Hard Turning

Advantages and

Reduced costs and increased flexibility make hard turning a viable alternative to grinding for the finish machining of shafts and cylindrical components. The added bonus of hard turning's ability to machine heavily interrupted cuts gives it additional possibilities in the gear industry.

"Pump shafts are probably the biggest example," says Tom Sheehy, senior application engineer with Hardinge Inc. of Elmira, NY. Hardinge manufactures high-precision lathes and tooling designed specifically for hard turning applications. "We've done a lot of testing for some very big-name pump companies, and we've done gear faces and held within three-tenths on overall width, down to less than 50 millionths flatness and better than an 8 Ra surface finish down the gear face."

In addition to machining hardened gear faces and outside diameters, hard turning can also be used to create special geometries, Sheehy says. "On a splined drive shaft, we have gone in and actually plunge-cut grooves. The spline teeth are already in there, but we can go in and put a groove in there for a retaining ring, which is a very hostile environment for a cutting tool."

In addition to pump shafts and transmission shafts, hard turning also has other gear-related applications. "We do a lot of side gears and differential gears for rear ends," Sheehy says. "After they've been pre-turned and hardened, we come in and do a lot of the facing and turning of the overall diameter and length."

But before you go out and buy some CBN or ceramic inserts to try them on your old engine lathe, you have to know a thing or two about what makes hard turning successful, says Hans Strey, project manager for Hardinge.

Some manufacturers have misconceptions about hard turning, Strey says, because they've tried it on an older piece of equipment or they didn't understand the importance of the tooling, and the result was poor tool life, which makes the process seem more

William R. Stott, Managing Editor

Applications in the Gear Industry

expensive. "They think it doesn't work," Strey says.

"You can have an XYZ brand machine and put hardened material on it and a CBN insert, and you can hard turn, but for how long and how effectively and how accurately?" Strey says. "Can you remove hard metal? Almost everybody can do that. But is your process stable and your machine process-capable?"

Process stability and system capability are what make the difference between being able to hard turn five pieces per insert and being able to hard turn 500 pieces per insert. "There's a lot in the machine tool—the collet, the spindle, a hydrostatic way system," Strey says. "There is a lot to it."

But it all boils down to three very specific requirements for successful hard turning, Strey says: "Number one, rigidity. Number two, rigidity. Number three, rigidity."

To develop a successful hard turning process, you have to look at six key areas for rigidity, Strey says:

Machine Rigidity

A machine designed for hard turning uses components that are designed to withstand the high cutting forces. That means a superior linear track, ball screws and machine base.

Vibration Dampening

That old engine lathe built decades ago may look sturdy, but it's probably not up to the task. A modern machine with a polymer-concrete casting has many times the vibration dampening ability of those old cast-iron bases.

Solid Workholding

Just like the machine, the workholding has to be rigid. "If your workholding looks like swiss cheese inside, it won't be rigid," Strey says.

Rigid Tool Location

"The closer you can hold the part to the spindle bearings, the better off you are," says Sheehy. For example, Hardinge has a patented collet spindle that allows the part to be placed inside the spindle, very close to the bearings. "Again, it's that focus on rigidity," Strey says.

Part Rigidity

Not all parts are suitable for hard turning. In particular, if the length-to-diameter ratio is too high, the part will not be rigid enough. Those parts have to be finished by grinding. When the part is supported with a tailstock, the length-to-diameter ratio can be as high as 8:1, Strey says.

Rigid Tools

A rigid tool must have a good-size tool shank and minimal overhang, Strey says.

Each of the six areas is just as important as the others, Strey says. "If you change something on the part rigidity, you'll

continued

have a huge impact. If your machine stiffness is not that good, it has an immediate impact on the process. While all the other five may still be at peak levels, that one element is going to wreck your process."

Strey and Sheehy agree that not all parts are candidates for hard turning. "Hard turning is somewhat of a niche," Sheehy says. "If you're going to try to produce a part that's 1" diameter and 6" long, and it's 62 Rockwell C, grind it. You're not going to hard turn it. It would be very, very difficult to hard turn because of the length-to-diameter ratio. The part doesn't have the rigidity."

On the other hand, Sheehy says: "If you take a 6" diameter part that's 1" long, bring it to me. That is a very good candidate for hard turning."

When it is applicable, hard turning often has many advantages over grinding. One of the biggest advantages is reduced cycle and setup times, Strey says. "Typically, metal removal rates are four to six times higher versus grinding."

But even more important is reducing the number of setups. On a typical part, Strey says, you might have to finish machine the outside diameter, inside diameter and face. On a grinding machine, that would require three different grinding wheels and three different setups. On a lathe, you might need a different tool to go inside the bore, but for machining faces, shoulders, radii, forms, contours or tapers, it's the same single-point tool, just with a different program.

"Today we have lean manufacturing," Strey says. "Nobody wants to have any parts on the shelf. Companies can't afford that anymore. That means they will produce two or three coming down the aisle. That means machines have to be able to be set up quickly to accommodate a flexible process. Hard turning is a big, big link in that process."

Also, Strey adds, in the early days of hard turning, the only ones who could commit the resources toward ensuring the process was stable were the larger companies. But today, the biggest benefits of hard turning may be realized in the smaller shops, where flexibility is most important.

"In the mid-'90s, certain companies were already in production doing hard turning," Strey says, but he adds that it's getting more prevalent in smaller operations. "That is where the big benefit is—the smaller operations—30, 50, 80 people."

Sheehy adds that a lathe designed for hard turning can also do soft turning, so the machine that cuts the part can also be used to finish it after heat treatment. "I can hard turn on it today, I can cut aluminum tomorrow, I can use the tailstock next week. That's the flexibility part," Sheehy says.

Other possible cost savings with hard turning versus grinding include lower energy costs, easier chip removal and not having to use or dispose of coolant. Also, according to Sheehy, the total machine tool investment is probably around half the cost of a grinder.

Hard turning has really picked up over the last three to five years, Sheehy says. The reason has been the increase in availability of CBN and ceramic inserts that make the process more practical for a wider variety of applications. "The tooling technology is finally starting to catch up with the ability for hard turning," Sheehy says.

Despite the gains of hard turning in many manufacturing environments, there are still many applications for which it's suitable, but for which it isn't being used. In part, that's due to people having tried it and failed or having tried it with limited success. "They think it's witchcraft," Sheehy says. "They think it's a black art. But when you come right down to it, it's metal removal. Whether it's soft or hard, you still have to understand the theory behind it." ■

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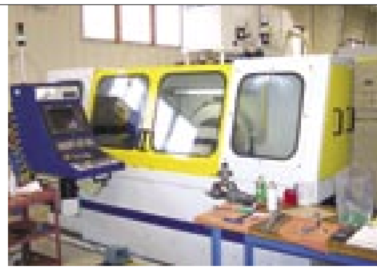

Man with a Mission

In 2002, Fred Young was contacted by a manufacturer with a problem. NASA had contracted the business to make parts for the space agency's two Mars exploratory vehicles. The parts included 12 gears for the vehicles' wheels, but the company couldn't make them to NASA specifications. Could Forest City Gear?

Yes.

But first, NASA had to change the design.

Young and his employees cut gears; they don't design them, but they do check designs before production to make sure they're possible. The wheel gears were designed with severe crowning on their teeth and were designed for shaping. That was a problem. Forest City would need a special shaper cutter with enough side clearance to create the crowning. Producing the cutter would've been difficult, Young says.

So he talked NASA engineers into slightly adjusting the design so the teeth could be hobbed using a special small diameter hob.

The tweak did the trick. Forest City crown hobbed the gear teeth on the titanium wheels, six for each rover, and shipped them out. In summer '03, NASA launched Spirit and Opportunity on their Mars missions. In January '04, the two rovers landed on the red planet.

Today, a year later, Spirit and Opportunity are still tooling around Mars on their Forest City gears.


My Other Gears Are On Mars
Forest City Gear manufactured 12 spur gears for the wheels of two Mars exploratory vehicles. This scale model of one of the rovers commemorates Forest City's contribution to the NASA mission. The model sits atop a display case in Forest City's lobby, along with this aluminum version of the gear itself.

Doing a Few Things Very Well

Located in Roscoe, IL, Forest City is a niche manufacturer of loose, custom, fine- to medium-pitch gears. Young and his employees cut gears. They don't design them. They don't heat treat them. They don't turn gear blanks. They don't even cut all types of gears. They limit themselves to spurs, helicals, worms and worm wheels.

They can hob, shape and broach, and they can gear grind, skive, deburr and chamfer. So they can create gears to AGMA Q14 quality. After they're