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SPECIAL FOCUS:

MAKING AUTOMOTIVE PARTS

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Taking The Plunge

A look at the advantages of plunge turning hardened parts.

It's no secret that turning hardened automotive parts, such as bearings, gears, shafts and pinions, is becoming an increasingly attractive alternative to traditional grinding operations. Accordingly, a growing number of hardened parts—those in the 45 to 68 HRC range—are now being successfully finish-machined this way. This has been made possible by improvements in machine tool rigidity and the development of polycrystalline cubic boron nitride cutting tools.

Speed, flexibility and reduced energy consumption are a few of the benefits being realized through hard turning, a process the automotive industry began experimenting with more than 20 years ago. In the mid-1990s, though, a process called "plunge turning" emerged that is now rewriting the rulebook on hard-part machining.

In plunge turning, the entire cutting edge, or a portion of the edge, is utilized to make an orthogonal cut. This contrasts with conventional hard turning, in which just the tool's tip is used.

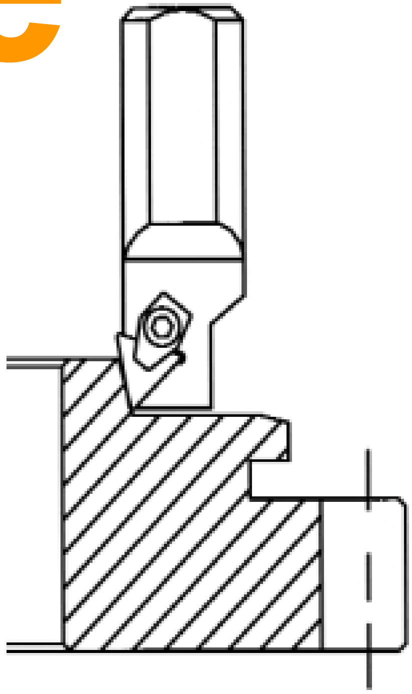
The productivity improvements possible with plunge turning are even more impressive than with hard turning. Compared to grinding, hard turning can reduce machining time by 60 percent. Plunging can cut machining time by up to 90 percent, compared to grinding. And, the surface integrity of plunge-turned parts is comparable to that achieved when grinding.

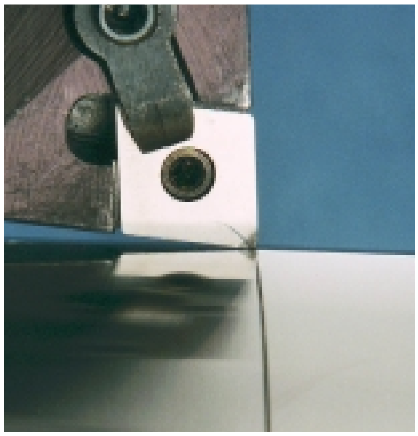
Meeting Tight Tolerances

The most critical properties of ground or hard-turned components are dimension (diameter), roundness, straightness, bearing area, surface finish and residual stresses. For the first four of these properties, tests performed by Carboloy have shown that tight tolerances are achievable when plunge turning gear wheels or bearing rings (Table 1).

In conventional turning, which generates a continuous groove, surface finish is largely determined by insert nose radius, feed rate, cutting speed and DOC. In contrast, the surface quality of plunge-turned components is mainly dependent on the quality of the cutting edge. As a result, plunge-turned components display low residual stress in the axial direction, and their sealing properties are equal to, or better than, ground parts.

The distribution of residual stress in the tangential direction is more interesting. Surfaces that have been plunge-turned, conventionally hard-turned or ground are significantly different from one another. Plunging introduces compressive residual stress at the surface, while conventional hard turning and grinding create tensile residual stress at the surface. (CRS has a positive effect on a component's fatigue-resistance characteristics.) TRS generated during hard turning changes into CRS at approximately 2µm below the workpiece surface. With grinding, TRS extends





All images: Carboloy Inc.

In plunge turning, the entire cutting edge, or a portion of it, is used to make an orthogonal cut (top). That compares to conventional hard turning, in which just the tip of the tool is applied to the workpiece (bottom).

deep below the surface before it changes into CRS.

Carboloy found that after a tool plunged 150 workpieces, the machined parts exhibited signs of TRS at their surfaces. But, the affected zones on the plunged workpieces were significantly less than those of the parts that had been conventionally hard-turned. The same held true after plunging and hard turning 250 workpieces.

Diameter	± 0.0006” (0.015mm)
Roundness	± 0.00015” (0.004mm)
Straightness	± 0.00015” (0.004mm)
Bearing Area	90% deep [0.00008” (0.002mm)]*

*This percentage defines how much bearing or contact area a surface has after machining. Here, it means that at a depth of 2µm, 90 percent of the material in the part profile remains.—Ed.

Table 1: Tolerances achievable on a gear wheel or bearing ring when plunging.

Also, as tool wear occurs during conventional hard turning, more heat is generated at the tool/workpiece interface. This leads to the buildup of “white layer” and the creation of a tempered zone in the workpiece. When plunging, the white layer and tempered zone are significantly reduced. This is because plunging develops less flank wear on the tool edge due to the shorter cutting time per machined surface.

Plunging also generates lower cutting forces and less friction, which results in less heat being introduced to the center of the workpiece. The increased volume of the plunging insert also helps to dissipate the heat more efficiently.

Hard Facts About Costs

Objections to both conventional hard turning and plunge turning typically involve the high initial cost of PCBN tools. They cost 10 to 20 times more than conventional tools.

However, studies have shown them to be 10 to 300 times more effective in hard-part applications in terms of overall productivity and tool life. These findings are partly based on a tool-cost-per-part analysis.

For a better understanding of the economic benefits of hard and plunge turning, it helps to consider a few factors that are sometimes overlooked by the accounting department. These include the lower tool-change, setup and cycle times, as well as reduced machine maintenance, better part quality and lower machine tool cost.

Part of the cost-effectiveness of hard and plunge turning can be attributed to the machine tool itself. A CNC lathe typically costs one-half to one-third as much as a grinder. Also, CNC lathes are much more flexible in terms of their machining capabilities. Tool changes can be made in less than 2 minutes, for example, eliminating the production time losses that arise when changing a wheel. This flexibility allows fast, cost-effective production of small batches of parts.

Low maintenance is also a benefit. Worn PCBN tools can be quickly removed and replaced, and, compared to wheels, they require no truing or dressing to maintain their cutting profile. CNC lathes also take up less floor space than grinders, require no flume systems and, for many hard-turning applications, do not even require coolant.

In fact, since hard turning and plunging effectively remove metal by “peeling” the softened chip from the workpiece, coolant generally is not recommended. This helps keep costs down while eliminating the environmental complications associated with coolant use. Dry machining also reduces the time and money spent on government-regulated chip disposal and reclamation processes.

Greater flexibility, faster tool changes and longer tool life make it easy to see why hard turning has become so popular—and why plunge turning is steadily gaining converts.

About the Author

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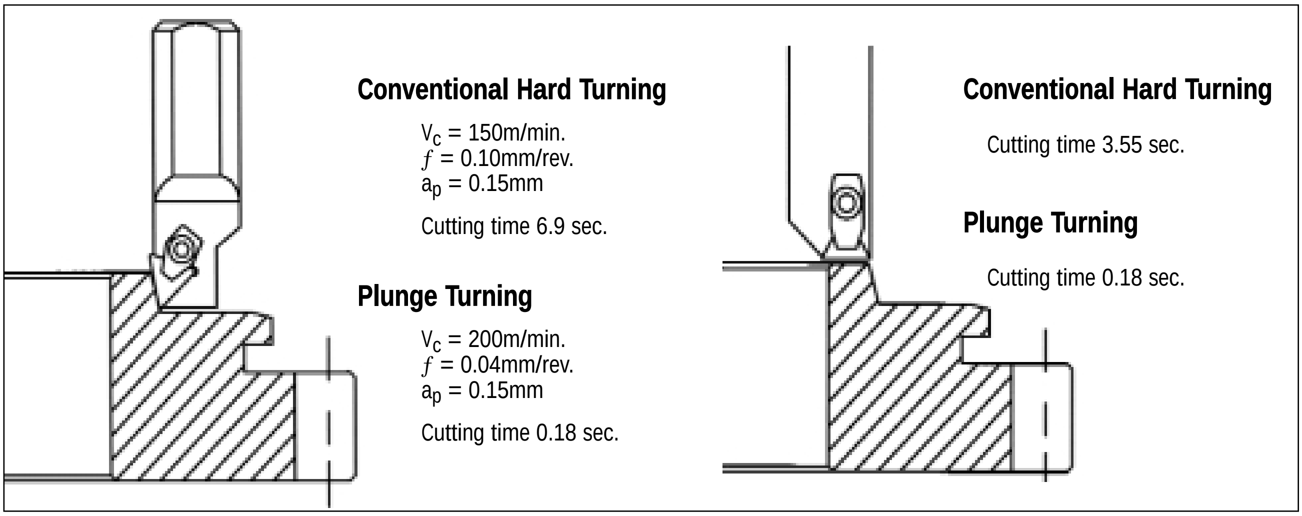

Two examples of the time savings possible when plunge turning a gear compared to conventional hard turning. V_c = cutting speed, f = feed and a_p = DOC.