Gear Drives Great and Small Part I: Micro Gearheads

With many companies and researchers exploring the benefits of miniaturization, gears and gearheads are being designed and built to meet the requirements of increasingly tiny applications. Companies like Micro Mo Electronics are in the forefront of this effort. "We were interested in creating a very small gearhead that still had practical, real-world applications," said Steve O'Neil, the vice president of advanced research and planning. What Micro Mo developed is a planetary gearhead that is 1.9 mm in diameter. "This is considered an optimal size," said O'Neil, "because the unit can still generate useful power."

While the unit is not yet being used on a production basis, it is under consideration for a number of applications that call for precision miniaturized power transmission. "Right now," said O'Neil, "there are a number of beta projects going on that use these gearheads. Security, industrial hygiene and medical applications are being explored including minimally invasive surgical instruments and diagnostic technology."

The planetary gearhead is made using LIGA technology. LIGA is a German acronym for Lithography, Material Removal and Molding, a process similar to that used to make microchips. The difference is that the plastic gear material is injected into molds in the final part of the process.

The output statistics for this tiny gearhead are impressive. The unit can be ordered with ratios 3.6:1 to 47:1 depending on the needs of the application. At a 47:1 gear ratio, the gearhead's output torque for continuous operation is 150 μNm and 300 μNm during intermittent operation. The unit can take input speeds of up to 20,000 rpm continuous and 50,000 rpm intermittent with output of up to 100,000 rpm and can operate in temperatures ranging from –20°C to 60°C (–4°F to 140°F).

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Exploded view of the 1.9 mm planetary gearhead. Courtesy of Micro Mo Electronics.

Gear Drives Great and Small Part II: Monster Gears

At the other end of the size spectrum stand the huge, steel-cast ring gears made by the Falk Corporation for the mining industry.

Welcome to* Revolutions*, the column that brings you the latest, most up-to-date and easy-to-read information about the people and technology of the gear industry.* Revolutions *welcomes your submissions. Please send them to* Gear Technology*, P.O. Box 1426, Elk Grove Village, IL 60009, fax (847) 437-6618 or e-mail* people@geartechnology.com. *If you'd like more information about any of the articles that appear, please circle the appropriate number on the Reader Service Card.

Chile's Atacama Desert is home to the Escondida Copper Mine, the location of the world's largest horsepower driven ring gear drive. The custom-made, steel-cast gear is 43.27 feet in diameter and weighs 190,000 pounds. It is driven by two pinions and a pair of 9,000 horsepower, 176.5 rpm synchronous motors. With a reduction ratio of 17.48:1, the drive can produce 9.3 million ft-lbs. of output torque at a speed of 10.1 rpm.

The semiautogenous grinding (SAG) mill, built by Allis Mineral Systems and powered by this gear drive, is a recent addition to the Escondida Mine. The 36-foot diameter mill grinds large chunks of ore, some as large as a foot in diameter, into smaller, gravel-sized pieces. Until recently, operations such as Escondida's SAG mill had to rely on complex and expensive wrap-around motor configurations to drive the mill. Such systems were high maintenance given their vulnerability to dirt and debris. However, advances in large gear technology now permit mines and other heavy industrial operations to use the more reliable, lower maintenance and less expensive pinion/ring gear drive configurations.

"These advances," said Craig Danecki, mill products business unit manager for Falk, "include new materials and new ways to cast them. We use *full ring risers and fill the molds from the* bottom. The risers allow any dirt or debris that might be in the mold to float to the top while the excess steel feeds the center of the casting as the piece cools. We also use software to analyze the way steel will act within the mold. This is similar to the finite element analysis we apply to the gears as well."

Kalgoorlie, Australia is the site of another of Falk's giant ring gears, this time at the Fimeston Gold Mine. While *slightly smaller than the Escondida ring* gear, the 40-foot diameter ring gear manufactured for Fimeston shows just how quickly such a gear can be transported around the world.

"We usually ship by boat, but this was a breakdown emergency job," explained Danecki. "The mine was experiencing power failures due to extreme electrical storms. These power outages were damaging the gear they were already using because of the way the motors would *shut down when the power failed. If their* mill shut down because of a failed ring gear, they were looking at losses of nearly $60,000 per hour, so the insurance company approved the air freight."

These huge ring gears are made in quarters, cast from heavily alloyed chromium-nickel-molybdenum steel, normalized and then tempered. The pieces are then finish ground to AGMA 12 tolerances with surface finishes between 63 and 100 RMF. The gear sections have bolting flanges set at the same angle as the helical teeth. When the gear is put together, these flanges are locked into place with steel dowels and split locking pins. The pinions are made from forged ingots in a process that drives any defects into the center of the workpiece. The pinion is then rough cut, carburized and finished.

While 43 feet may be the largest gear Falk has made to date, there is an even bigger one in the works. "We're working on developing a 60-foot diameter gear for a shale-oil drilling company in Canada," said Danecki. "A test operation down in Australia has been using a 15-foot gear to work out the process, and now the full scale operation is being studied."

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Putting a New Spin on Gear Manufacturing

For the makers of die cast metal and injection-molded plastic gears, there is a process that promises to cut costs and production time for small- to medium-sized runs. Called spin-casting, the method is also useful for rapid prototyping as well as the fast manufacturing of replacement parts. "With plastic materials such as polyurethanes we can achieve very high tolerances," said Sherif Nasser, technical sales and training manager for Tekcast Industries, Inc. "With metals, such as zinc alloys or aluminum—which is really only suitable for rapid prototyping because of the temperatures involved—the tolerances are slightly lower."

According to Nasser, the process begins with the model or prototype of the part you want to make. From this a

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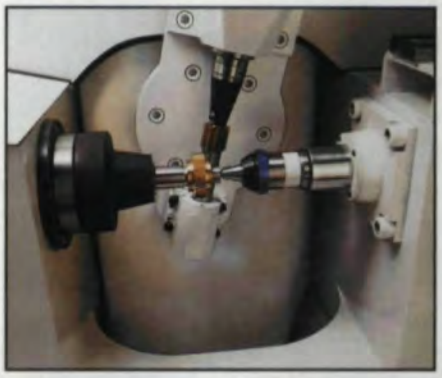

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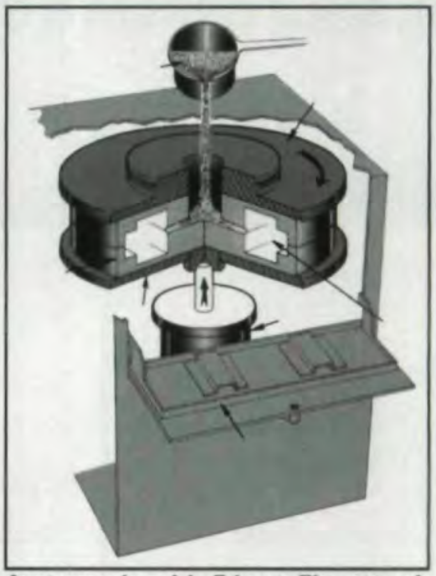
mold is made using a silicone rubber compound called Teksil that is highly temperature resistant. "This silicone mold has the exact cavities needed to duplicate the original," said Nasser, "and it can be anywhere from 9 to 30 inches across and up to 10 inches thick." Once the shapes are cut and molded around the model parts, the upper and lower halves of the mold are brought together around the model and the entire assembly is placed in a ring-shaped vulcanizing frame and put into an electrically heated vulcanizing press for curing. Hydraulic force clamps the mold frame shut between the heated platens, forcing the silicone into all crevices and around every detail of the model. The resulting mold is tough, resilient, dimensionally accurate to .008" and heat and chemically resistant. After vulcanization, the mold can be easily flexed to release the patterns (and later, parts) from the cavities—even patterns with a wide variety of undercuts. At this point, gates and vents can be cut into the mold with a sharp knife or scalpel. If the initial tests show the need for greater flow or more air venting, these gates and vents can be easily expanded on the spot.



A cut-away view of the Tekcaster™ courtesy of Tekcast Industries, Inc.

After the mold is made, it is placed in the spin-casting machine—a patented, front-loading unit called a Tekcaster™—and spun. Molten metal or plastic is then poured in. Centrifugal force pulls the liquid through the gates and into the molds, ensuring that the cavities are completely filled. With this method, metal castings are made at a rate of 50 to 60 cycles per hour. With plastic, the rate is typically 10 to 15 cycles.

According to Nasser, "With plastic we can make any kind of gear you can think of, bevels, spur, helical. With zinc alloys, we can do anything except helicals."

So what are some other reasons to consider spin casting? Cost and speed, according to Nasser. "With spin casting, if you have the model, the mold can be made for less than $100.00 and takes about three hours," said Nasser. "With spin casting you can go from prototype to production in a couple of days. With other methods it could be anywhere from one to four months before you start producing parts."

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