There's a Great Future in Plastics

It would appear that Mr. McGuire was right

Erik Schmidt, Assistant Editor

The first thing you see when you walk into Winzeler Gear is a pretty face.

No, scratch that — the face is beautiful. Streamlined with chiseled cheek bones, delicate yet bold and strong, a half dozen photos of the feminine face line the building's entranceway, enclosed tastefully in simple black picture frames, beckoning you to come further in with its pleasant warmth, repelling you to turn and leave with its foreign presence in such a location.

This can't be the right place, can it?

Then you look closer.

Dangling loosely on dainty wrists, hanging down from an exquisite pair of ears, sparkling loud and clear even in the black and white photos, is jewelry made of tiny plastic gears. You look to the corner of the foyer and see a fashionable white dress resting on a wardrobe — and that too is made of gears.

OK, this *is* the place.

So you step inside.

The unmistakable bangs and clangs of heavy machinery roar dully in the distance. More pictures hang on a wall to the left, the first of a gear-shaped vodka bottle — "Absolut Winzeler" scrawled across the bottom in white typeface — the second of a square-toothed rock formation that juts sharply into a blue sky in the background.

Before there's time to question the building's interior decorator, an elderly man appears from around the corner. A pair of chic glasses rest over kind eyes; his head is shaven bald like a Shaolin monk.

His presence here seems about as fitting as everything else.

"We don't look like a gear factory," says the man, John Winzeler. "And that's the point."

Doing it Differently

Winzeler, president of Winzeler Gear, has been in the industry a long while, and the whole time he's been trying to cultivate a different (*different* — get used to that word) kind of culture at his factory in Hardwood Heights, IL.

"Think differently," the company's website says. And Winzeler does:

Gear jewelry, gear dresses, gear decorative headpieces, gear paintings, gear sculptures… the entire Winzeler factory is a shrine to indomitable creative thought. Perhaps in a different place, with a different man, the motif may come across as forced, but at Winzeler Gear it is integrated so seamlessly

All photos courtesy of Kleiss Gears, Inc.

and with such genuineness that is feels completely organic.

And, when you really think about it, the connection makes perfect sense. Plastic gears *are* different.

Metal gears, naturally, are much more commonly applied within the industry and are better known. But over the last decade or so, plastic gears — lighter, quieter alternatives to their metallic cousins — have begun to gain some serious traction as a viable, and oftentimes better, solution.

"Thirty years ago when I started doing this, plastic gears were 'cute,'" says Rod Kleiss, president of Kleiss Gears, Inc. (Granstburg, WI). "They were used in a few little things, but anything that was quite serious you would expect failure if the material was plastic. So as I got more into it I realized there were a lot of convenient but poor choices being made on the design and everything about the gear.

"We started working on gear design and started making the normal starting material work much, much better in gearing. The more we got into it, the more we got challenged with just far we could take plastic gears."

Most plastic gear manufacturers use, or have used, a material known as polyoxymethylene (POM), a thermoplastic that offers high stiffness, low friction and excellent dimensional stability. Kleiss used a variation of POM, also commonly referred to as acetal, for most of its applications up until about 15 years ago. Winzeler, meanwhile, has used a popular POM produced by DuPont called Delrin for over 50 years. Celanese (Irving, TX), a specialty materials company that supplies plastic to gear manufacturers, makes its own version known as Hostaform, a product Celanese Senior Design Engineer David Sheridan called the company's "workhorse." POM/acetal-based gears are used in the majority of interior applications within the automotive industry.

"Acetal is a proven gear material," Sheridan said. "People know how to design with it, they're comfortable designing with it and in typical automotive temperatres up to 85°C, there's no reason acetal can't keep working. It works beautifully now."

Essentially any interior application in an automobile, from power windows to car seats, can be driven by an acetal-based plastic gear. Over the years, company's like Celanese have been able to improve and innovate on these POM materials to make them more durable and versatile.

"We have continued to make improvements to our acetal product line," Sheridan said. "We have a new line of glass-reinforced acetal that is a game changer. It's not just a little bit of an improvement, it's a significant improvement. It's not just additives, there's actually a difference in the base polymer that shows a drastic improvement."

Because of these recent innovations, acetal-based plastic gears are now applied in places that were once impossible

"We have begun making plastic gears for much more rugged applications than were previously possible," Kleiss says. "Right now, we're the primary producer of gears that go into corn seeders. These things get bounced over fields and they have 60 to 120 of [plastic gears] on a single implement. If they had metal gears on these things they would weigh a ton and it would be useless.

"Plastic gears are providing an answer that wasn't available with the metal technology."

So while plastics gears are certainly different (i.e. better) than they were a decade ago, there are, of course, still limitations — the main barrier being heat. Winzeler summed it up with proper panache when he said that the "nemesis of plastic gears is high temperatures."

"Delrin is our favorite material, and it does everything we want in a material up to about 85°C," Winzeler says. "The one thing that is very important to understand about many of these engineering materials is that having knowledge of how these materials process has a dramatic impact on the ultimate strength and durability of that part, and also its long term stability. There's a lot of science that goes into it once we have a part designed so that we can achieve consistency over very large volumes.

"In terms of gear applications for the amount of work we can do within a certain amount of space, Delrin does everything we want it to do, but it does not do well once it gets over 85°C, meaning it does not work in the engine compartment and it wouldn't work in the transmission. Once we get into those applications we get into more exotic materials that are more difficult to process.

"The biggest problem with plastics — and it hasn't changed — is that at some point they melt."

Taking the Heat

If the big question in plastic gearing is "how far can they go?" (and it is), then what exactly is the answer?

Most seem to think that, realistically, high-speed, high-torque applications in transmissions are both the present and future of plastic gears due to their ability to eliminate noise at the front end of an automobile.

"Under the hood gears have been looked at for a number of years, and I think manufacturers are satisfied that there are plastic solutions," Sheridan said. "The only gears in automotive that have yet to be tackled by plastic gears are drivetrain gears. Whether or not that's going to be feasible, I don't know. It's all going to come down to material peformance and material improvements."

For Kleiss, that material improvement Sheridan spoke of might be PEEK.

A colorless, organic polymer, PEEK (polyether ether ketone) is a semi-crystalline thermoplastic with excellent mechanical and chemical resistance properties that are retained to high temperatures.

More importantly — and most relevant to this particular discussion — PEEK melts around 343°C (662°F). Some grades have a useful operating temperature of up to 250°C (482°F).

In other words, it can take the heat — and then some.

"We got to this point where we're taking the normal engineering materials — nylon, acetal, etcetera, and we're beginning to make power gears with them" Kleiss says. "That was all good to a point, but then we got introduced to PEEK, and that is a very unusual plastic.

"It has much higher temperature capabilities than the other materials. You have to mold it at 700°F. In its virgin state, it has a low modulus. Now, low modulus is a detriment in general, because a gear will fail because it bends and breaks. So in a power situation you want a stiff gear to carry a lot of

load. But what we began to discover is that plastic fits a niche of gearing in quiet applications — when you have vibrating drives you have to use scissors gears and do a lot of damping and things like that. With plastic, that low-modulus material sort of acts like a spring. It takes care of a lot of problems just by the nature of the material, if everything else is right.

"About 10 to 15 years ago is when we got our first customer that said, 'What about this PEEK material?' That's when we started working with it and found a fundamental difference between it and all the other plastics. We walked away from fillers and said that we were only interested in [PEEK] in its virgin state, because that's where we can make the most accurate gears.

"Now we have a material that we think can withstand the kind of temperatures we're going to expose them to in these high-torque applications. It is able to withstand higher temperatures than any other material that we know of — and heat is the fundamental enemy of thermoplastics."

While new, more exotic materials like PEEK bring added benefits to the table, they also have an innate problem — they're more difficult to work with.

"If a customer comes to us and says that they have an application and they think it will work in [an exotic material], well it may work in that application but it may be very difficult to develop a mold to use that material and a molding process that is consistent and repeatable over a large volume," Winzeler says. "The more exotic the materials become the more challenges we have as processors.

"Because we're looking at large volume applications, we need to work with a material that offers consistency and repeatability. We have to ensure that we get structural integrity and dimensional accuracy from part to part — from Part 1 to Part 1 million to Part 10 million. If we can't do that consistently than we don't have a viable business model.

"They're all tradeoffs. What the product engineer with our client wants may not necessarily be a good solution for our manufacturing floor. And some of that is learning curves and knowledge and so forth. That's the challenge with some of these newer, more exotic materials, is that we don't have the lessons learned; we don't have the design data; we don't have the history of performance successes of knowing what we can and cannot do. That's currently an ongoing R&D process."

Another issue when dealing with exotic materials is cost. And when you combine the decreased knowledge base with the increased price, it stands to reason that while these newer materials do provide added benefits, their inherent deficiencies will probably prevent them from ever becoming the "workhorse" material that acetal currently is, according to Sheridan.

"Let's be honest, cost is king," he said. "Folks aren't going to pay more than they have to. The higher temperature materials require higher temperature equipment to manufacture. The hotter things are, the more specialty equipment you need to handle them, to operate them, to manufacture them, and all of that is added cost as well. Plus, they're newer and not known as well."

So, instead of doing what Kleiss did—which was to essentially throw previous materials out the window and focus on developing a new, more advanced material like PEEK— Celanese has continued to work intensively with Hostaform, "it's bread and butter," while dabbling in perimeter exotic materials like Fortron PPS, a high-temperature semicrystalline polymer.

Winzeler, too, has continued to perfect DuPont's Delrin by making minor changes and slight tweaks to that pre-existing, familiar source material.

"I don't know how many materials are out there, but let's say feasibly there might be 200 materials that might be used for a gear," Winzeler said. "Our research is focused on maybe 10 materials. So what we've tried to do is learn a lot about a few materials to really apply them well. This is not only taking into account their performance, but the economics. What do they cost in the raw state, and what do they cost to convert into a plastic material?

"We continue to go deep into [Delrin]. That's our sweet spot. The perimeter is these exotics. We're convinced that in our universe—and that includes under the hood—that it can be done with very few materials. You just need a lot more knowledge."

Knowledge is Power

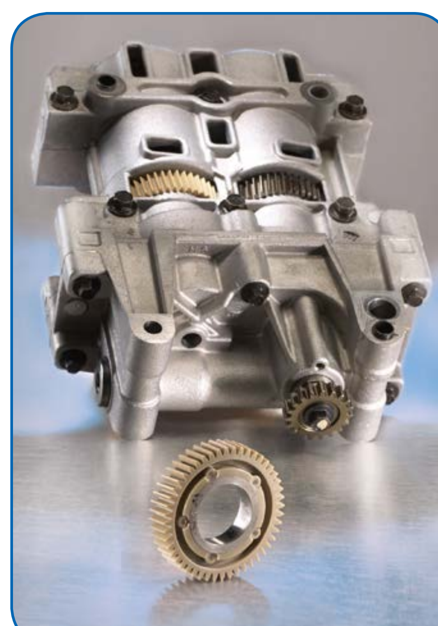
Between Kleiss, Sheridan and Winzeler, you have three fairly different points of view on what the vehicle to the future of plastic gears is.

What the three industry experts do agree on, however, is that whether you're using an exotic material like PEEK or a tried and true substance like Delrin or Hostaform, knowledge is the key to unlocking their potential, because—in theory—the only limitation to how far plastic gears can go is our own lack of knowledge and a dearth of sufficient testing.

Winzeler gave an example of the problem:

"Thermoplastics tend to have fairly high rates of thermal expansion," he says. "So, let's say that we were going to take a transmission gear that's 12-14 inches in diameter, and it can replace the metal gear. If you wanted to understand it's behavior radially and how it's going to grow or shrink depending on whether its –40° or 120° you would have to make parts, measure the delta over the temperature range independent of moisture and other environmental conditions that might affect the size, to understand that.

"The data that they publish on a standard ASTM test bar does not relate to the manufactured product because of how it's gated and how this is done



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or that's done. So that's where this knowledge base is so nebulous.

"We've had applications where automotive has come to us on large gearing and the client said, 'Prove to us on paper that this will work.' The answer from us was that you have to go do it and measure it, and the mentality with a lot of the very large corporations is that if 'you can't prove by computer then we aren't going to consider it.'

"The barrier [for plastic gears] is the knowledge of all the parameters of all these materials in the application so that you can do good product design. And that's huge. It takes a lot of time to accumulate that data."

Kleiss agrees that testing is vital to the continued advancement of plastic gears.

"You have to realize what you're working with and how you need to work with it, he says. "You can't use convenient logic on a plastic gear. You have to be very specific about what you're seeking."

More and more, plastic gears are capable of doing jobs in the automotive forum that could previously only be accomplished by metal. Kleiss says he doesn't see that process stopping — or slowing down — anytime soon.

Because plastic gears aren't worse than metal ones.

They're just different.

"Plastic is not necessarily a weak alternative," Kleiss says. "Sometimes it can be the absolutely preferred choice." **PTE**

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