Heat Treating on a Grand Scale

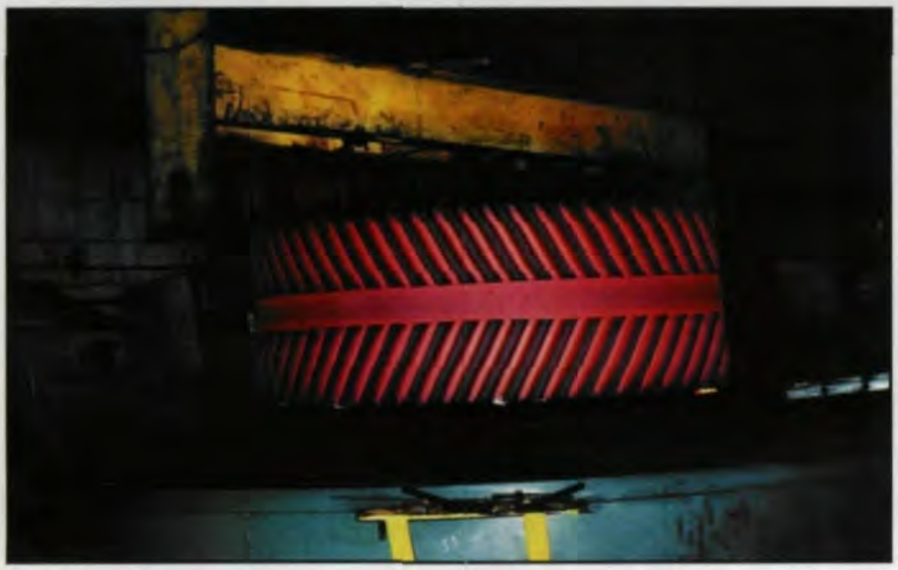
The gear, a double helical with a 106" outside diameter and a 36" face, weighs 40,000 pounds. Destined for use as an intermediate drive gear for a hot strip mill in Latin America, the specifications called for an effective case depth of 0.250" and a nominal surface hardness of HRC 58–62 with a surface carbon content of 0.70–0.90%. The manufacturer turned to Metlab of Philadelphia, PA, to do the job.

According to James Conybear, one of the owners of Metlab, "We get orders from all over the world and heat treat two or three huge gears a month." His partner, Mark Podob, adds, "We carburize and nitride gears for mining equipment, mills, cement plants, ship drives, and the military. There is only one other furnace in the world that can accommodate the sizes we work with."

When working with such large workpieces, Podob and Conybear say that the real key is uniformity of heating. Without it, the process is imprecise and unrepeatable. Three major areas of concern determine the uniformity of the heating process: fixturing, quenching and process control. If these areas are not carefully watched, there can be problems. "With these big assemblies," says Conybear, "their weight will crush them. The material tends to sink into itself, almost self-forging, with the inside material moving toward the outside." That leads to distortion. "Most gear designers can design for dimensional change," says Podob, "so the key is to make the process precise and the results repeatable." That is accomplished by proper fixturing, quenching and process control.

Fixturing. "You have to make sure the part stays straight," says Podob. "With a big gear, you can pick it up with a three-point loading if, in the furnace, it is resting on a flat plate." With proper support, the slumping and tooth distortion effects of self-forging can be kept to a minimum. "With splines," adds Podob, "the easiest way is to support the tooth section and control the heating to minimize distortion.

Process Control. This covers the precise, uniform heating and cooling (quenching) cycle, as well as the atmosphere within the furnace itself. "This is very important because these gears are in the carburizing furnace for 8 to 10 days," says Conybear. "We have to know what is happening to them so we can make adjustments as the cycle continues." This is accomplished using samples of the same material as the workpiece as well as a standard sample that Metlab uses to gauge how well the process is working. According to Podob, throughout the cycle, these material samples are cut and inspected. Diffusion calculations are then performed to check the progress of the carburization process. In the case of the 40,000 pound gear mentioned above, the workpiece and samples were of 4320 steel and they underwent 200 hours (8.3 days) of carburization.



40,000 lb. double helical gear on its way to the quenching tank. Courtesy of Metlab.

Precise heat soak and quench control are important to minimizing tooth distortion. "The key is to minimize the differential temperatures within the part," says Podob. "If you heat big gears too fast, the inside moves to the outside." You also have to cool them down just as carefully, quickly moving the hot workpiece to the quench tank before it can begin to cool. "You need to have a large volume of quenching fluid, usually oil, with good circulation and temperature control," says Podob. "It also helps to have good material to begin with."

Not all materials are suitable for this kind of application, so making the right choice of material takes on added importance when designing very large gears. "We are often involved in the design stage," says Podob. "When you design one of these large components, you have to be more of a materials engineer to make sure that the workpiece will make it through the heat treating process with a minimum of distortion."

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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.

The SProcket Variable-Ratio Transmission

Say the words "continuously variable transmission" and most people familiar with the concept will envision V-belts and a split pulley. The ratio is changed by increasing or decreasing the split between to the two pulley halves. This works because the distance of the V-belt from the axis of rotation and the transmission ratio are proportional to the separation of the pulley halves.

Continuously Variable Transmissions Today. The problem with a belt-driven system is low torque capability, since torque depends on the frictional force that maintains the V-belt's contact with the pulley. This is solved by using corrugated belts and pulleys or chains and sprockets to provide positive, non-slip engagements. For such an arrangement to be truly continuously variable, a complex kind of corrugated pulley or sprocket with a continuously variable diameter and a constant rib pitch would be needed. While the advantages of using continuously variable transmission technology are very real, the drawbacks of present designs—limited torque, expense and complexity, size and weight, are problematic. What's more, according to Vince Bakulich, president of Revolution Industries of Santa Monica, California, many present designs are not really continuously variable at all. They adjust from one ratio to the next incrementally. Also, many designs are simply not practical or adaptable to everyday use. Recognizing the need for a simple, continuously variable transmission suitable for high-torque applications, Bakulich thinks he has come up with a better way.

The SProcket. Bakulich has designed the SProcket, a continuously variable gear or power transmission that operates at any discrete ratio within a finite range while constantly engaged and under load. Referred to as either an Infinitely Variable Transmission or a Continuously Variable Ratio Transmission (CVRT), the SProcket's corrugated belt maintains engagement while the gear circumference expands and contracts. "There is no slippage," said Bakulich. "You have a direct connection between the chain or belt and the driving member. Take a motorcycle. You have a chain and a sprocket—a solid connection." Bakulich then explained that in a motorcycle you have an internal transmission with three or four ratios. If, however, you could change the size of the sprocket, you could have an infinite number of ratios within a given range. Its ability to change the circumference of the gear is what permits variable speeds and power transmission. This change in circumference, called actuating the gear, can be accomplished in a number of ways, according to Bakulich, including hydraulically, mechanically, electrically or pneumatically. "It really depends on the application and the size and weight requirements." Then he added that the applications for this technology are very real and practical.

"Imagine getting in your car," said Bakulich, "and pressing the accelerator to get the engine up to 1,500 RPM, or whatever you need to provide enough power, and leaving it there at a constant speed. Then, you press a button up to go faster or down to go slower." Bakulich explained that with a conventional automobile, to go faster you have to accelerate the engine. In an automobile equipped with a CVRT, you would be adjusting the transmission instead of the engine speed.

CVRT Advantages. This example points out one of the main benefits of continuously variable transmissions—fuel efficiency and energy conservation. Other features of the SProcket design include precise gear ratio selection, continuous power transmission over the entire range of gear ratios with no belt slipping, high versatility and strong, simple construction. The prototype was built with readily available, off-the-shelf parts. Also, the speed at which gear ratios change can be altered allows the CVRT to go through its entire range of gear ratios as slowly or as quickly as necessary.

Applications and Response. According to Bakulich, the greatest use of conventional continuously variable transmissions is in the auto industry. Other applications include utility and constant velocity motors and HVAC units, bicycle chains and sprockets, motorcycle and electric vehicle transmissions, pumps, and wide variety of others. "The SProcket can be used on a wide variety of applications," said Bakulich. "but a unit would need to be designed to fit each one individually. We have had some interest from industrial and automotive manufacturers, but not too much response yet from Detroit."

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Pushing the Envelope With Plastic

Achieving higher power density in an existing design space is one of the chief goals of today's gear designer. Because of the economic and design advantages offered by plastic materials, plastic gear engineers are developing some of the most innovative solutions.

Kleiss Gears, Inc., of Shoreview, MN, has developed some designs that promise increased torque capacity, reduction ratio and strength, says company president Roderick Kleiss.

Kleiss has worked with gear design-consultant Alex Kapelevich to develop a general purpose design for asymmetrical plastic gears. Although the designs haven't been used in production yet, they were developed as a possible solution for a lawn sprinkler manufacturer who had problems with broken gear teeth because of a rugged product assembly process.

Kleiss Gears actually worked on two designs to increase the strength of the gear teeth, the asymmetrical set and a beefed-up symmetrical set with increased pressure angle. According to Kleiss, both sets performed well in their tests. "The asymmetrical set was obviously stronger than the symmetrical set," Kleiss says. However, the manufacturer chose to go with the standard gears because of the disadvantage of having to ensure the asymmetrical gears were going the right direction during assembly.

Despite this, Kleiss believes the asymmetrical design shows great promise for future applications. "We expect to see a 15–30% increase in strength," Kleiss says.

Kleiss Gears has also developed an orbiting, or planocentric, gear design that promises to deliver high torque output and high reduction in a relatively small package. The company is exploring the possibility of using this design in several applications, including a trolling motor steering mechanism, Kleiss says.

According to Kleiss, this application is especially well suited for plastic. "Internal gears always face limitations with cut gearing," Kleiss says. With plastic, the designer can develop the teeth for maximum strength without having to worry about the tooth generating process. The high pressure angle in this set would be extremely unusual in cut metal gears, Kleiss says.

The orbiting design is still in the development phase. Kleiss is working on ways to overcome the uneven torque distribution on the carrier pins, and the company is developing an output coupler that will help to balance the bearing load.

Another issue that often concerns plastic gear designers is the heat generated by the drive system. "Heat is the killer," Kleiss says. Although the gear teeth in the orbiting gear set do not generate much heat, they have to be insulated from the heat generated by the motor, Kleiss says.


An asymmetrical gear set. Courtesy of Kleiss Gears.


Planocentric gear set. Courtesy of Kleiss Gears.

Kleiss sees much promise for this design. "I think this is just the beginning," he says. These gearsets will be ideal for developing a compound differential, Kleiss says, because they'll offer an extremely high reduction in a small package with good radial load output. ○

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