Advanced Concepts

Michael Fleming, Seco Tools

for Hard Turning Gears

Since the late 1980s, examples of hard turning replacing grinding operations have been well documented. Advantages such as low cost per part, process flexibility and environmental benefits are often stated as reasons for adopting hard turning. In many manufacturing organizations, hard turning has been accepted and implemented.

As an accepted machining technology, hard turning's expected improvements are the same as for all other machining processes. For example, continued pressure is placed on manufacturing to reduce total cost per part in order to remain competitive. Consequently, high-productivity machining is now a driving force in the development of PCBN (polycrystalline CBN) tooling.

This article looks at two high-productivity tooling concepts, plunging and wiper technologies, and explores the opportunities for both concepts. Using practical gear machining examples, comparisons of surface finish, cycle times and tolerances are made to highlight the capabilities of these different machining concepts.

Hard turning is an accepted machining process for finishing hardened workpiece materials. It is flexible, efficient and cost effective compared to other machining techniques. Since its introduction, and with the assistance of machine tool builders, the development of new PCBN grades and improved tool fabrication methods, hard turning has continued to generate significant performance improvements.

Transmission components are often hard turned, and in this article, an automotive synchromesh component is machined using different tooling concepts. The number of different operations on the component highlights both the advantages and limitations of the different concepts used. Whereas several years ago the hard turning options were quite limited, today there are a number of options available. It is important, therefore, that manufacturing processes should be designed around manufacturers' needs, matching tool technology with manufacturing output.

Hard Turning—Basic Technology

When talking about basic hard turning technology, most people refer to using standard ISO insert geometries in

continued

Figure 1—A typical hard-turned part.

Component	**Synchromesh gear**
Material	Case hardened steel
Hardness	60 HRC
Operation	Facing, OD and ID turning
Conditions	
Tool material	Secomax CBN100
Cutting speed	200 m/min
Feed rate	0.015–0.04 mm/revolution
Depth of cut	0.15 mm
Coolant	Yes
Result	
23 grinding machines replaced by 4 CNC lathes	

Figure 2—A standard CBN100 insert from Seco-Carboloy.

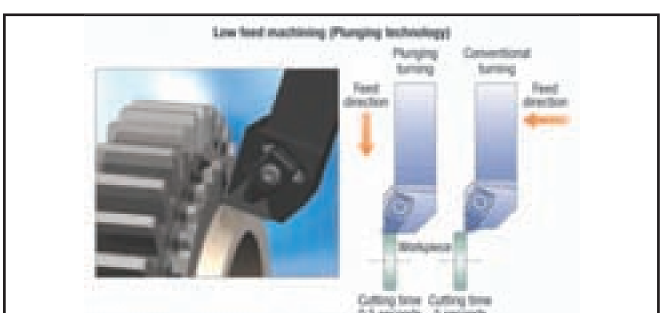

Figure 3—Plunging technology vs. conventional turning.

standard toolholders to machine hardened components by generating the required component profile. A typical hard turned part is seen in Figure 1.

The machining process usually involves multiple operations, such as ID boring, facing, back facing and turning the synchromesh taper. Since this can be achieved in one machining setup with hard turning, there is an immediate benefit compared to grinding. Eliminating setups results in the reduction of reject parts due to positional inaccuracies. Dimensional and surface finish tolerances are met by adjusting machining parameters. Component holding and machine tool stability also play an important role. This technology has been used very successfully since the late 1980s and continues to be the basis for replacing grinding operations.

High-Productivity Machining Techniques

As with all developing technologies, once the basic concept has been accepted, modified concepts inevitably evolve. In the case of hard turning, the current emphasis is on increased productivity. Interestingly, one process uses low-feed machining. The other, as one might expect, is a high-feed finish machining technique.

Plunging Technology

Plunging essentially uses a significant part of the cutting edge length to generate the machined surface. The concept is not entirely new, since it has been used very successfully in the plunging of valve seats in engine cylinder heads. However, with the development of solid PCBN tool materials, the concept of plunging has expanded into other application areas. For example, the triangular shape of Seco-Carboloy's CBN100 inserts give them six cutting edge lengths (Fig. 2), making that product especially well suited to plunging operations as well as conventional turning techniques.

The main advantage of plunging compared to conventional hard turning is the reduction in cycle time, which can be anywhere between 75–90%. Figure 3 shows the basic principle of plunging.

The process relies on a number of key factors. The insert edge quality is important in achieving good surface finish and maximizing tool life. It is also necessary to increase the cutting speed and reduce the feed rate. This reduces the cutting forces, ensuring excellent dimensional accuracy. To maintain dimensional accuracies, the insert is allowed to dwell at the base of the cut for two to three revolutions. To avoid the cutting edge profile affecting surface finish, a small axial movement is made. With these techniques employed and a good machine tool setup, it is possible to achieve consistently high surface finishes and component accuracy. In gear turning, plunging has been used for machining gear faces and the synchromesh tapers. The longest edge to have been machined by plunging with PCBN is 16 mm.

Wiper Technology

Wiper technology has been proved in tungsten carbide tooling. The advantage of using wiper inserts is the ability to machine at higher feed rates. The concept of wipers is shown in Figure 4. Effectively, the wiper concept is to put a large radius or series of large radii behind the nose radius. This gives the insert the same effect as a larger radius or round insert where the wider contact area broadens and reduces the depth of the peak-to-valley surface finish ratio generated by hard turning. This allows the feed rate to be increased, without reducing the surface finish. With advancements in tool fabrication techniques, it is possible to apply the concept to PCBN inserts. The benefits of using wiper technology for hard turning is two-fold: Firstly, the productivity improvements, and, secondly, the reduced contact time, which provides improved tool life. In gear machining, a wiper insert is typically used for machining the internal bore.

One of the latest developments in PCBN wiper technology is the development of the Secomax CBN100 Crossbill wiper insert (Fig. 5). This insert combines the advantages of solid PCBN with a left- or right-handed wiper design. Until recently, wiper designs on solid PCBN inserts were limited in their ability to machine towards a shoulder. This is due to the wiper design on one edge giving the reverse design on the opposite side of the corner radius. The introduction of the CBN100 Crossbill insert has addressed this issue. The CBN100 Crossbill is available in both right- and left-handed formats. It can be used for axially turning (with all the benefits of wiper technology) towards a shoulder, but due to the design, it can also machine radii.

Applying High Productivity Techniques

Wiper and plunging processes can be applied to a range of different applications in high volume production. For example, in gear cone taper turning, a combination of plunging and wiper is often the best solution. A typical synchromesh gear, including dimensional and surface finish tolerances, is shown in Figure 6. The first critical area is the synchromesh taper (Fig. 7). To machine this surface, there are three options: 1) conventional turning, 2) plunging or 3) wiper technology. Conventional turning is the tried and tested method and acts as the benchmark to compare against plunging and wiper technologies. In conventional turning, the cutting speeds and feeds used would be in the region of 150–200 m/min. and 0.1 mm/revolution, respectively. The parameters used for plunging are seen in Figure 8. As mentioned earlier, successful plunging relies on an increased cutting speed and reduced feed rates.

The insert used is a solid Secomax CBN100 triangular insert with negative tool geometry, which provides six cutting edges per insert. In plunging operations, tool positioning is critical, as this will be replicated on the workpiece. In machining the taper, a special 'custom' toolholder is required to provide the 6.5 degree angle, and final adjustment of the angle needs to be done on the machine. The major benefit of plunging is in the reduction of cycle time. Plunging at a feed rate of 0.04 mm/revolution, the depth of cut is completed in four revolutions plus a nominal dwell, giving a contact time of 0.04 seconds, whereas conventional turning requires 4.96 seconds. As well as the cycle time improvements, there are additional benefits with plunging. Figure 9 shows the general effect of insert nose radius on surface finish. As expected, the larger the nose radius, the better the surface finish. Interestingly, when compared to conventional machining, plunging usually

continued

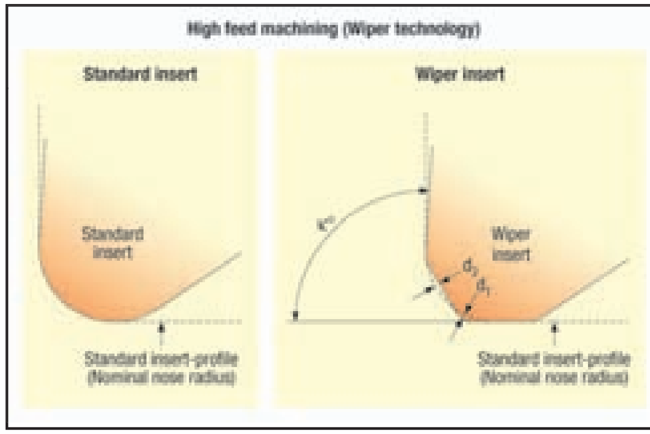

Figure 4—Comparison of standard insert geometry and wiper insert geometry.

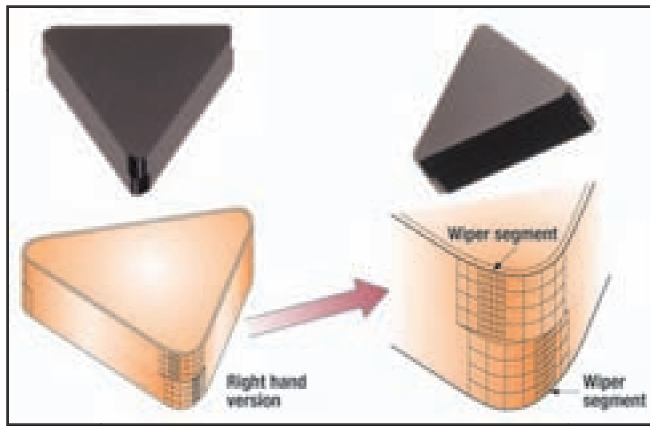

Figure 5—The Secomax CBN100 Crossbill wiper insert.

Cone taper (first arrow)	
Angle	6.5º ± 0.04”
Diameter	58.92 mm ± 0.025
Roundness	0.004 mm
Straightness	0.002 mm
Surface finish	0.2 µm Ra
Bore (second arrow)	
Diameter	47.75 mm ± 0.015
Roundness	0.004 mm
Straightness	0.003 mm
Parallelism	0.006 mm
Surface finish	0.2 µm Ra

Figure 6—Tolerances for a typical synchromesh gear.

Figure 7—Manufacturers have several options for machining the synchromesh taper.

Figure 8—Parameters for plunge turning a synchromesh taper.

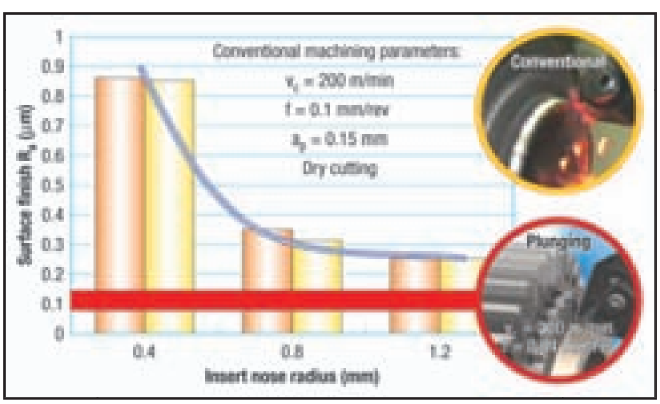

Figure 9—The general effect of insert nose radius on surface finish.

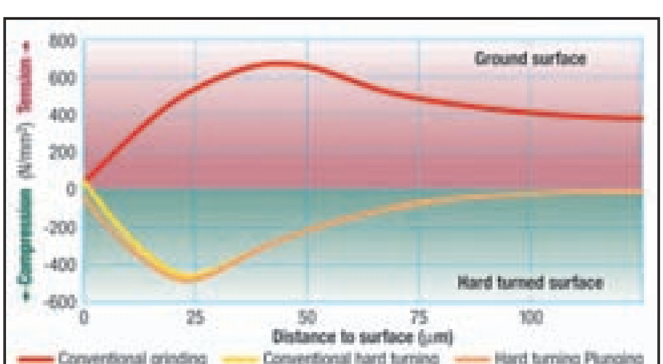

Figure 10—Differences in part stresses depending on type of machining.

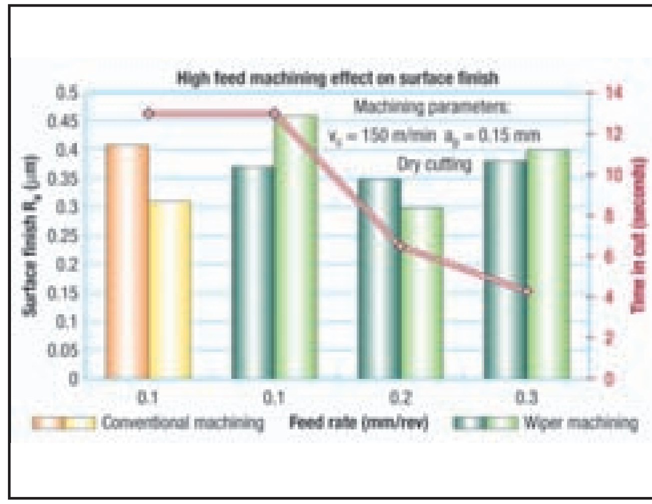

Figure 11—There is little or no advantage to using a wiper insert at low feed rates.

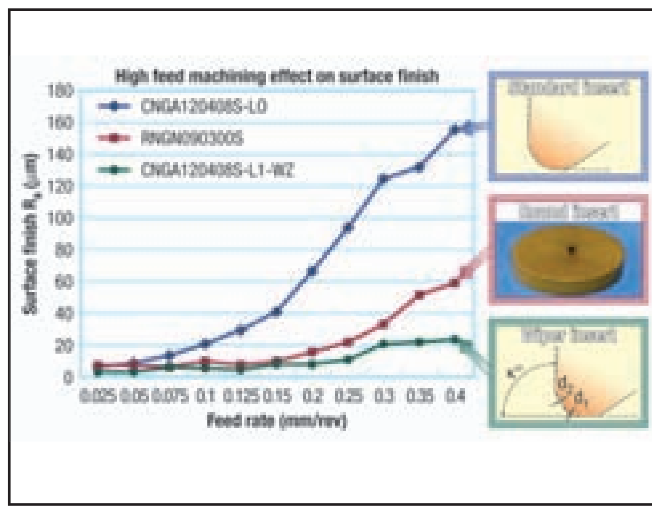

Figure 12—Round inserts are an alternative to wiper technology for through-hole boring or OD turning.

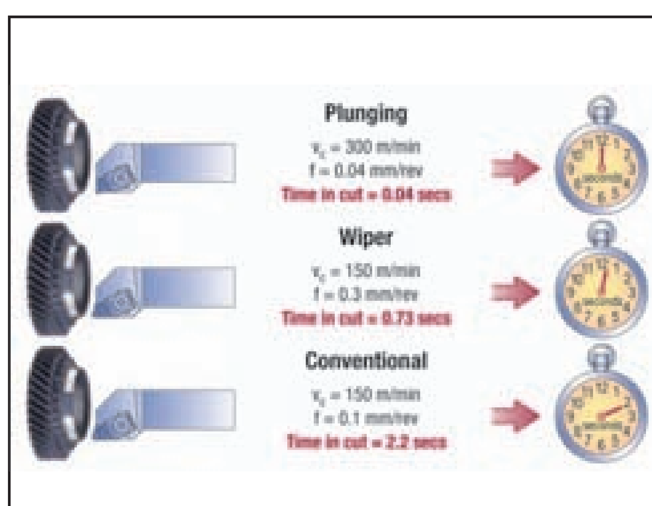

Figure 13—Options for front or back facing.

produces a much better surface finish.

Analysis of residual stresses in machined surfaces have also shown plunging to have a positive benefit, depending on a number of factors, such as edge condition, machining parameters, etc. It is possible to put the complete surface of the machined part in compression. For dynamically loaded parts, this, of course, raises interesting possibilities. Figure 10 shows the main difference in stresses between conventional hard turning, plunging and a rough ground surface. Plunging the surface also removes issues related to the spiral or helical surface finish effect created by the helical tool path of conventional turning.

Using wiper technology on the tapered cone is an option if a reduction in cycle time is required compared to conventional turning; however this would require setting the insert to the cone angle to ensure a proper wiper effect. The bore of the gear can be machined using either conventional or wiper inserts. Because of the length of the bore, plunging is not a viable option. The main benefit of using a wiper insert is to increase stock removal rates without affecting the surface finish on the component. As Figure 11 shows, there is little or no advantage to using a wiper insert at low feed rates. Depending on the wiper design, feed rates can be more than three times higher than for conventional turning. Potentially, this can lead to reduced cycle time as well as longer tool life. An alternative to using the wiper concept is to use an insert with a larger nose radius, such as a round insert (Fig. 12). While this alternative is acceptable for through-hole boring or through OD turning, it is not possible to machine up to shoulders, limiting its application. Using either a wiper or round insert with a larger contact area does increase the pressure on the cut, although because cutting forces in hard turning are low, this does not usually present a problem in achieving dimensional accuracy.

Often, the final operation is the facing of the front and/or back faces. All three options are possible and, of course, because the area is small, the cycle time in all cases is low (Fig. 13). Nonetheless, there is an opportunity to minimize cutting time by employing plunging techniques.

In industrial applications it is important to combine the available technology with manufacturing requirements. Figure 14 shows the preferred option for one transmission maker. Plunging with solid CBN100 is used for the tapered cone and front face. The bore is machined using a CBN100 wiper insert, and the rear face is machined using the conventional geometry on the CBN100 wiper insert.

Conclusion

By taking an automotive synchromesh gear as an example, the author has shown how multiple machining operations can be machined with conventional hard turning in one setup, offering increased positional accuracies as well as reduced cycle times. Compare this with the more traditional grinding techniques that are inflexible and require several grinding machines to complete the part. The result is the continuing trend towards finishing parts by hard turning with PCBN. With the emphasis of industry very much on increased productivity by reducing cycle times, the two new machining techniques discussed in this article make a significant contribution. While both techniques have some limitations, it has been demonstrated that when the component geometry allows it, the use of plunging and/or wiper technology offers significant improvements in cycle times and therefore increased productivity.

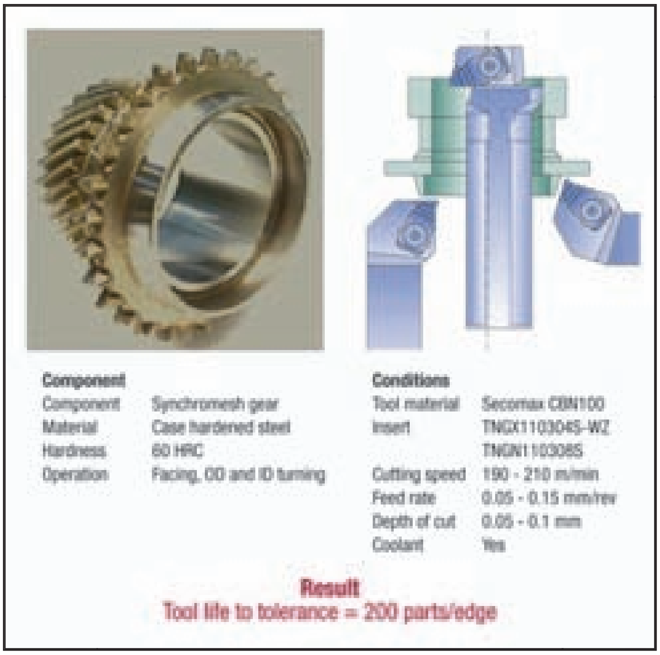

Figure 14—The preferred option at one manufacturer is to use plunging for the tapered cone and front face and wiper inserts for the bore and rear face.

For more information:
Seco-Carboloy
11177 E. Eight-Mile Rd.
Warren, MI 48089
Phone: (800) 832-8326
Internet: *www.secocarboloy.com*