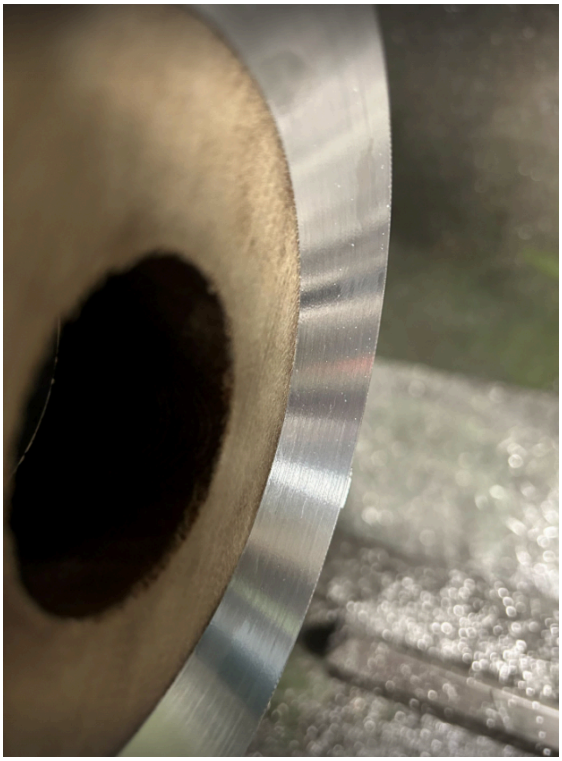
Nozzle_Exit_GOW152SAC24

1. Starting from bar stock (6” or 5” OD), Cut off a ~4.25” length section. Try to make the cut as vertical as possible to make centering on the lathe more consistent.
2. Using the 4-jaw chuck on the lathe, center the stock. Take off faces and OD turn until surfaces are smooth and concentric.
3. Flip the stock in the jaws, gripping on the smooth surface. Use a dial indicator on the already-turned surface to ensure that the piece is fully concentric. OD turn and take faces until the original stock surface is completely gone
4. Measure the total part length and OD at both ends. Visually inspect part for concentricity as a sanity check.
5. Waterjet soft jaws from 1/2in. thick aluminum plate for the CNC to effectively grip the part.
6. The CNC CAM should be written in two stages to bring the stock closer to final part diameters. Roughing with the CNC drastically reduces machining time, but it must be programmed carefully to allow extra room for precision and concentricity correction on the lathe.
    a. On both sides, CNC the OD’s to ~0.125in larger than final diameters. For the nozzle-taper side, do not overshoot the length of cut (i.e. if final length is 1.70in, only cut to 1.6in with CNC). For the phenolic-interfacing side, overshooting the depth is a good idea (just ensure you don’t crash into the vice/soft jaws). Ideally, you don’t leave a shelf, but if there is one, it can be removed on the lathe later on before step 9.
    b. On the nozzle-taper side, bore a pocket that is approximately 0.100in under the final minimum ID (i.e. if final ID is 2.418in, CNC to 2.300in) as deep as possible with provided end-mills/part length.
    c. On the phenolic-interfacing side, bore a pocket that is 0.100in under the final maximum ID (i.e. if final ID is 3.5in, CNC to 3.4in) to a depth not greater than 0.125in under final length (i.e. if final depth of 3.5in section is 1.4375in, CNC to 1.3in depth).
    d. Ensure that there is a through-hole by boring a pocket of identical diameter to step 6b on the phenolic-interfacing side to ~0.125in beyond the calculated required depth.
7. Once the CAM is written and the CNC is completed, take measurements of the resulting part to serve as a baseline for future steps.
8. On the lathe, start by gripping the larger OD (phenolic-interfacing side) on the 4-jaw. Ensure concentricity, and make sure the jaws don’t grab on the plunge point from the CNC.
9. Take a face to get a z-axis zero.
10. Take a shallow pass on the OD to final length to get an x-axis zero. Measure length and OD with calipers to set your current tool position.
11. OD-turn to final diameter and length, taking measurements after every other pass to ensure you don’t drift or overshoot.

12. If there is an external tapered section (i.e. for weight savings), set that angle on the taper slide and cut until flush with the final OD. This isn't critical, so don't ruin your OD surface for it. You should overshoot the length to ensure a flush meeting point with the larger OD turn later on.
13. Set the taper-slide angle to the desired internal angle (i.e. 15 degrees). Verify multiple times using a dial indicator to measure rise over run. Cut the internal taper with 10-20 thou passes (boring bars don't like deep cuts normally) after setting your RPM according to the formula. Running the lathe too fast could cause tool chatter and a bad surface finish.
14. Cut the internal nozzle taper until the final exit diameter is achieved. Take great care in measuring this exit diameter as close to the exit as possible, as measuring a taper properly is difficult and can result in cutting the exit too large if done incorrectly. Overshoot the depth of this taper into the part to avoid an undersizing issue with tolerances. You do not want to have a cylindrical section between the phenolic and aluminum nozzle exit.
15. Once the internal nozzle taper is cut, flip the part in the jaws. Ensure concentricity with the nozzle taper by using the dial indicator on the OD from step 11. If you indicate on the larger OD towards the end of the part, you could accumulate a concentricity error with future internal boring operations.
16. OD turn to final diameter and overshoot the length of cut to meet with the external taper that was cut in step 12. This should result in a smooth transition.
17. Configure the taper slide to the angle of your phenolic-interfacing surface (i.e. 45 degrees), and rotate the tool holder to hold the boring bar parallel to the z-axis. Use the boring bar with carbide insert and not the HSS bar, as the end of the HSS bar extends beyond the cutting tip and makes the next operation impossible.
18. ID bore to the final minimum ID (i.e. 2.418in based on step 6b). Do not overshoot this diameter. For measurement, use a telescopic gauge with calipers.
19. ID turn to ~20 thou under final maximum ID. This should ultimately match-fit with the phenolic insert if possible in a later step. The depth of this cut should be indexed as a distance from the base of the part (the nozzle taper side), not the current part length. Measuring from the clamped end ensures that tolerancing issues don't accumulate in the middle of the part. You should undershoot the depth of this cut by ~20 thou and bring it to final depth in the next step.
20. Cut the internal phenolic-interfacing angle until you meet with the larger ID that was cut in the previous step. You should then continue taking passes in increments of 1-2 thou until you meet the nozzle taper at a knife edge (Do not overshoot), working in reverse (i.e. start at the center of the part and work outward radially). This will allow you to cut the phenolic-interfacing taper while simultaneously increasing the ID from step 19 to final measurement, matching the phenolic piece, in one continuous operation. This ensures you aren't left with an internal step, and it makes a smooth transition between the two tapers and between the phenolic-interfacing taper and cylindrical section.
21. Once the phenolic-interfacing angle is cut and the maximum ID from step 19 is finalized (i.e. the phenolic piece fits inside if you're match-fitting), you can proceed to take the final tapered cut as shown here:

22. Without changing the taper angle set in step 17, take tapered faces off of the end of the part until your final part length is reached, or until this taper meets flush with the phenolic insert. The final fit should look like this:



23. Debur as necessary before drilling bolt holes
24. Set up the part on the rotary mill and ensure that it is properly centered using the dial indicator.
25. Set your initial angle to 0 degrees, and note the angular position of the adjustment wheel. There are finer markings on this wheel that can be used to ensure completely even angular spacing of the bolts.
26. Use the edge-finder to set your zero positions according to the drawing specifications. You want the mill to be properly centered, and you don't want your bolt holes misplaced, so always double check by measuring visually and with calipers.
27. Confirm your tap with the chart in the shop, and drill the holes all the way through.
28. Without removing the part from the jaws, you can use the tap to thread all of the bolt holes. Make sure the tap is level when inserted, and make sure you completely thread the holes. If you stop early, the bolts may not fit.
29. Debur and clean the threads when you're done. You can also cycle a bolt through all of the holes to ensure they are properly threaded and clean.