Getting In Sync

Power skiving is here to stay, and as a result of this industry shift, it's become paramount to improve how well machining spindles synchronize with each other.

Alex Cannella, Associate Editor

Advanced cutting techniques like gear skiving are forcing multitasking machine manufacturers to improve their machine spindles' synchronization.

Gear skiving is making big waves in the gear industry. Though the process has existed for over a century, recent advances in machine construction have finally brought it into the spotlight as a competitive manufacturing process. For certain types of parts, especially internal gears, a high-end, dedicated gear skiving machine — like those produced by Gleason, Klingelnberg, Pittler, Profilator, Toyoda and others — is the most productive option.

Unfortunately, not every gear manufacturer has such a machine. However, many *do* have a mill-turn machine or multitasking machine, and although they'll never have the same productivity as a dedicated gear skiving machine, it *is* possible to do gear skiving on those. For this article, we talked with two machine tool manufacturers — Mazak and Okuma — to see how far they've come.

Gear skiving, in its current iteration, has come far and done much for the industry, specifically for the manufacturing of internal gears. As a high speed cutting process, it greatly reduces the time it takes to cut a workpiece. But as Arthur Bloch once said, "every solution breeds new problems." For multitasking machines, the problem of the day manufacturers face is getting a machine's milling and lathe spindles to synchronize at high rotational speeds. Dedicated gear manufacturing machines tackled this issue long ago, but for multitasking Millturns, high-speed spindle synchronization hasn't previously been a priority, and so they have some catching up to do. Making sure a machine's spindles are accurately synchronized to each other is vital for ensuring no errors occur during the gear skiving process.

"It's all rotational accuracy," Chris Peluso, lathe applications engineer at Okuma, said. "If the drives can't tell you where the spindle is at any given time, it can't match the two. The lathe spindle and the milling spindle need to be synchronized at a ratio based on the number of teeth on the part and the number of either cutting teeth or threads on the cutting tool. So if you can't maintain that perfect ratio at speed between the tools and the workpiece, you can come out with a bad part or have a catastrophic failure."

It's not hard to imagine how having the spindles out of sync would lead to catastrophic failure or bad parts. During these high-speed processes, both the workpiece and the cutting tool are in motion. Getting a specific point on a cutting tool to line up with the centerline of the workpiece it's meant to cut while both of them are spinning at high speed is like getting celestial bodies to align. It needs very exact timing to happen. And as with any cutting process, it needs to happen repeatedly in rapid succession. And because it's gear production, it needs to be done with accuracy requirements of within a few microns. *And* each spindle needs to move at an entirely different speed. For example, a workpiece's spindle could be moving at 500 rpm, while the cutting tool's spindle needs to move double that. And when you break down all the different variables at play in a particular gear — the dimensions and number of teeth, the speeds each spindle needs to move at for the tool to meet the workpiece in the intended manner, the cutting tool being used, and the angle it strikes the workpiece at — it becomes obvious how being just a hair off with any of these variables can result in a drastically different cut than desired, and that includes the timing of the spindles.

(Editor's note: high-end, dedicated gear skiving machines typically offer synchronized spindle speeds of 3,000 rpm or higher.)

Accuracy requirements are always high in gearing applications, but with all these different moving parts, gear skiving makes those demands tighter than ever, which is why the issue has suddenly come into focus. Multitasking machines traditionally haven't needed to synchronize their spindles as tightly as dedicated gear manufacturing machines, as they've generally been within necessary tolerances for other cutting techniques, and if it ain't broke, there's no reason to fix it when there are a dozen other ways to reduce manufacturing time. But now that gear skiving is growing in popularity, multi-tasking machine manufacturers are looking to their spindles with higher scrutiny.

"If an endmill in a milling operation would fluctuate plus or minus, say, 5%, that's not really going to cause any issue in terms of chip load," Joe Wilker, advanced product manager, hybrid machines at Mazak, said. "The chip load will vary, but a very, very small amount. But we can't have that type of variance in a gear skiving application. So we have to have much finer control of both the milling spindle's rpm and the part spindle's rpm."

That shift to electrics versus gear-driven machinery is the primary way companies such as Okuma and Mazak have been solving the synchronization issue. A big part of the equation is moving away from spindles with mechanical drives and instead opting for ones driven by electric motors. But there are other steps involved, as well, such as Okuma's "High accuracy C-axis," which features a higher resolution than competing encoders and have an accuracy of ±2.5". Okuma also tries to ensure high accuracy by producing everything in-house, which can help reduce the amount of confusion involved in maintaining and tweaking machinery.

"Because it is all in-house, we can tune the servo-drives," Peluso said. "So how much gain is needed for positioning versus how much is needed for locational accuracy, that can all be modified by the people here in the U.S.…Say they have a one manufacturer's control and somebody else's drive, who's responsible for tuning the drive to work with the control? With us, there's only one source. There's only one person to talk to. If it's the control or the mechanical side, we have all the resources at our disposal here."

Mazak, meanwhile, recently developed a pair of new multi-spindle multitasking machines that were unveiled at the last IMTS. One is the Integrex e-1250V/8 AG (Auto Gear), a vertical multitasking machine. The other, the Integrex i-200ST AG, a horizontal multitasking machine with a tilting B-axis. Both machines are capable of manufacturing gears, as well as other gear components such as shafts, rings, complex workpieces and gearbox parts.

"These AG machines are for shops that normally would turn away gear work or send gear work out and/or do not have the capital to purchase a high production gear machine," Wilker said. "With one machine platform, one work holding the overall part accuracy is improved within relation to part datums and gear features."

The machines also run Mazak's *Smooth Gear Cutting* software packages for skiving, hobbing, and milling, in addition to their gearskiving abilities.

Both companies have upped their programming game, simplifying the complicated process of gear manufacturing and its numerous variables to just a few required data points. Mazak has their Smooth series, and Okuma has their own built-in gear programming function along with a servo-navi designed for tuning spindles. All the user needs to know are a few gear factors such as the module or number of gear teeth, and by answering these few questions, the CNC software builds the fully editable programs that are required for cutting the feature, including the emergency retract routine, which keeps the spindles in sync while the cutter moves to safety.

"We basically developed some user-friendly CNC technology programming, making it easier for operators at all skill levels to program gears," Wilker said. "There's always been this black voodoo of 'Oh, gear cutting. That's over here in the black box and nobody knows anything about it.' And we see it as: 'It's basically part geometry.'"

"You don't have to sit there and calculate what rpm does the main spindle need to run, and then what speed does the work spindle need to go, and if I want to do this number and depth of cuts, how do I do all of this?" Peluso said. "So we really simplified the programming standpoint."

Through software and mechanical improvements, the issue of synchronizing spindles has actually become pretty well-tackled, at least in the minds of the experts at Mazak and Okuma. Manufacturers have gotten spindle synchronization to where standard modules are produced with relative ease. But like anything else in manufacturing, there's always room for improvement, and dedicated gear machines still have the edge in their max speeds that spindles can synchronize at. And going back to Arthur Bloch, every solution still breeds new problems. We'll see what new problems arise to be tackled next.

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