The Measure of a Gear

Plastic gears still have an entire frontier to explore, and how they measure up against their steel cousins is a question still being investigated.

Alex Cannella, Associate Editor

Any time someone takes a look at plastic materials for gears, the question inevitably comes up: How well can it compete with steel? Typically, the way it goes is that every year we check in, sit with bated breath to see if somebody came up with a plastic material capable of standing up to the same pressures as steel, and then the news we report is a more underwhelming "well, they're getting stronger, but not yet."

According to Stefan Beermann, CEO of *KISSsoft*, however, that's looking at the question the wrong way.

"It would be wrong to play plastic against steel, although the question is typically phrased that way," Beermann said. "There are typical plastic applications and typical steel applications. The question is what torque do we want to transmit and what is the cost structure."

Beermann views plastic gears instead as a product that have carved a niche of their own. There's no sitting around waiting for them to "compete" in this case. They're already here doing their own thing. The question of steel versus plastic isn't one of competency or technology, it's a question of priorities and what you need to get a job done.

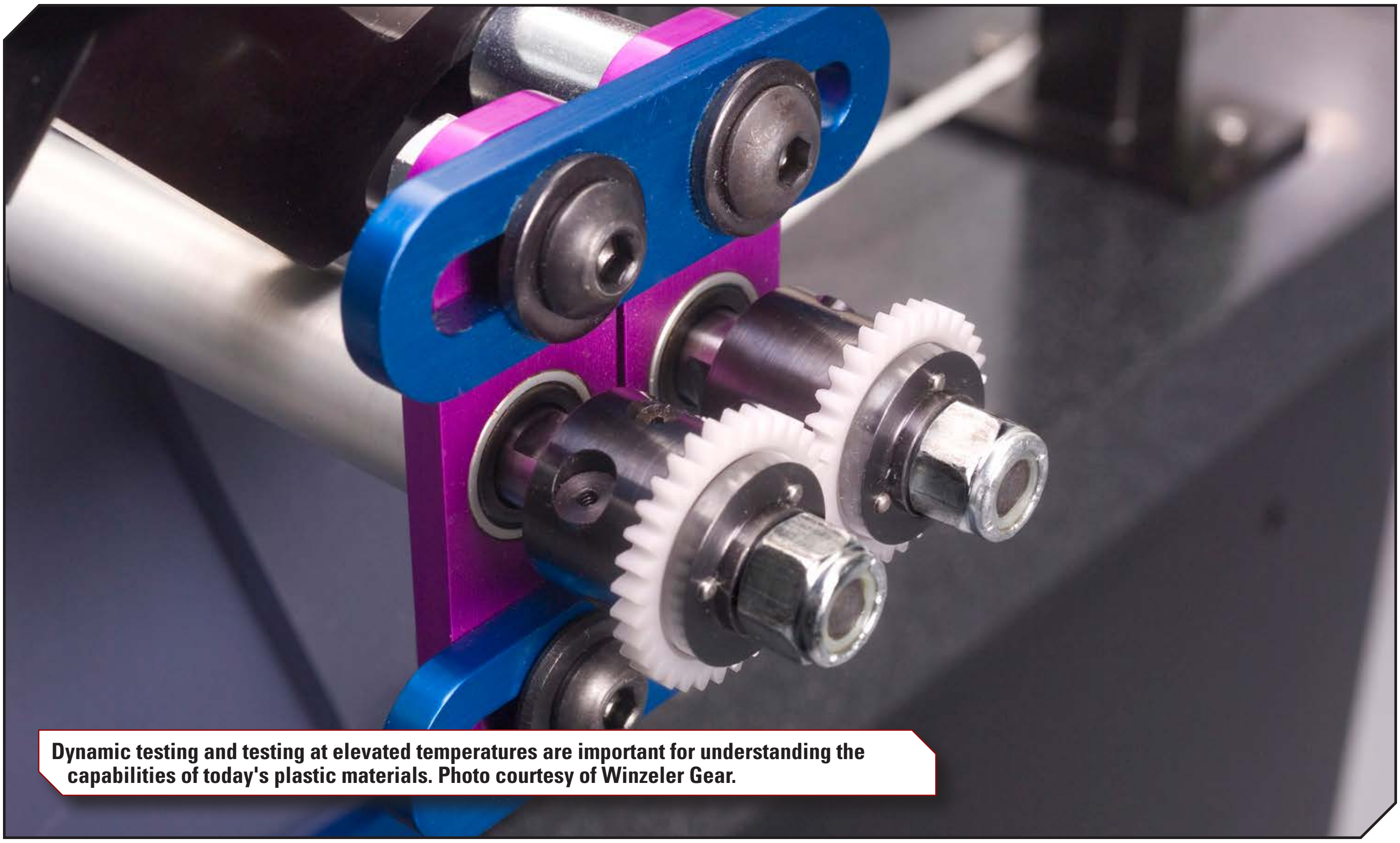
"Plastic gears are unbeatable in typical actuator applications with a large batch size," Beermann said. "On the other hand, in gearboxes, where large torque occurs and the size is somewhat limited, steel is the material of choice."

But that said, Beermann also noted that this perception is starting to shift. "What changed a lot in the last [few] years is that engineers now take plastic gears as a serious alternative. They started to treat them as 'real' gears."

As John Winzeler, president of Winzeler Gear, noted, one primary advantage some plastic gears hold is how many teeth can safely share loading, achieving some rather impressive contact ratios. In particular, he cited one material, Delrin, a proprietary material sold by partner business DuPont.

"The beauty of our favorite material [Delrin] is the fact that if you're designing with metal gears, and most gear designs, if you get more than a contact ratio much above 1, you probably have failure, because the teeth do not flex," Winzeler said. "The phenomenon we have with Delrin is that in highly loaded applications, up to 85 degrees Centigrade, we can have up to four teeth in contact and not have failure. So you have tremendous load sharing."

While in some cases, as with actuators, plastic gears are a clear choice, in others, it's more of a gray area. Take automotives, for example. According to Winzeler, one of the trends in the automotive space right now is to make everything more compact,



Dynamic testing and testing at elevated temperatures are important for understanding the capabilities of today's plastic materials. Photo courtesy of Winzeler Gear.

a trend that plastic gear manufacturers are adjusting to design around. Steel or reinforced plastics have a natural advantage here. As space grows tighter, plastic gears have a harder time keeping up with the stresses that come with an increased power ratio, not to mention their significantly lower melting point. And to muddy the waters even further, plastic gears can be reinforced with filler materials that will allow them to withstand higher temperatures, but in turn make the gears even stiffer and exhibit contact ratios more like their steel competitors. Often, it's a worthwhile tradeoff, but it's always a tradeoff.

"[Reinforcing plastic material] leads to higher stiffness and higher strength, especially for the root," Beermann said. "For housings and other non-gear parts, the story ends here. In case of gears, however, we have two opposing trends: the higher strength allows higher root stress. On the other hand, the higher stiffness reduces the contact ratio under load, thus increasing the root stress. Besides higher costs for the material and a more complicated molding procedure, fibers can also cause tribological problems: If significant wear occurs, at some point the fibers will come to the surface (more precisely, the surface comes to the fibers)."

But plastic gears also have an edge of their own. Due to being softer materials, they can reduce, though not single-handedly solve, gear noise, a primary and ever-growing focus for the increasingly electric-based automotive industry. As engines begin to ditch their gas motors, gears quickly become the loudest part of the machine, and the squeaky wheel gets the grease. In the case of gear noise, it's an almost literal saying. Sometimes, you can even take things one step further and mix rubber into the plastic, making the gear even softer and quieter.

But while plastic gears can help, Winzeler noted that ultimately the issue of gear noise is a system-wide problem that requires you to look at more than just a gear.

"Companies are coming to the plastic material suppliers and saying: 'make us quieter systems,' but it's really a system," Winzeler said. "The gears alone aren't going to do it."

Taking the Measure

For Winzeler, the primary division between steel and plastic gears is one of knowledge. As a new concept (at least relatively to steel gears), plastic materials just don't have the weight of as many years of research behind them. While the occasional conference headline touts a bold future of new plastic materials better than ever, Winzeler is instead digging deeper into the ones we already have.

"Plastics, unlike steel, there's still not the wealth of data for structural durability or design data to know as much as we need to know," Winzeler said. "And so the work that we're doing with our partner DuPont continues to be dynamic testing and doing testing at elevated temperatures to learn more about the materials we have today instead of the next generation material."

According to Winzeler, much of today's gear design either comes from tribal knowledge or historical data, but what Winzeler is pursuing, along with their partners Dupont, is more

Molded gears made from DuPont's Delrin material. Photo courtesy of Winzeler Gear.

dynamic testing under broader ranges of conditions.

"We have to know the limits of the materials," Winzeler said. "We have to know the limits of the processes we're using for those materials. We have to know are the parts designed or optimized for the process of the material, and the engineering tradeoffs that go into product design for gears and gear transmissions."

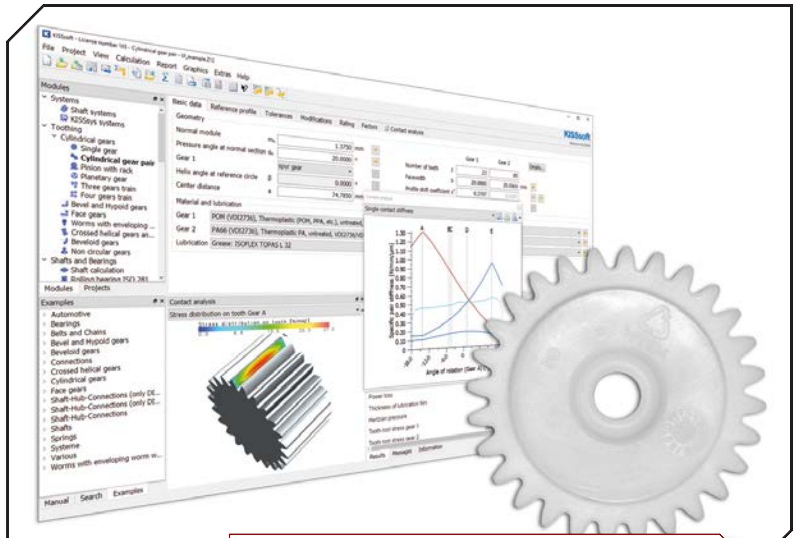
Brian P. Stringer agrees that more testing is needed to better understand the capabilities of plastic gears. Stringer is manager of sales and application engineering for *KISSsoft* in the United States and Canada. "Specifically, we need to gather root and flank fatigue data," Stringer says, "and we need to do this at *many* different temperatures, unlike steel."

One of the biggest challenges, Stringer says, is that there are no agreed-upon standards for how this testing should be done. "Very few companies are following the same testing procedures and using the same types of testing stands and set-ups to achieve apples-to-apples results, so it is difficult to trust any data you get unless you can confirm *how* it was gathered," Stringer says. Another significant challenge is the cost of prototypes. You can't just slap a gear blank on a machine, cut a test gear, and then proceed straight to manufacturing. For a plastic gear, you have to go through the more expensive process of developing a mold before you've even got a prototype. You basically have to spend just as much to prepare a test design as you do for a full mass production run.

For the most part, Winzeler isn't quite ready to fully discuss their ongoing research, but there is some fruit that it's borne. Most notably, they've been working to use their findings to design what Winzeler calls "new families of materials with low emission capabilities."

The ultimate goal here, however, is to reach the point where you can cut out that expensive testing phase with molds — to go straight from a computer simulation and right into production.

"That's the endgame…" Winzeler said. "That's where the world's headed. That's where it wants to go. Is that next year? 10 years from now? 20 years from now? I'm not sure. But because of the cost of product development and testing and everything that goes on, the more that can be done with computer simulation, the shorter the lead time and the lower the investment."



Tooth contact analysis of a cylindrical plastic gear. Image courtesy of KISSsoft.

Simulating Plastics

So speaking of, where are we at with plastic software? One of the more recent announcements in the field comes from *KISSsoft*, who have partnered with material supplier Lehvoss to expand their already considerable software suite.

First, the nitty gritty details. *KISSsoft* has added six new Luvocom materials from Lehvoss, high-performance materials designed to provide quality "mechanical properties" while still performing at temperatures above 200°C. This comes in addition to the 55 plastic materials that *KISSsoft* is already capable of simulating.

Currently, *KISSsoft* allows users to do both wear and static strength calculations for all six new materials, but in the future, the software suite is likely to expand those possibilities: At present, Lehvoss is working on fatigue strength testing.

According to Beermann, the partnership, as with many features with *KISSsoft*, primarily came about by customer request, and it's just one of a list of changes *KISSsoft* is slipping into their latest release. Alongside the new materials will be a new module the company's calling "KISSdesign," which expands their simulations of gearboxes, as well as quality of life improvements such as aysmmetric gear contact analysis (LTCA) and a partnership that allows the software to connect to SKF servers and use their calculations when needed.

Gleason in particular has been enjoying the benefits of *KISSsoft*'s software suite, making the software a part of their plastic gear manufacturing process, and perhaps becoming the software suite's own first anecdote to roll out.

"We have developed proprietary in-house mold bases, called our Quick Tooling, to limit the amount of expense and time needed to produce the molds," Stringer said. "The molds still offer the same quality as production style tooling, with the added benefits of less setup and changeover time, faster delivery, and lower overall cost."

According to Stringer, Gleason's managed to use these molds to produce up to AGMA 2000 Q11-quality molded gears in as little as four weeks while also applying the company's already existing No Weldline technology.

"We are sometimes able to run up to four different parts and materials in the same mold base and press in the same day," Stringer said.

Much in the same vein as what Winzeler Gear is doing, the primary benefits Gleason is seeing are speed and improved prototyping.

"*KISSsoft* helps us maximize gear design and system capabilities," Stringer said. "Our Quick Tooling helps us experiment with many different materials and tooth forms quickly to provide customers with as many options as possible to try during the testing phase, and our No Weldline Technology allows us to produce the most concentric and accurate gears in the market."

When taking the measure of a plastic gear, the question is increasingly not if it can outperform its steel counterpart, but when and where. Which isn't to say that metallic components are at risk of being overtaken or anything seismic like that, but rather that instead of combating them directly, plastic gears are finding their own comfortable niches where they excel. And as companies like Winzeler and *KISSsoft* keep working, they're only going to get better.

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