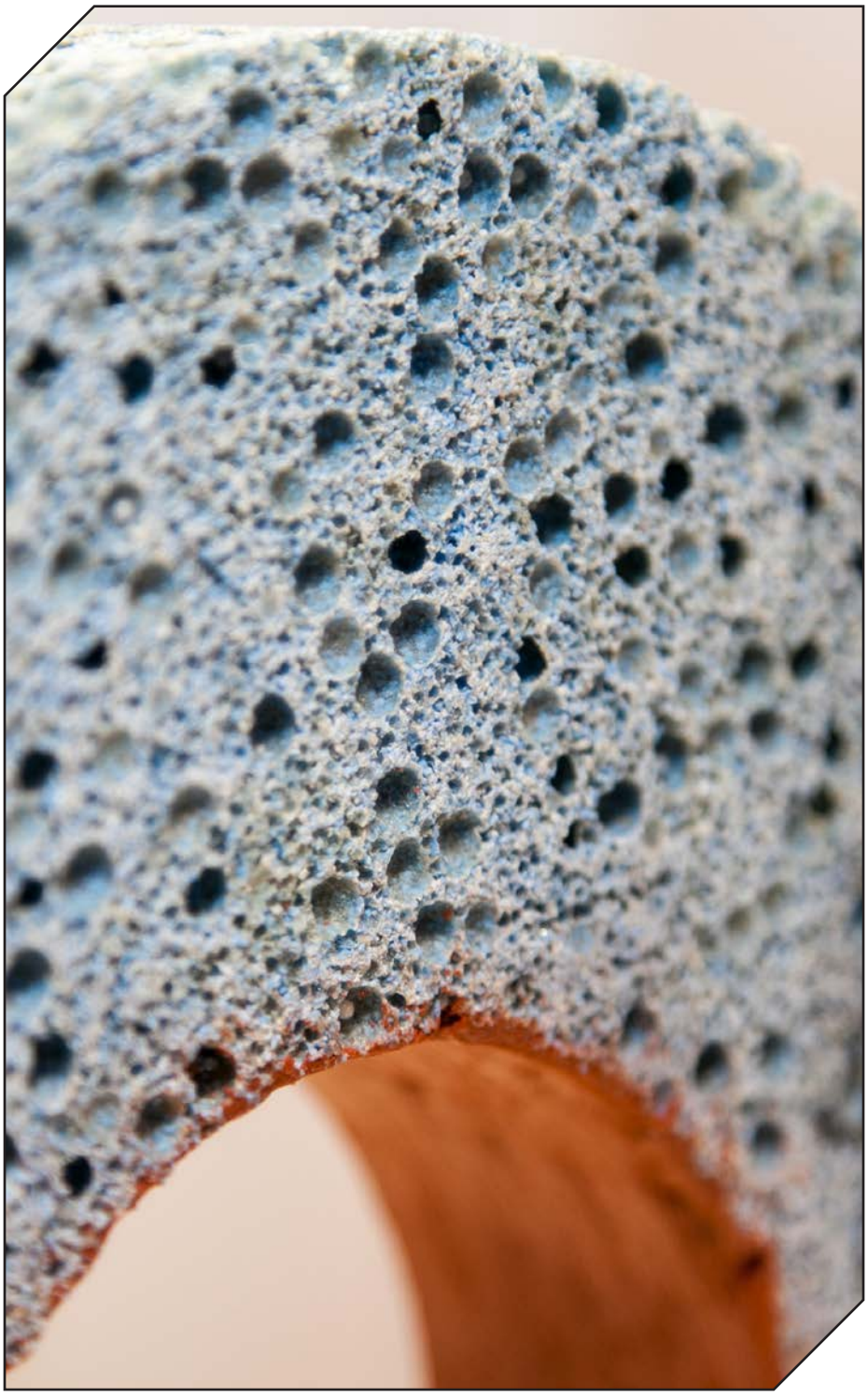
Gear Grinding is Getting Easier, Better, Faster, Stronger

Erik Schmidt, Assistant Editor



Liebherr is well-known as one of the world's largest privately owned companies—a titan in heavy industry specializing in cranes, trucks and mammoth earth moving and mining equipment. But Andreas Mehr, grinding and shaping technology developer and consultant at Liebherr Verzahntechnik, GmbH, Kempten, Germany, is one of the world's leading experts in a much smaller area of focus:

Gears.

The grinding of them, to be exact.

And despite the rather minute scale of a cylindrical gear in comparison to, say, the LTM 11200-9.1, Liebherr's nine-axle mobile crane with a 100 m (328 ft.) telescopic boom, their importance in Liebherr's overall productivity is no small matter.

Quite simply: no gears, no Liebherr.

Recently, *Gear Technology* met with Dr. Mehr at Liebherr Gear Technology, Saline, MI, where he spoke of Liebherr's cutting-edge, state-of-the-art grinding processes to make gears quieter, stronger and more efficient.

Bring (Down) the Noise

When talking with gear experts like Mehr, Gleason's Dr. Hermann J. Stadtfeld and Dr. Antoine Türich, or David Goodfellow and Mark Ritchie from Star-SU, the main questions they pose when it comes to gear grinding are clear.

"Our customers—automotive, truck transmission, tractors, and also industrial gears—we see the upcoming question: How do you improve the power density per unit?" Mehr says.

"The other thing that customers ask is what possibility do you have to decrease

gear noise? This is especially big in the automotive section, but it's also coming up in the industrial section because if you have a transmission in an escalator it should move nice and quiet. Also transportation systems in production facilities should move without noise. At the moment, these are the two big questions of our customers."

In other words: How do we make gears stronger and quieter?

In terms of advancements with machinery, Liebherr recently introduced the LGG 180 for profile and generating grinding. According to a recent press release, the machine combines short grinding times with consistent high large-scale production quality, thanks to a one-table design and a new-design grinding head. The advantage to the one-table solution is higher quality throughout the entire production. Every machined part is manufactured under the same conditions for the highest reproducibility. The one-table approach provides the statistical capability and reliability in continuously producing controlled µ-range finish quality.

The new grinding head allows for rotation speeds up to 10,000 RPM and has spindle power of 35 kW. Given this performance data, the head enables high cutting speeds and high feed rates. The new grinding machine can exploit the considerable potential of the innovative abrasive 3M Cubitron II, the press release said.

But then again, none of that information is necessarily going to stop the presses.

What *is* groundbreaking, front page material, however, are the processes and the math Liebherr is utilizing to get the most out of its LGG machines.

"We can now do these noise excitation optimized modifications — NEO modifications," Mehr says. "That means we create a defined waviness to reduce noise in a high-frequency whining noise. These modifications are not new. You can make them on the old Maag gear grinders, where they do generate grinding with indexing in a single flank contact. But these machines have completely gone away from the market.

"Now, Liebherr developed the mathematics and the machine dressing and machine movements to bring this correction possibility into the continuous generating grinding process. That was the trick — and that is absolutely brand new.

Maag machines, which were prominent in the 1970s and 80s, have all but vanished from the market in present times as modern machines have gotten faster and more efficient.

"There are still a few old ones kicking around, but they are tremendously slow," says Scott Yoders, Liebherr's vice president of sales. "The cycle times are like one hour — I'm sorry, one day — for a part. But [when it comes to NEO modifications] it's the same principle."

Instead of letting a possibly groundbreaking innovation die with the old Maags, Liebherr dusted off the decades old process developed by its very own Dr. Gerd Sulzer and applied it to cutting-edge technology.

And what they discovered was a revelation to modern generating gear grinding.

The situation is that we can now apply [the NEO modifications] to generating

grinding, says Yoders. "And that is really state of the art."

Idle Time is the Devil's Workshop

Türich, vice president of product management - grinding solutions, of Gleason Corporation (Rochester, NY), has also been working on conquering his own burdensome list of gear grinding problems. One of which, like Liebherr, has been noise reduction.

"We have a slogan — which is a bad slogan — but we say, 'Singing gears are happy gears,'" Türich says. "But nobody wants to hear the gears in the gearbox because it's a terrible noise. So noise issues are an important factor."

Another concern, though, is shortening grinding time, a point that brought the conversation tangentially back to both Cubitron II and Liebherr.

"To speed up the process is a never-ending story," Türich says. "Every time we think, 'Wow, this must be the pinnacle,' someone else is coming on the market with a new grinding material and you can once again increase your productivity.

"One important point here is the grinding material Cubitron II, and I'm quite sure [Mehr] over at Liebherr also told you about it, because they are heavily advertising this technology as well — and they are right, it's really something that is maybe a game changer."

But grinding time, according to Tuerich, isn't the only thing that matters.

"It's not everything," he says, "because at the end what counts is the cycle time. You also have to add non-productive idle time, which is loading and unloading. If you're doing gear grinding, you have to index your parts in order to mesh them together with the grinding wheel. If you can grind faster and faster but you're not working on your idle time, then your idle time, in proportion, will get higher and higher. This is something that customers don't like.

"This is something that we've recently worked on. Our latest development is a new grinding machine called 200GX, which is a new double-spindle grinding machine. There are two work spindles, and on one spindle we are doing the grinding cycle, while on the second spindle — it's the non-productive spindle — we are exchanging the workpieces and clamping and indexing the workpieces, to minimize the idle time.

"This is our latest machine development, although I should say this is nothing really new to the market since there is already some competition on the market for a couple of years."

Among those competitors are Reishauer, which introduced their double-spindle concept several years ago, and Star-SU LLC (Hoffman Estates, IL), a company that prides itself on the uniqueness of its gear grinding machines and its ability to consistently produce products "equal or better" than anything else on the market, according to president David Goodfellow.

"We have a lot of gear grinding equipment in both the horizontal and vertical environment," says Mark Ritchie, Star-SU's vice president of sales - engineering. "Right now we're promoting the G 250, which is our vertical twin-table machine, which is capable of being converted into a single table machine up to 450 mm parts. In conjunction with our

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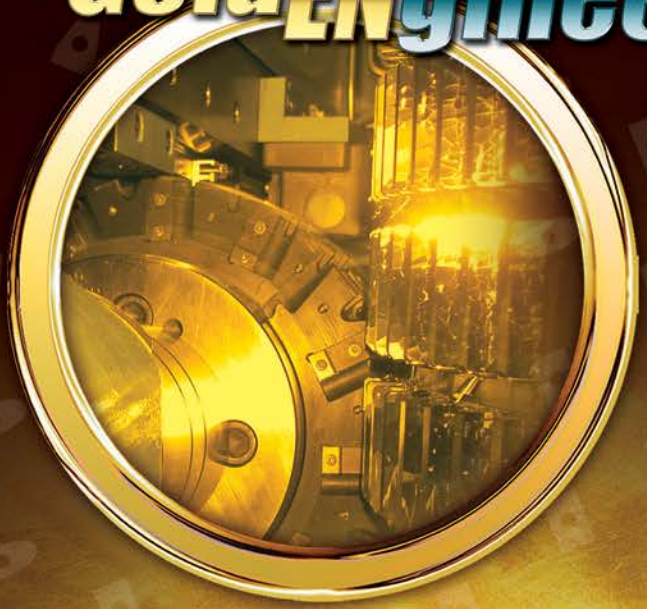

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ability to contour dress and bias grind we also have technology in our control that manages all transmission errors that are known to cause noise issues in a gear set. We have also developed technology that allows us to manage the surface pattern and roughness of the gear surface to further reduce the noise of the gears and increase the surface toughness.

"For us, that's kind of a unique thing where it gives us a little bit more modularity, if you will. We're using the same machine for various part sizes. We do have some very interesting technology that is available on the G 250 that we don't see on a lot of our competitors. We have the ability to use threaded wheels with an outside diameter of 110-90 mm for special applications.

"We also have a spindle multiplier that we use with very small CBN wheels that allows us to do higher production, difficult-type parts up to 24,000 RPM. These are some of the unique features of the G 250."

The G 250 machine, which debuted at EMO in 2011, is based on the established concepts of the Samputensili S 250/400 G machine—so consider it the latest evolution of a product line that has long been considered one of the industry's standard bearers.

"The vertical machines are more orientated toward the automotive industry," Goodfellow says. "Very high-volume production, and of course the trend today in automotive transmission boxes is going away from hob and shaved to hob and ground gears. This leads us, therefore, to the promotion of the G 250 double-spindle machine, which takes cycle time out of the machine. It can change the part very quickly and we're grinding parts down in about 10 seconds.

"So you need to change the workpiece from the ground piece you just did to the next piece in less than two or three seconds. Otherwise, if you have a five second cycle time between workpieces, then 50% of your grinding cycle is in your workpiece changing.

"Everyone is in a fight now to take the idle time out of the grinding process. That's the reason for the double spindles."

Interestingly enough, for a company that routinely throws out the "unique" designation when speaking of its machines, Goodfellow surprisingly downplayed the notion that there's much of a difference between what companies such as Reishauer, Kapp, Gleason, Liebherr and Star-SU are doing in terms of gear grinding.

"There's nobody that has a super special, unique thing that is so different that nobody else can do it," he says. "It's always about who has the faster load-unload; whose got the more reliable machines; whose got the latest technology; whose got the best accuracy.

"I believe we are equal or better than anybody else that's out there."

Goodfellow paused briefly after that confident declaration, and then added:

"You also often don't know what somebody else has got on the drawing board. But it will certainly be worth visiting us at EMO Milan to see what new technology advancements we're coming out with."

Carrying the Load

Twenty-five years ago, Liebher's Sulzer had one of the busiest drawing boards in the industry.

Among several processes Sulzer patented while at Liebherr was one for a form of polish grinding that created a fine surface finish on cylindrical gears.

"It's an old concept," Mehr says. "It was from the same guy: Dr. Sulzer. He had a very creative brain. He patented the process in 1988 based on an electroplated CBN tool for roughing and finishing and a resin bonded wheel for super finishing mounted on one arbor … nobody wants to have it. Twenty-five years running this patent, nobody asks. Now the patents are over and everybody wants to have it.

"Therefore, we had to [change the process a little bit] due to the new abrasives [on the market] — for example, roughing with Cubitron II to get a fast roughing process, then maybe we make a finishing with a finer grit size, and at the end [we use] the resin bonded, synthetic, elastical polishing worm."

Liebherr's polish grinding process is past testing and is close to going into production, Mehr says.

According to Reishauer, polish grinding is a final machining sequence performed on a manufacturer's existing gear grinding machines that consists of one polish grinding pass with a resin bonded section joined to a vitrified bonded threaded grinding wheel, said Walter Graf, marketing manager for Reishauer AG, during a presentation on polish grinding at the CTI Symposium held in May in Novi, MI.

According to Graf, the aim of polish grinding is a reduction in surface roughness without altering the gears' macro geometry, the gears' flank topography and the material surface structure. The polishing process has to remove the peak surface roughness, reduce the core roughness, but leave intact some of the peak valley roughness such that transmission oil films continue to adhere to the transmission gears. Because the surface roughness of a polish ground gear is substantially reduced, it will cause less friction in a transmission and, consequently, would offer increased load-carrying capacity and a reduction in power loss.

"The reason for [polish grinding] is that some customers want to increase the load carry capacity on the gear flank," Mehr says. "You also can get a better efficiency out of the transmission, because you can change the transmission oil; you can make it more liquid so that the slipping wear when the gears are running through the oil can be reduced.

"It's possible, but not the biggest aim for the customer to reduce gear noise with this. It's really load carrying capacity of the asymmetric gears and the efficiency of the transmission — those are the two big aims."

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