Extreme Deep Hollowing

By: Lyndal Anthony

Give me a lever long enough and a fulcrum on which to place it and I shall move the world.

Archimedes

First, this article covers hollowing to depths that commercial boring bars will not go, in excess of thirty inches (76.2 CM) deep. The deeper/bigger you go, the difficulty/danger expands exponentially. **Also, DO NOT forget how dangerous it is to have several hundred pounds of rotating mass in your lathe, which can turn lethal in a heartbeat!)**

First, I mount/hang the workpiece between centers. I use an "Elio" style drive center. (http://www.onegoodturn.ca/store/index.php?route=product/product&product_id=167) which I bury in the drive end of the workpiece. I use a center for a metal lathe which I bury on the tailstock end, although I am considering using a 1"- 8 live center with a faceplate lag screwed on the end of the workpiece. (I may even lag screw both ends.) I use a portable power planer to knock down the high spots which also helps balance the workpiece a little better.

I am not marketing boring bars or building them for anyone else. I just like to figure out how things work. There are as many designs as there are inventive turners, so this isn't intended as the standard in boring bars including telescoping, round, and/or square bars. It is just information about what it takes when you try going extremely deep with the cutter/boring bar hanging over the tool rest an excessive length.

I've made vases and hollow forms up to about 20 inches (50.8 CM) deep, but I decided to try and make a vase about forty-eight inches (121.92 CM) tall, and soon discovered that the boring bar I was using was far too small. I googled articles on deep/deep hollowing but came up empty. After a posting on an AAW forum, I was contacted by Dennis Gooding, an engineer from Oregon that offered to help me with designing a boring bar big enough to hang over the tool rest four feet and yet be rigid enough to withstand the forces that a boring bar cutter would exert, and in turn flex/bend my boring bar.

Many boring bars on the market will easily handle depths of up to 20 inches (50.8 CM) deep and a few will handle depths to about thirty (76.2 CM) inches deep, but I wanted to go deeper. Another area of concern was the actual weight of the bar itself. With smaller bars it makes sense to use solid bars, but when the size increases, the only real option and engineering standard is to use tubing. As an example, the largest bar I have built is about three and a half inches (8.89 CM) in diameter and is fourteen feet (426.72 CM) long and weighs over two hundred pounds. If it were a solid bar, it would weigh well over seven hundred pounds! My home made captive floor mounted tool rest is about 400 pounds and has a roller in the bottom so I can move the boring bar easily. I tried a Powermatic Outboard toolrest, but it was just too light and easily moved around and the three point location proved to be too “tippy”.

I have to point out that the only way to even attempt to hollow something this long and heavy is to use a substantial steady rest (pictured on the tailstock end of my lathe) to anchor the unsupported end of the workpiece. (I had to beef up my steady rest and floor mounted captive tool rest a BUNCH to withstand the extra weight and spinning mass! I am even in the process of building a six wheel steady rest with four 4” 400 lb capacity wheels on the bottom and using the smaller steady rest on the drive end for extra safety. A face plate screwed to the drive end of the workpiece or chuck absolutely will not hold the workpiece when working very far from the headstock. I even use my steady rest when making hollow forms a foot long. It just makes sense to me to be safe as possible and it is easy to use.

What is a turning gouge other than a lever? Sure it is sharpened to cut the wood and there is a lot of science given to sharpness and cutting angles and tool design, but it is still a lever. If you’ve ever had the tool extended over the tool rest very far, you’ve learned about the leverage.

Cutter dynamics

Again we have to talk about safety. Doing deep hollowing can be dangerous and/or fatal even for experienced turners.

Next, we have to know a little about how a cutter works. If you look at a standard twist drill, the cutting edge has a knife edge to it. It is designed for cutting steel which is rather tough. This knife edge is designed to help the drill to self-feed into the cut. If you use a twist drill on soft materials like aluminum, copper, or wood, you are supposed to flatten the cutting edge, turning it into a scraping edge.

There are a number of cutters used for hollowing and each design, shape, and size will affect the cut. A scraper will not self feed, but gives a rough finish unless it is used in a shear cut configuration. A cupped shaped cutter gives a much smoother cut since it is a hooked cutter, but can tend to self feed into the wood causing a much more aggressive/deeper cut than is desired. Rolly Munro and Sorby Sovereign tools have a chip breaker mounted on top of the tool to control the depth of the cut. The actual size of the cutter will affect the amount of wood being removed, the same as if you use the full width of a one inch (25mm) scraper instead of a quarter inch (6mm) wide scraper.

With that said, when you are using a cutter deep inside a hollow form and the cutter is hanging over the tool rest a matter of inches OR feet, the leverage induced on the cutter versus the size/ length of tool handle will cause or resist vibration of the bar while it is cutting. The vibration causes the tool to flex. If the tool flexes and allows the tool to go below the centerline inside the form, it will cause the tool to take a heavier cut exacerbating the vibration. If the tool is slightly above the centerline, the vibration will cause the tool move down and away from the cut allowing the cutter to take a smaller cut. This is the exact opposite of how the tool works on the outside curve of cut because the inside works exactly the opposite. Another thing that can cause/add to vibration is the speed of the hollow form. Lowering rpm's can actually reduce sympathetic vibrations.

The angle of the tool can make a tool cut differently. A skewed cut actually takes a shallower cut.

Now for the boring bar:

The first boring bar that I made a couple of years ago was a cross between Lyle Jamisons' design and Steve Sinners' design. It was 1 ¼ inch (3.175 cm) in diameter and six feet (182.88 cm) long. It worked great with my Rolly Monro carbide hollowing tool up to about twenty-four inches (60.96 cm) deep, but then it started to flex way too much. (Steve Sinner is able to go thirty inches (76.2 cm) deep, but he is a lot more experienced than I am.) I next tried a boring that was two inches (5.08 cm) in diameter and eleven feet (335.28 cm) long, but it started to flex at about thirty-nine inches (99.06 cm) deep. The laws of physics can be challenged, but not one has ever broken those laws.

About this time I posted a question about deep/deep hollowing on the AAW forum trying to find information on boring bar systems that could go more than thirty inches deep and received several replies, one of which was from Dennis Gooding.

Dennis explained that for a given weight, pipe/tubing is much stiffer than solid bars. Over long lengths, solid material will actually sag under its own weight. Mass is important and works as an advantage on smaller boring bars, but at some point, it is too massive to handle. Also, bridges are designed to flex. If they are too stiff, they tend to crack and fail, but when we are trying to make a cut on wood, we don't want any flex.

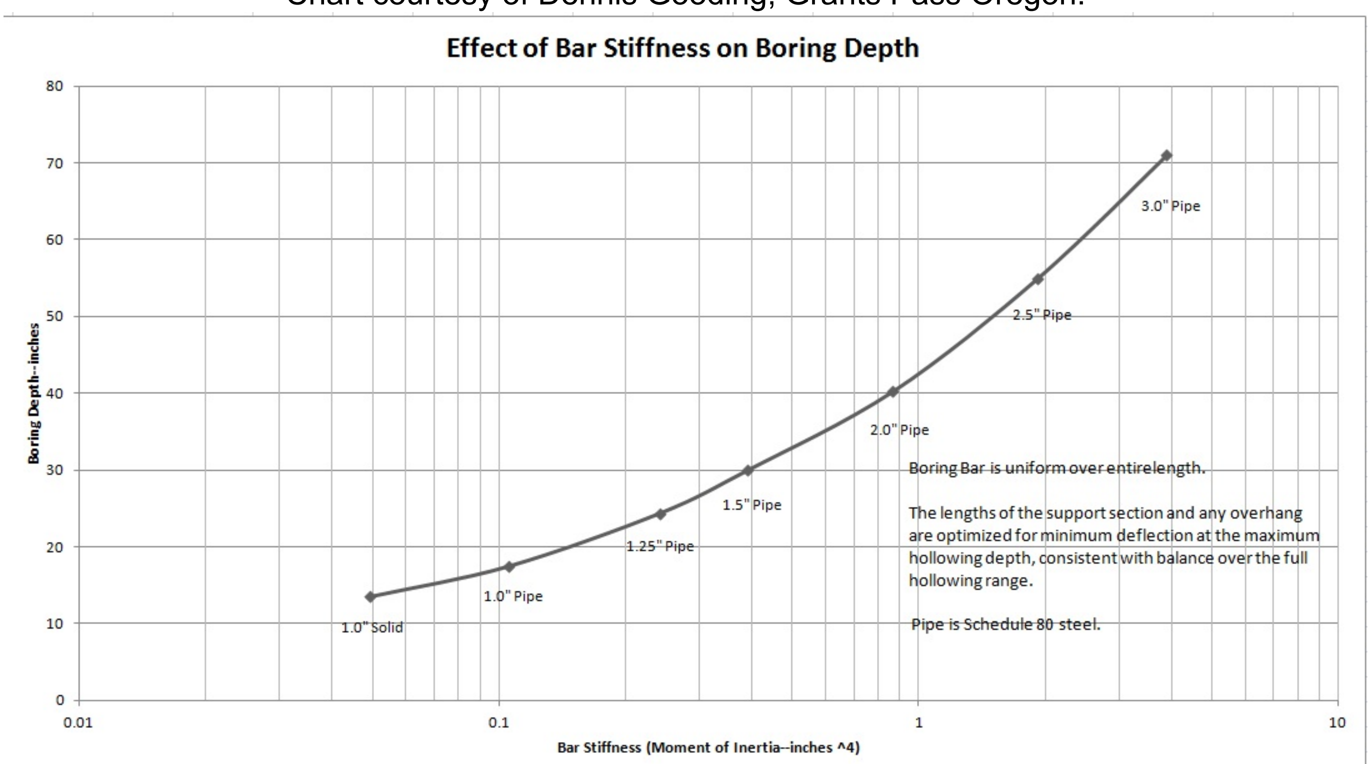
After a short conversation on the phone, Dennis and I both agreed that we needed some data on how much force is exerted on the cutter itself, so I designed a fixture to try and measure the actual tool pressure exerted on the tip of the cutter. Dennis also did tests to try and gather the actual tool pressure. Dennis plugged that data, (about thirty to forty pounds) into the computer program that he wrote to analyze boring bar designs and tool pressures. (During this time I drove Dennis a little crazy by submitting several boring bar designs I dreamed up to be analyzed.) Dennis even invested in a data gathering system consisting of a precision electronic accelerometer, an analog-to-digital converter, and a laptop computer to collect real-time acceleration data measured at the tool/cutter end of the boring bar. In other words, it defines how much pressure was being exerted by the cutter on the boring bar.

My goal was to bore four feet deep with as small a diameter bar as possible. What Dennis' program suggested was a boring bar made from two and one half inch diameter (3" in reality, 7.62 cm) schedule eighty pipe. I had some three-inch schedule 80 pipe available and it cut nicely and didn't flex at all hanging four feet over the tool rest.

We also have to keep in mind the leverage that is imposed on the handle. I read once that a tool handle should be six to eight times the length that overhangs the tool rest, which makes sense for handheld tools. Dennis's computer analysis shows that for a given maximum tool overhang, there is an optimum total length for the boring bar and an optimum spacing between the tool rest and the outboard rest. Making the bar too long leads to increased tool deflection under load. My boring bar is anchored at the very end by a floor stand roller captive tool rest that now weighs about four hundred pounds, so it is anchored pretty solid. My biggest boring bar is three inch (8.89 cm) schedule eighty pipe three and a half inches in diameter and fourteen feet (426.72 cm) long with one ten-foot (304.8 cm) long pipe used as an outrigger to counter twist and add mass. The reason for the excessive length is so the bar doesn't "teeter totter" on the tool rest and raise the "handle" end of the bar.

The chart below depicts the relative capabilities of various boring bar designs. Specifically, it shows what hollowing depth can be achieved for each choice of bar while maintaining the same tool deflection under a given tool load. In each case, the length of the bar and the support spacing are assumed to have been optimized for the intended maximum hollowing depth. The actual hollowing depths shown are nominal values observed in experiments but may vary considerable depending upon operator skill, type of cutting tool used and possibly other factors. A further note: When comparing solid bars to pipe bars, keep in mind that pipe is specified by its nominal inside diameter. Therefore pipe of a given named "size" almost always will be stiffer than a solid bar of that actual diameter.

Chart courtesy of Dennis Gooding, Grants Pass Oregon:



Reference:
Steve Sinner boring bar: (http://www.thesandingglove.com/Advanced-Lathe-Tools-Boring-Bar-Systems.asp).
Rolly Monro Tools: http://www.rollymunro.co.nz/tools.html
Mike Hunter Tools: http://www.hunterwoodturningtool.com/
Brian McEvoy: http://www.onegoodturn.ca/