Alternatives to Gear Grinding

Honing and cup wheel superfinishing can be a cost-effective and higher-quality alternative to gear bore and face grinding. Nagel Precision provides the details.

By Sanjai Keshavan

STRINGENT NVH REQUIREMENTS, HIGHER LOADS, AND THE TREND TOWARD MINIATURIZATION TO SAVE WEIGHT AND SPACE ARE FORCING TRANSMISSION GEAR DESIGNERS TO INCREASINGLY TIGHTEN THE SURFACE FINISH, BORE SIZE, BORE-TO-FACE PERPENDICULARITY TOLERANCES AND FLATNESS ON THE BORES, AND THRUST FACES OF TRANSMISSION GEARS, AS ILLUSTRATED IN FIGURE 1.

Figure 2 shows tightening of surface finish tolerances over the last three decades for automotive pinion gears, challenging the manufacturing engineers to produce higher quality gears. Surface finish Ra specifications of 20 uin was common in the 1980s, it was then lowered to 8 uin Ra in the 1990s. It is not uncommon to see specifications like < 4 uin Ra for surface finish on bores and faces, 0.0002" bore size tolerance, 0.0002" bore to face perpendicularity and under 20 uin flatness requirements.

Increasingly, most gears used in high-load applications are following this trend. In many of the gear manufacturing shops that we have seen, grinding is the final processing step for both faces and bores. The goal of this article is to expose manufacturing engineers, especially in shops specializing in small and medium production runs, to cup wheel finishing and honing technology as a potential alternative to grinding.

Especially in non-automotive environments, pinion gears today are predominantly produced in the following ways:

- Bores are first turned, heat treated (for hardened gears), and then honed or ID ground. Faces are then double-disk ground to achieve final thickness and parallelism.
- Or after turning and heat treat, a twin spindle ID/face grinder is utilized to grind the bore and the face in the same setup.

Both processes have their advantages and disadvantages. When the gear faces are double-disk ground there is no control over the bore-to-face perpendicularity, which results in increased NVH during operation. With ID grinding, when performed on a twin spindle machine this problem will be overcome as the part is held in the same position as the face and bore is ground. However, for gears with smaller

Fig. 1: Typical tight-tolerance pinion gear.

diameters and relatively deep bores—with length to diameter ratio of 2:1—honing has a real advantage in speed of material removal, and over 5:1 deflection of grinding spindle will cause the bore to taper. If a finer bearing like plateau honed finish is desired, neither ID grinding nor double-disk face grinding can achieve it, and a secondary finishing operation typically has to be instituted.

Honing and cup wheel superfinishing was developed to address these problems, and they have been utilized successfully in the automotive production environment for some time now. In a high volume automotive environment, cup wheel finishing and honing are typically standalone processes. For low- to medium-volume production shops, however, this means two processes as opposed to one. Integrating these two separate, proven processes into a single system now enables low- and medium-volume gear manufactures access to the same technology utilized by automotive OEMs, eliminating the need for multiple equipment. Figure 3 illustrates a Nagel cup wheel superfinisher and bore honing machine.

In this method of processing the gear is cup wheel superfinished by clamping on the bore, and

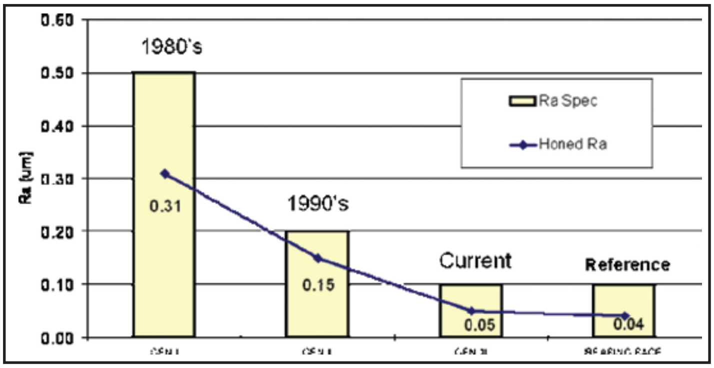


Fig. 2: Graph illustrating tightening of surface finish tolerances.

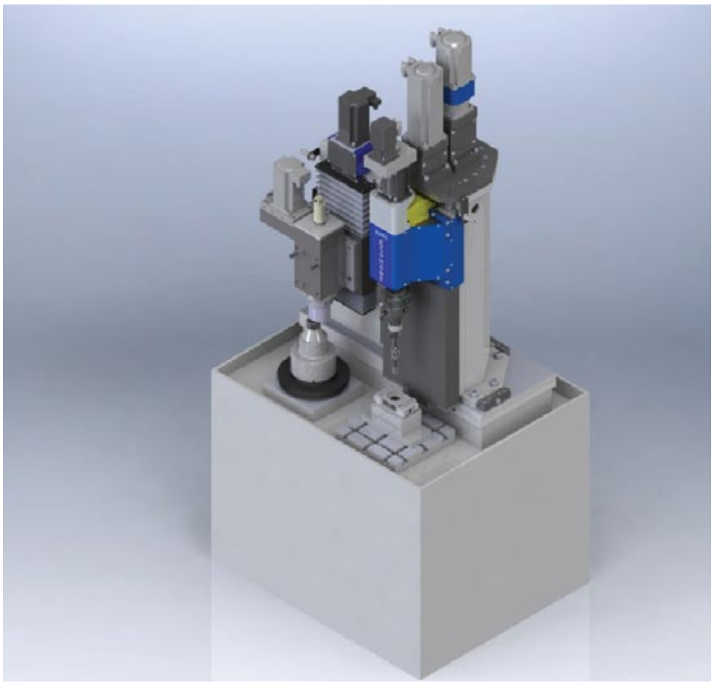


Fig. 3: Nagel SPV 150 cup wheel face superfinisher and ECO bore honing system.

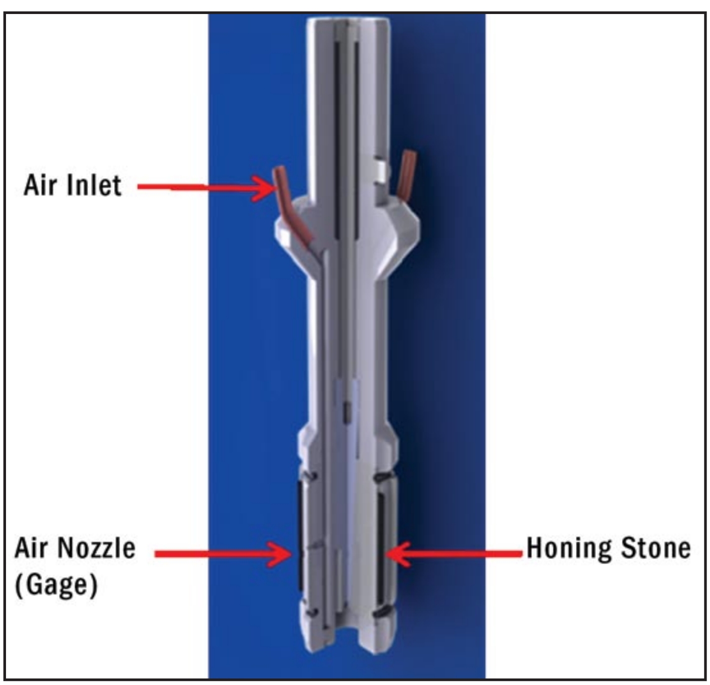


Fig. 4: In-process gage embedded in Nagel ECO 40 honing tool.

then bores are honed by locating on the finished face, yielding excellent bore-to-face perpendicularity. And both honing and cup wheel superfinishing can yield bearing race-type mirror finishes.

The SPV 150 cup wheel head is equipped with three servomotors for part rotation, cup wheel head rotation, and cup wheel positioning. The part can rotate up 3,600 rpm, and the wheel up to 2,500 rpm. Upon finishing one face, the part is turned 180 degrees and the other face is finished. The stock removal is split equally between both the faces. The servo-driven machine positioning system can accomplish a part thickness tolerance of .001” (25 um) or higher. For tighter thickness tolerances—in tenths of an inch—contact type in-process gauging can be integrated into the machine.

The ECO 40 honing head consists of three servo motors for spindle rpm, spindle stroking, and tool expansion. The tool expansion servo can be integrated to machine in-process air sizing or post-process gauging system for automatic tool wear compensation. Or the wear compensation can be accomplished with the touch of a button based on independent offline gage.

For bore sizes over 20 mm, an in-process process non-contact type air gage can be imbedded in the tool itself (fig. 4). The gage can detect the type of form error such as taper, hourglass, or barrel-shape, and make automatic adjustments to the honing program to correct the form error. Smaller bores are measured by post process gages, which could be inside or outside the machine. The machine can be automated or tended manually.

HONING AND ID GRINDING

Precision ID grinding machines are several times more expensive than an equally capable honing machine. Even more important is that the accuracy of the grinder is dependent on the machine’s positioning capability, while accuracy is mostly tooling dependent with a hone. Periodic checks, calibration, and refurbishing are needed to ensure that positioning tolerances stay tight on a grinder. A honing tool, on the other hand, has float built into the tool or fixture, making them less sensitive to positioning accuracy. Unlike a grinding wheel on the end of an arbor, the honing tool isn’t subject to spindle deflection. The tradeoff is that any given honing tool is very bore-size specific, so more honing tools need to be stocked than grinding wheels.

Another important advantage of honing is that, should a part come off a hone a few microns too small it can be run again, while that’s not possible with ID grinding. Also, grinding can’t produce honing’s characteristic crosshatch pattern and plateau finish on the bore surface. This has proven to be a desirable feature for maintaining a hydrodynamic lubrication layer for rotating members.

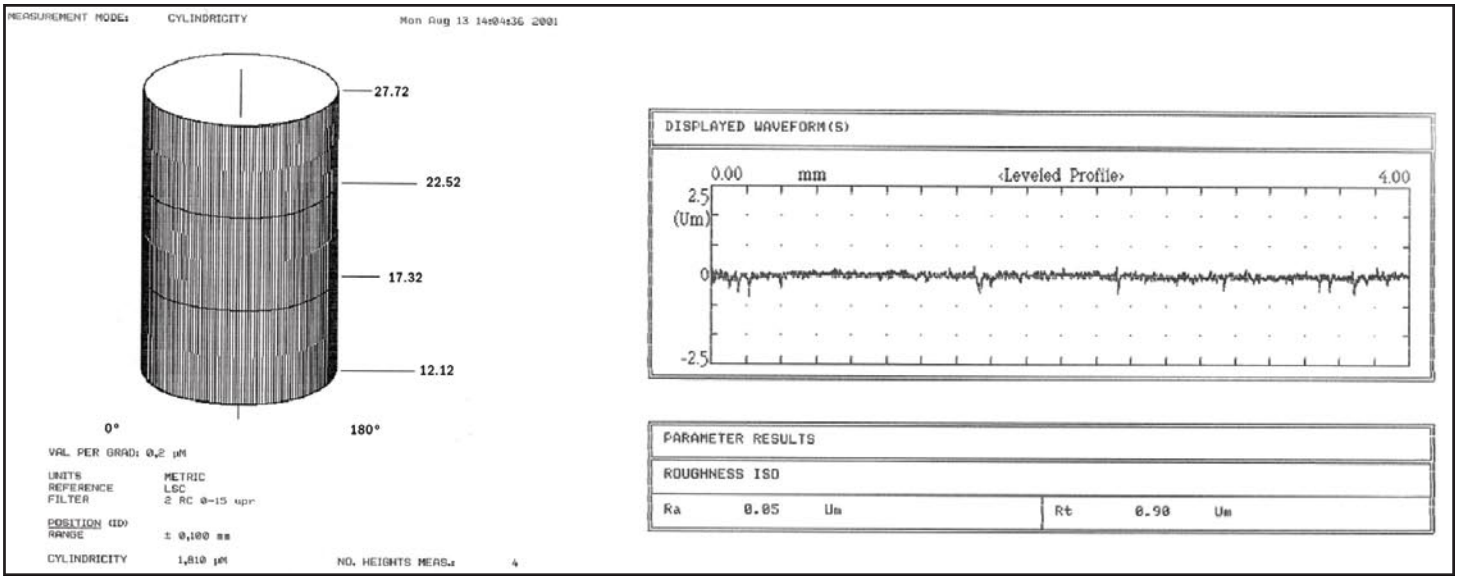


Fig. 5: **Illustrates .001mm bore cylindricity and .05 um surface finish after hone.**

Bore size permitting, the dual expansion and in-process gauging that can be built in honing permits roughing, finishing, and gauging, and all on one spindle. Getting a fine finished bore starting with a heat-treated surface with one spindle is now a reality. For smaller bores with lower volumes requiring finer surface finish, when dual expansion is not possible the part may have to be rerun with finer stone in a single spindle setup. Honing the parts twice—once with a coarser stone, and again with a finer stone—would create a finish with deeper valleys and lower peaks, making it a surface suitable for bearings. Figure 5 is a cylindricity trace illustrating 40 uin cylindricity (LHS) and 2 uin Ra plateau hone finish. As it can be observed, the trace has deeper valleys and lower peaks.

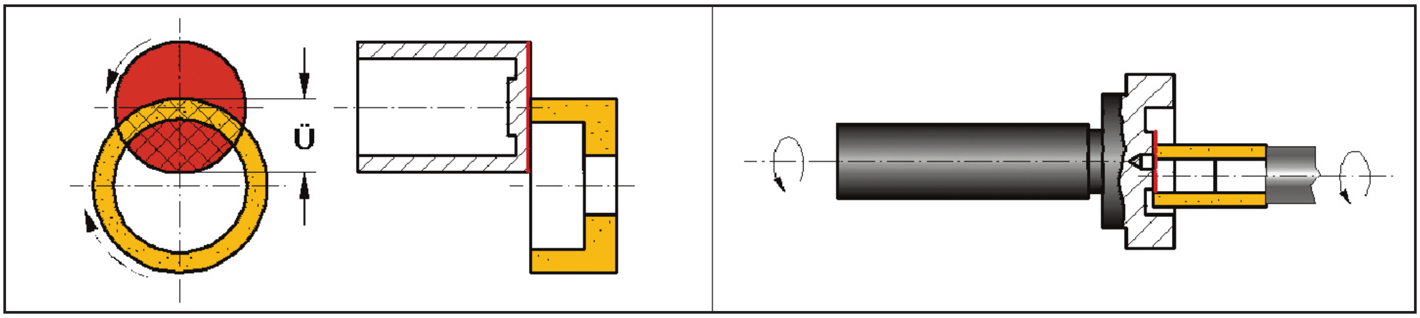


Fig. 6: **Schematic of Nagel SPV 150 cup wheeel finisher.**

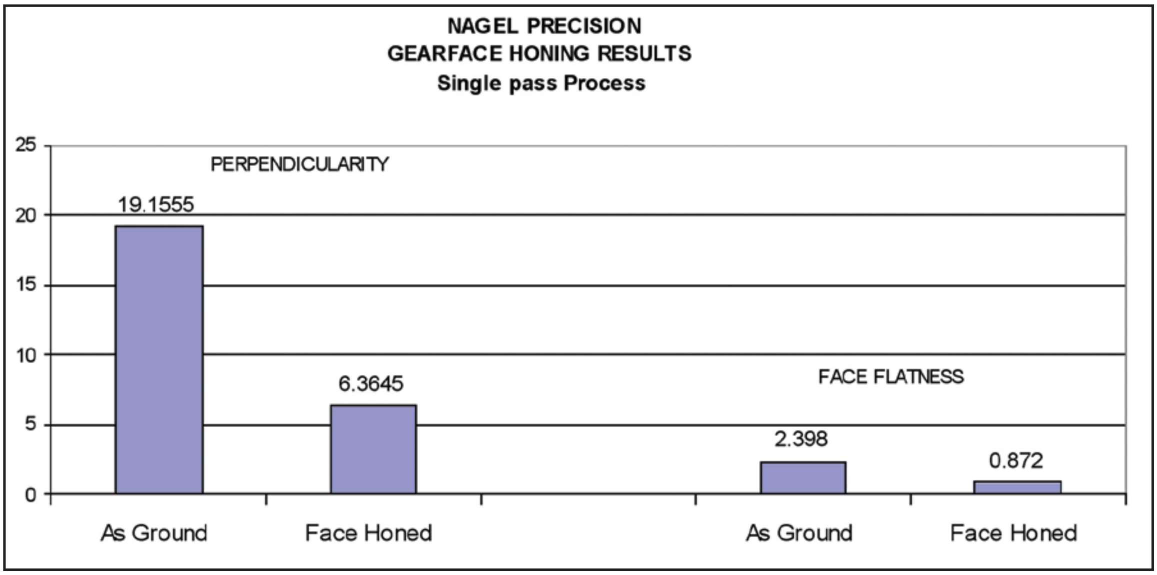
CUP WHEEL SUPERFINISHING AND FACE GRINDING

The SPV 150 face finisher differs from conventional grinding operations. The accuracy of ordinary grinding operations depends on rigid fixturing, as well as the accuracy of the grinding wheel's position relative to the part, whereas the SPV 150 utilizes free cutting cup wheels and the tools self dress and conform to the contours of the part. This automatically compensates for inaccuracies in the machine.

During this operation, the gear is clamped on the bore diameter and rotated in a direction opposite to that of the cup wheel at a high surface speed. To prevent variations in flatness or axial runout when finishing flat surfaces, the cup wheel tool substantially overlaps the surface of the part during finishing (fig. 6). The machine can remove as little as a few microns of stock to a few hundred microns very quickly. If the gear is coming straight out of heat treat and a mirror-like finish is desired, another pass may be necessary to accomplish the task. This can be achieved either by rerunning the part or by mounting an automatic cup wheel changer, which would change the wheel quickly and enable roughing and finishing in the same setup.

Bore-to-face perpendicularity is comparable with a cup wheel finisher and ID grinder. Cup wheel superfinishers can yield finer finishes, though, and are not as dependent on machine accuracies as grinders are. Double-disk face grinding, on the other hand,

Fig. 7: Comparision of bore to face perpendicularity and flatness after grinding and cup wheel face finishing.



yields a higher production rate and excellent parallelism between faces. They do not impact the bore to face perpendicularity tolerance, however. Figure 7 provides a comparison of bore-to-face perpendicularity and flatness on a cup wheel finished face vs a double-disk ground face.

In conclusion, the honing and cup wheel processing that has long been the predominant way of making pinion gears in high-volume automotive applications is now possible in a lower- and medium-volume environment.

ABOUT THE AUTHOR:

Sanjai Keshavan is manager of the ECO Hone Division of Nagel Precision, Inc. Call (734) 426-1812 or go to [www.nagelusa.com].