

Boring Facts (Summary of Boring Notes)

0. **Understand EVERYTHING Matters.** Using a boring bar to simply enlarge an existing hole is a straightforward process. However, when trying to hit a particular size and tight tolerance, everything begins to matter: boring bar selection and setup, cutting edge geometry, tool deflection, lubrication, cutting parameters, chip evacuation, part temperature, and our ability to measure the bore accurately and precisely. If you cannot force yourself to be a little OCD, you might not be good at precision boring.
1. **Boring Bar Selection.**
 - a. *HSS.* Cheaper, tougher, and can be reground.
 - b. *Tungsten Carbide (WC).* Can tolerate much more heat (2.5X > HSS). 2.5X stiffer than HSS. These boring bars are available as a small piece of tungsten carbide brazed to a steel shank or as an indexable boring bar profiled to accept industry standardized, quickly replaceable WC inserts. Indexable boring bars are available made from steel (cheaper) or WC (stiffer, but more \$).
 - c. *Corner Radius.* A smaller corner radius produces a better surface finish and can achieve tighter tolerances, but is more fragile and fractures much quicker than a larger radius. So typically larger Rs are used for roughing and smaller Rs are used for finishing.
 - d. *Coatings.* Heat resistant coatings are used allow higher surface (spindle) speeds and thus faster boring in tougher materials like steels and titanium. The most common tool coatings are TiN (titanium nitride), TiAlN (titanium aluminum nitride), and TiCN (titanium carbo nitride), which typically allow 25-30% higher surface speeds than uncoated tools.
2. **Boring Bar Setup.**
 - a. *Maximize Stiffness.* As with all metal cutting processes, stiffness is key when boring, so do everything you can to maximize it: use the largest diameter boring bar and the shortest extension length possible. If boring deeper than 5 bar diameters, consider using a more expensive WC bar.
 - b. *Proper Rake Angle.* The rake angle is the angle at which the tip of the cutting tool is presented to the workpiece. Some boring bars have alignment flats, which make proper rake angle adjustment simple (as there is no option). Others require you to set the rake angle for the type of material you are cutting: positive rake angles for weaker materials and neutral or negative rake angles for stronger materials.
 - c. *Set Centerline Height.* Setting proper vertical centerline height is critical when using boring bars (much more so than when using normal OD cutting tools). If unsure, load a piece of material and make a very shallow (0.005" or so facing cut with the lathe in reverse to check.
 - d. If you are a spiritual person, a prayer can't hurt either.
3. **Selection of Cutting Parameters.**
 - a. Begin with a cutting speed equal to half the typical computed value and work your way up if vibration and tool life allow it. The primary reasons are the reduced stiffness due to the cantilevered nature of boring bars, as well as the difficulty of providing consistent lubrication to, and chip evaluation from, the cutting edge of the tool unless flood cooling, as in a CNC lathe.
 - b. A safe maximum depth of cut for typical boring bars is twice their corner radii. There's also a safe minimum depth of cut, below which the tool constantly transitions between cutting and smearing, leaving a very inconsistent size and finish. This safe minimum depth of cut is typically around 0.002" to 0.005" depending on the material. Harder / stronger materials usually can tolerance a smaller minimum depth of cut.
 - c. A safe maximum feedrate for a boring bar is one quarter of the corner radius.

4. **Ideology for Repeatable Results.** Consistency is crucial to obtaining repeatable results when using boring bars. Meaning, you want to vary the fewest parameters possible during each cut, and preferably only one at a time. Anything that affects the cutting force at the tool tip will change the amount of material removed, or the surface finish obtained: depth of cut, feedrate, lubrication, corner radius, part temperature, etcetera.

Let's say you are trying to thru-bore a 1" hole in a piece of 303 stainless steel. One approach would be as follows:

- a. Remove as much material as possible by drilling, since it's the most efficient method of material removal. When doing this, be sure to leave enough stock for the next step. Leave the bore about 0.050" small in this case.
- b. Perform a few test cuts to check how the boring bar is cutting. Rarely will a boring bar cut perfectly. If you try to remove 0.010" off the diameter of the bore, it may only remove 0.0096" on the first pass and another 0.0004" on the spring pass. (A spring pass is simply a second pass that helps compensate for tool or part deflection during the first pass.) It's important to make a couple passes and write down how much each removes so you can take the average and know what to expect when it matters.
- c. Do not try to sneak up on the final size. As anti-intuitive as it may sound, the best results are not obtained by making smaller and smaller cuts until you reach the desired size because of the safe minimum depth of cut discussed in Step 3 above. The best results are obtained by repeatedly removing a similar amount of material on each pass and using the resulting measurement data to make small adjustments to each subsequent pass. On the 1" 303 example piece, the final cut would remove 0.005" to 0.010" from the diameter to bring the part into final size tolerance.

5. **Bore Measurement.**

- a. Many measuring instruments of various quality exist for trying to measure bore diameters: calipers, micrometers (OD and ID), telescoping gages, gage pins, bore gages, etcetera.
- b. In the accurate words of Israelle Widjaja, "*properly measuring things is hard ☺.*"
- c. Rule of Ten: the gage or measuring instrument should be 10 times as accurate as the characteristic (i.e. smallest tolerance) to be measured.
- d. A measuring instrument is useless if not calibrated regularly against a calibrated gage.
- e. A measuring instrument which offers no constant torque method of measurement is junk; also, those that do only work if the clutch is rotated at consistent and constant velocity.
- f. Whenever possible conduct measurements as close to NTP (normal temp and pressure) as possible (68°F & 1atm (14.696 psia)).
- g. Whenever possible measure in an environment that will not damage the part or measuring instrument if either is dropped.
- h. Clean the contact jaws or tips with alcohol and a piece of tissue paper before use.
- i. Double check the zero of the measurement instrument before use.
- j. Understand metals have a typical coefficient of linear expansion of 0.000010 in / (in-°F); therefore holding on to a measuring instrument and/or a part long enough will cause a 2" nominal part to change length 0.0006" due to temperature change alone.
- k. Always take at least three measurements to be "carelessly certain" of the ballpark value.