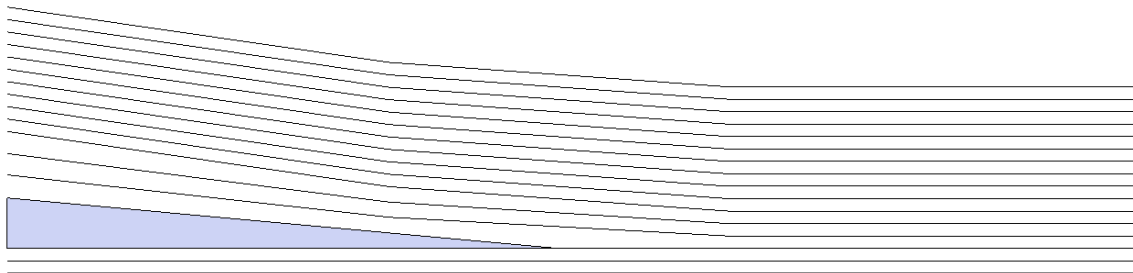
- Scraping lifts and pulls wood fibers up and out. If you skew/shear scrape, it reduces the tear out, but it is still there. If a negative rake scraper is used, the negative rake wants to push the wood fibers back into the wood before scraping them off which again, reduces tear out. It reduces but does not eliminate tear out.
- Using a shear cut causes the tool to cut as a reduced bevel angle. (*Skewing the body of the plane lowers its effective cutting angle, which can work in your favor or against you. Skewing also changes the relationship of the cutting edge to the wood fibers, which can change the surface finish of the wood. Skewing makes the plane easier to push, but it can increase tear-out in some situations. In some rare reverse-grain situations, however, it also can reduce tearing.*)
(<https://www.popularwoodworking.com/woodworking-blogs/skew-the-handplane-sometimes/>
Recommended in depth reading: <https://handtoolmanual.com/hand-plane-tearout-how-to-defeat-the-monster/>)
- What I found to be most effective is to try and slice through the side of the wood grain. A shearing cut slides along the wood grain at an angle which can tend to wedge the wood grain up, but slicing slices through the wood grain cuts cleanly reducing tear out.

- What I further found was when you decrease the feed rate (the speed that you feed the tool across the wood grain) it effectively reduces the force on the wood fibers giving the cutting edge more time to slice through the wood fiber reducing the force exerted on the wood fibers.
- Also, the longer the cutting edge, the force exerted on the wood fibers will increase due to the length trying to cut more wood fibers all at once which can increase tear out.
- A wedging action also occurs when the cutting edge is slicing through the wood fibers which will cause the wood fibers to lift. Although a short wedge with a wide angle may do a job faster, it requires more force than a long wedge with a narrow angle which can be a double edge sword. It can be an advantage or disadvantage. A wide wedge as in the bevel on a bowl gouge will reduce the wedging effect on the wood fibers, but will slightly increase the force applied to the tool and wood grain. It is very much like the difference between an axe and a splitting maul. You can't chop down a tree with a splitting maul, and a splitting maul splits wood faster and easier than an axe due to a larger wedge angle.

Although the following is for hand planes, it also applies to woodturning

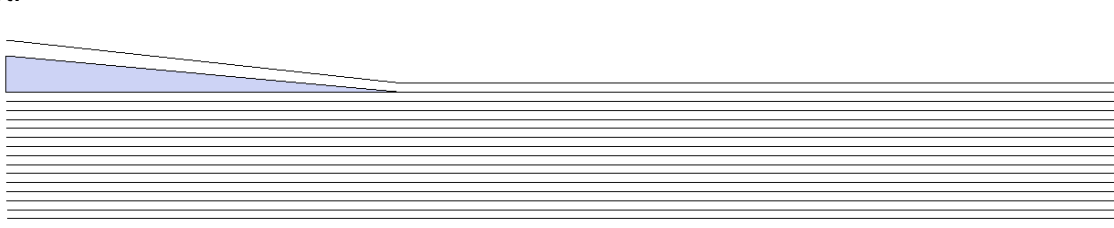
- *“Use freshly sharpened blade/iron and sharpen immediately again when the tear out starts to reappear. Sometimes you even need to do it every few minutes!”*
- *“Make thinner shavings, aim for 0,05mm (.002”) or thinner.”*
- *“Use a higher pitch/cutting angle. 55°-60° is enough for almost any tear-out.” (This is the same with woodturning. A shallow bevel angle will wedge under wood grain lifting the grain up increasing tear out.)*

Wedging action:

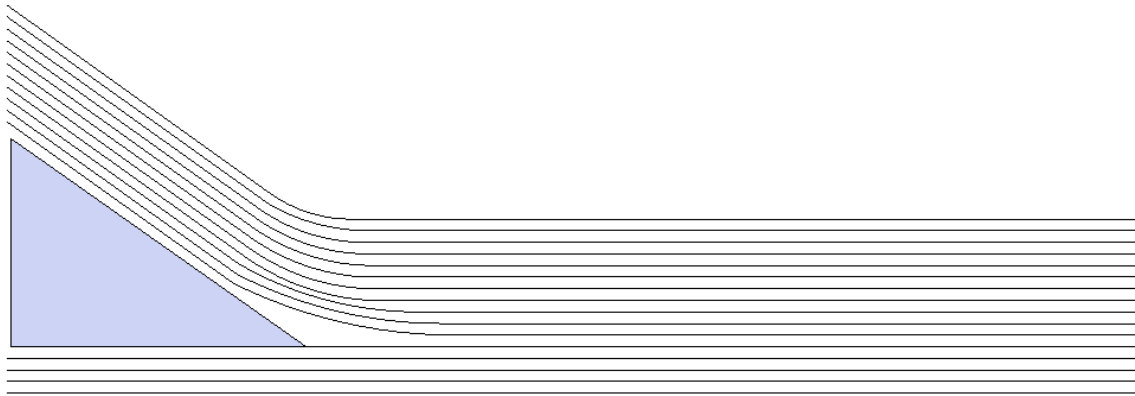


Thin but heavy wedging action. Note that many wood fibers above the wedge are still a splitting action.

Have you ever used an axe to split wood? If you have you have probably noticed that it is not a clean cut. The axe wedges the wood apart ripping along the grain. It is very rough, but it does split the grain. But, if you take that same axe and take a thin cut along the wood, it will cut cleanly instead of ripping the grain apart.

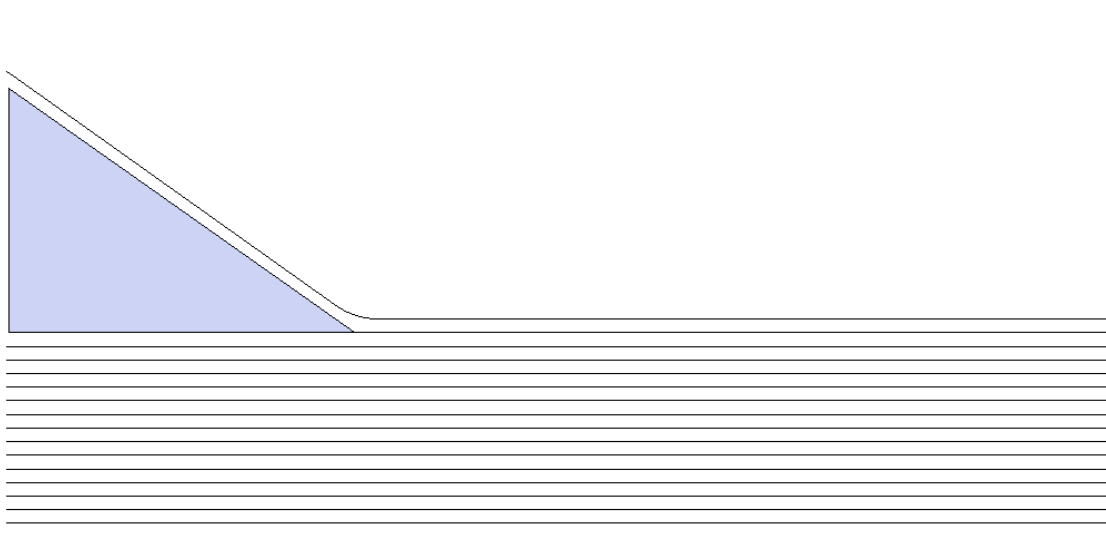


Thin wedging action. Note that only one wood fiber above the wedge is a splitting action, but the single thin wood fiber/grain is very flexible which will cut instead of splitting, reducing tear-out.



Heavy thick wedge action.

With the force of the thick wedge pushing at a greater angle, it takes a greater amount of force to feed the wedge into the wood fibers. Think of this as a bowl gouge versus a skew chisel. The skew chisel cuts aggressively because it is a thin wedge whereas the thick wedge of the bowl gouge is more controllable.



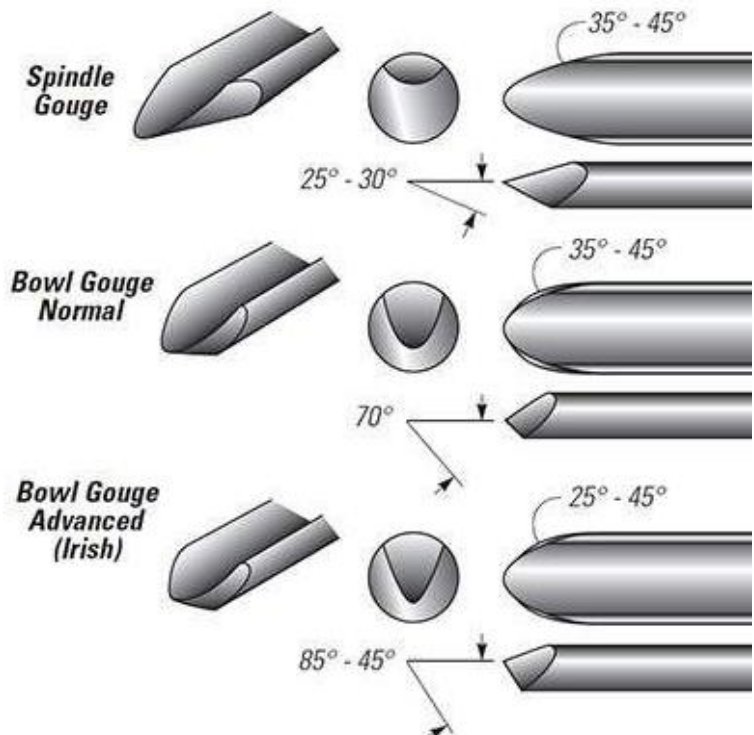
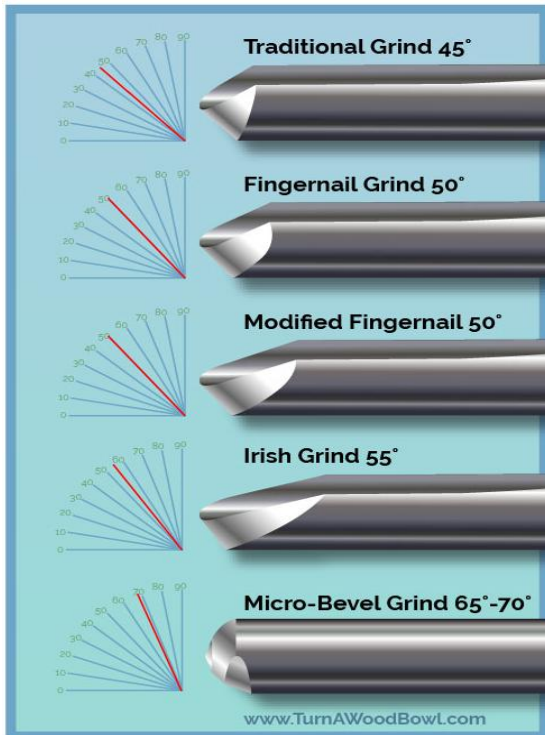
Heavy thick wedge action.

Note that only one wood fiber above the wedge is a splitting action, but the single thin wood fiber/grain is very flexible which will cut instead of splitting, reducing tear-out. What this means is that the bowl gouge will still cut cleanly if used properly.

The tradeoff with thicker bevel angle is the higher cutting angle always increases the power/force needed to cut. The larger/more blunt bevel angle is needed with a bowl gouge to follow the inside curve of the bowl.

So, what angle should you sharpen your gouge at?

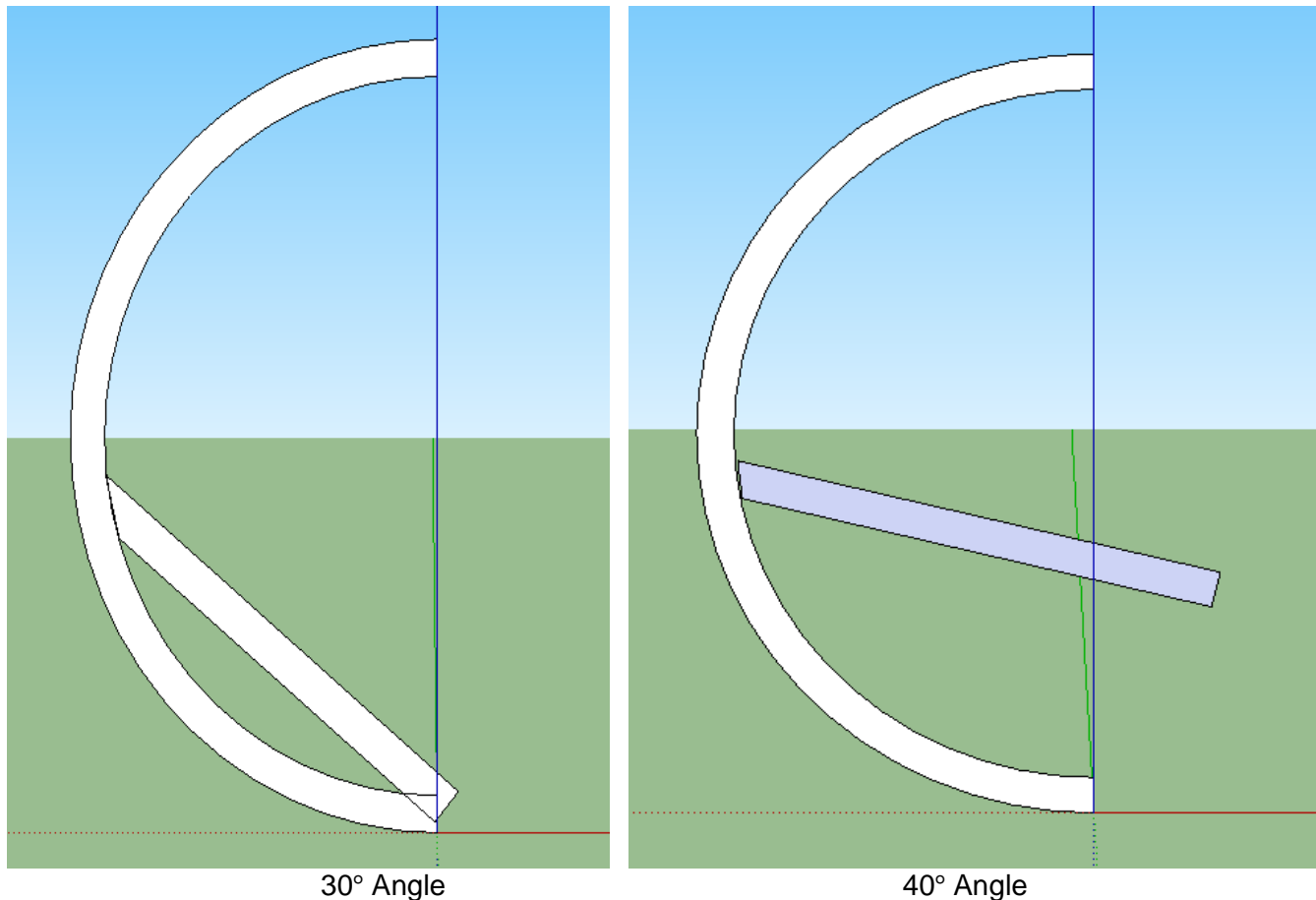
The pro's all have his/her idea of a perfect angle, but in the end it is more complicated than that.



Recommended Angle	30°	Spindle Gouges (for aggressive detailing)
	37°	Skew Chisels
	40°	Spindle Gouges
	45°	Bowl Gouges
	50°	Roughing Gouges
	55°	Bowl Gouges
	60°	Bowl Gouges (blunted for strong cutting edge)
82°	Bowl Scrapers	

Notice the difference in angles. Is there a single perfect angle?

The blatant answer is; there is no perfect angle. Some angles are a compromise to do inside radii and some are better at cutting face/end/wild grain. If there is an answer, the slimmer that cutting edge, the faster it dulls and the more aggressively it cuts.



The next thing to think about is how the cutting edge cuts the wood fibers. I have already talked about thin cuts, but another thing to think about is how wide of a cut and how the cutting edge is oriented to the wood fibers.

First, the width of cut

If the cutting edge is wide, then it will grab a lot of wood fibers all at once. The more wood fibers that are cut at once, the more force is exerted on the work piece which in turns will make tear out more likely. Think of grabbing a handful of hairs and pulling them out versus just one hair at a time.

Next, the orientation

If a scraping cut grabs wood grain and tears them up/out, then a skewed/shear cut is the cutting edge trying to cut at an angle with a wedging action. But if the cutting edge is oriented to parallel to the rotation of lathe and from the side of the wood fibers; by doing this the wood fibers are supported and will be cleanly sliced.

Slow Down!

The last thing to think about is the feed rate. During a rough cut all you are doing is wasting away wood, so the quality of the cut is not important. But, to get the best cut with little or no tear out, slow down. Slowing down gives the cutting edge ample time to cut through the wood fibers resulting in a cleaner cut.

And of Course

Sharpen, sharpen, and sharpen. When you shave with a single or double edge razor, you can feel right away when the razor starts to get dull and it pulls on the beard hairs, so it is the same with wood fibers.

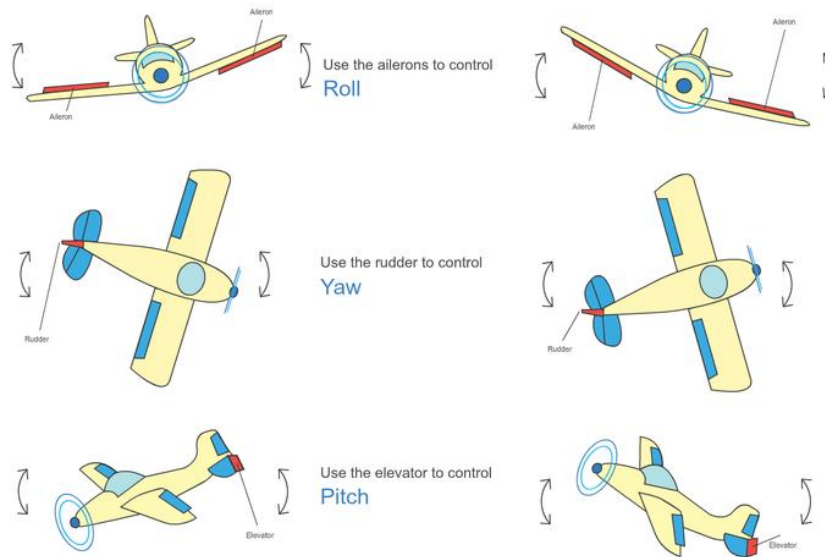
Gee I'm a tree!

Geometry; it has everything to do with how the tool cuts wood. The three things to be aware of are the rakes of the tool; neutral, positive and negative rakes.

- **Neutral rakes** are typically how you use a scraper. The cutting edge is perpendicular to the wood fibers. It is used without the support of the bevel and tends to grab the wood fibers and pull them out (tear out) uncontrollably.
- **Negative rakes** tend to push the wood fibers back into the wood before shearing them off so it not only reduces tear out, but it gets rid of the catchiness of a scraper. (Those of you that use inside scrapers and have large catches just turn it into a negative rake scraper and it will be much more controllable. You spread butter on your toast using a negative rake. But you use a positive rake to peel potato's.
- **Positive rake** means the cutting edge is angled up into the wood fibers making it cut very aggressively. Think of a twist drill. The cutting edge/lips of the drill have a positive rake which helps pull the drill bit into the work piece. In order to fully understand this, grind the cutting lips of the twist drill parallel to the drill bit, turning it into a scraper and try and drill a hole in steel. The drill bit is still sharp, but it won't self feed and it is nearly impossible to drill a hole in steel. The advantage with this is that now a turning tools cutting edge can be positioned to a positive angle and will help the gouge self feed into the wood which is great for roughing cuts.

What angle do I hold the gouge at?

It is simple. There is no perfect angle.



It is just like flying an airplane.

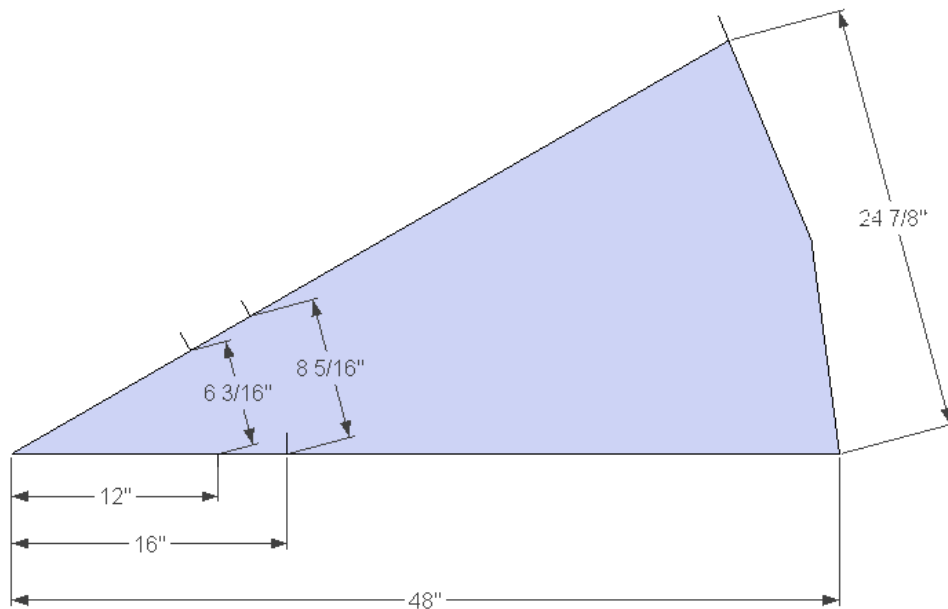
You constantly micro adjust the yaw, pitch and roll. An airplane travels through varying densities of air and changing air currents, so the pilot is constantly micro adjust the flaps on the wings to keep it level. When you are turning wood, the grain of the wood constantly changes in density and direction. You can start cutting side/long grain and halfway through the cut it starts to also cut end grain, but we can also throw in a knot or change in grain direction plus the cutting edge can start to dull, but with a subtle move, a new sharper edge can take over. So, the perfect cut changes and you need to constantly micro adjust angles while you are finding the optimum cut with the least pressure, grab and bounce.

How long should a handle be?

The general rule for handle length is 8/1. If the gouge hangs over the tool rest one inch, the handle should be eight inches long. If the gouge hangs over the tool rest six inches, the handle should be forty eight inches long.

Back to the inside scraper. Why do you get huge catches with it? Simple, it comes with a sixteen inch long handle, but if it hangs over the tool rest five inches, then the handle should be twenty inches long. Now factor in the propensity of a neutral rake which loves to dig in, the handle is way too short.

Another point to consider is that the length of the tool handle influences how smooth of a radius can be made with a long handle. It is a matter of ratio.



With a sixteen inch long tool, versus a forty eight inch long tool, you have to move the long handle three times as far. What this means is that the short handle moves a great difference in angle than the long one, so a smoother radius can be made with a longer handle. When a person chokes up on the handle nearer the tool rest, the distance that you move the tool is even smaller so it is harder to make those long smooth radius cuts.

The other factor is still a ration. Think of the teeter totter. If you put a heavy weight near the fulcrum of a teeter totter, a small weight will balance it. So if you find that you have to have a heavy handle or need to exert a lot of force to keep the gouge from flying out of your hands, then you need a longer handle.



If the gouge starts to bounce, maybe a longer handle will give you more control?

Sanding and perfect finishes

I have listened to professionals talk about honing the tools with 600 grit carbide stones and looking at the wood under a microscope to verify how cleanly that edge cuts, but consider this; I don't know of much of anyone that does NOT sand to remove tools marks or other imperfection.

So does having a perfect finish matter that much? Maybe sharpening with a 100 grit wheel isn't as important as getting smooth radius with less tear out and fewer tool marks or multiple radii that has to be sanded out anyhow.

References:

HAND PLANE TEAR-OUT – HOW TO DEFEAT THE MONSTER; <https://handtoolmanual.com/hand-plane-tearout-how-to-defeat-the-monster/>

Image references:

https://www.google.com/search?q=bevel+angle+for+spindle+gouge&rlz=1C1VFKB_enUS672US725&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjL5uaqz8XgAhWJ7IMKHVkpCEcQ_AUIDigB&biw=1366&bih=626#imgrc=YCvAMyMN5sdk0M:

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