Dramatic Temperature Reduction Yields Longer Life

On a speedway, race cars hurtle through turns at speeds of 170 mph, their engines reaching temperatures of 180°F. To survive those extremes, their gears are often exposed to another extreme, treatment at –350°F.

The treatment, cryogenics, is used on gears to make them last longer, to increase their dimensional stability or to remove stress from them.

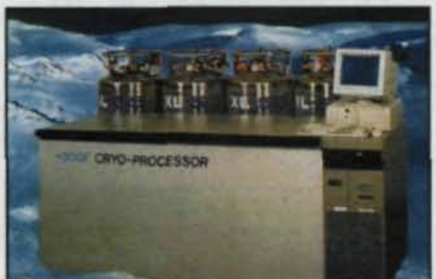
When cryogenics first became available for use on race car gears, the few companies that used the new technology kept it secret from the competition. Today, most companies require their race gears to undergo the treatment.

According to Rocky Beebe, general manager of One Cryo, a Puyallup, WA-based company that specializes in cryogenics, racing teams like Bob Panella Motorsports and others regularly send their gears in for treatment.

"Some of the racing teams want to treat the complete engine to make it tough enough to last 2–3 times longer. Others have trouble areas like the pinion and want us to concentrate on that part," he says.

The process works on nearly anything with moving parts. Gears, shafts, bearings and cases are treated for drivetrains and production machines. Among the gear-related applications for the cryogenic process are race cars, aerospace vehicles, tractors, turbochargers, even the brake rotors of ambulances.

In 1996, Lifestar Ambulance Co. in Springfield, IL, noted that its Ford E350 model rigs required a brake change every 9,000 miles. Van Prater, chief of operations for Lifestar, inspected the brakes



This machine lowers a gear's temperature by less than 1° per minute.

and noted the rotors were heat stressed and cracked, requiring a new set every third oil change. Lifestar consulted 300° Below Inc., a Decatur, IL-based company that specializes in low temperature cryogenic treatments designed to boost the performance and service life of critical components. Before its rotors were treated, Lifestar found that the brakes needed to be changed every 9,000 miles at $350 for each new set of rotors. After the treatment program, the rotors required changing every 55,000 miles.

"We were paying less than $200 to have a set of rotors treated and then inspected the brakes about every 6,000 miles. We had great luck, and the treatment ended up paying for itself," says Prater.

In short, the process involves lowering temperatures to –300°F to effect significant molecular changes, says 300° Below CEO Pete Paulin.

"There are mainly three benefits to undergoing the cryogenics process. First, it ensures a martensitic conversion from any retained austenite. Also, it relieves stress and promotes stabilization through thermomechanical compression and expansion. Finally, in ferrous materials, carbide precipitation leads to uniform refined structures enabling parts to withstand wear," Paulin says.

After parts undergo the procedure, the company claims they normally improve in performance and have reduced wear and breakage, sometimes expanding the life cycle by as much as 250–400%, according to literature from 300° Below. Treated tooling ranges from a handful of small drill bits to stamping dies that weigh upwards of 10,000 lbs. Cutting tools, such as hobs, can also be treated via the cryogenics process.

Whatever the end use, molecules are organized by closing the grain structure during the process. The material becomes more abrasion-resistant, but the hardness does not change, says Bob Reed, motor sports division manager at 300° Below.

"If we changed the surface to make it harder, then the product would become more brittle," explains Reed. Additionally, cryogenics is meant to affect the entire product rather than just the surface.

Treatment results vary from product to product, and some materials display resistance to cryogenics. Generally, higher carbon, higher alloy tool steels, martensitic stainless steels, some cast steels and gray iron have shown positive results. Mild steel and materials other than metal are among the components that are not recommended for cryogenic treatment.

Al Swiglo, a staff engineer with the Illinois Institute of Technology, investigated cryogenics for the U.S. Army. He was researching the manufacture of gears for carburized 9310 aerospace material and reviewed literature that analyzed breakage. Only one study provided inferior results for bending fatigue, but that test was done at different hardness levels, so it may be invalid.

"What we found was that for rolling/sliding contact fatigue, you could get 5% more loading capacity or 50% more life. Also, you could get [a] 50°F increase in the tempering temperature," Swiglo says. "Ordinarily, anytime you exceed the tempering temperature, or the temperature at which the part is heat treated, the hardness and life are decreased. Now, any time that part might get warm, we're raising the temperature that that could happen."

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Through cryogenics, products change on the inside, so it's impossible to see on the outside that the material has been changed. Only a microexamination at a high magnification would indicate if the parts were treated.

"If a company has good records to know how much use they would get for an untreated product, then they would see that the life of the treated product is much enhanced," Reed says.

The cryogenics process takes approximately 72 hours at 300° Below. Reed estimates the company's deep cryogenics machine lowers the temperature by less than 1° per minute, but he says parts could break if the machine quickened the process.

Treatment costs vary according to weight. For example, the cryogenics operation on a V8 automotive engine runs about $562. As a rule, the greater the weight, the lower the cost per pound.

Finances aside, by exposing gears to these sub-zero temperatures, manufacturers are making it possible for the gears to achieve faster speeds on the race course and longer lives for military aviation and ambulances.

Fast Induction Hardening—without Preheating?

Take a 4" internal gear with a 1" face width, place it in a circular induction coil, heat for 0.6 seconds—without preheating, and what do you get?

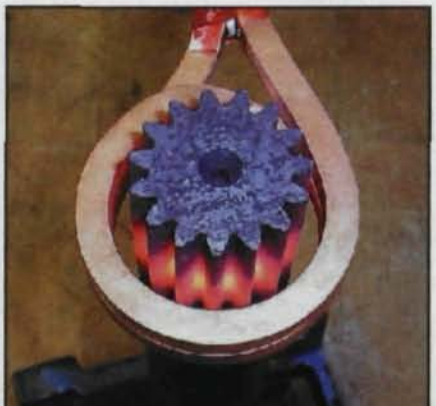
According to Mike Hammond, you get a gear with a uniform case depth from tooth tips to roots.

Hammond is president of Electroheat Technologies L.L.C. Located in Auburn Hills, MI, the company has a system that transmits medium and high frequencies at the same time to induction harden gears and other complex shapes.

Dual frequency induction hardening isn't a new process to the gear industry. Companies, like Contour Hardening Inc. of Indianapolis, IN, have offered that process to the industry for some time.

Simultaneous dual frequency induction hardening is a new process, though.

Electroheat's system can achieve such hardening via an IGBT, an insulated gate bipolar transistor, which is part of a power circuit design that allows the coil's power supply unit to combine and filter medium and high frequencies.



On a shaft, a spur gear pattern is induction hardened by a medium frequency and a high frequency transmitted at the same time via an induction hardening system from Electroheat Technologies L.L.C.

Hammond describes the transistor as rugged and able to handle high frequencies. Previously, transistors in power output circuit devices for high frequencies weren't resilient enough. They were susceptible to premature failure—"especially so in heat treating applications," Hammond says.

With an IGBT, Electroheat's system can create and combine a medium frequency in the range of 10–25 kHz and a high frequency in the range of 150–500 kHz.

According to Hammond, the power supply unit filters the combined frequencies so the high frequency's feedback doesn't damage the medium frequency.

"This has always been the obstacle to overcome," he says.

Transmitting both frequencies at the same time, Electroheat's system heats tooth tip and root at the same time.

"We don't overheat either area," Hammond says. "This allows us to use very short heat times with rapid quenching."

The system's quenching time is 2–5 seconds, depending on the gear. According to Hammond, some gears cool by mass quenching because the hardening process uses rapid, shallow heating, which lessens distortion in gears.

According to Hammond, the system creates greater tooth bending fatigue strength than conventional heat treat processes, contributing to a longer tooth life.

The system can be used to induction harden spur gears, worm gears, internal gears and helical gears. Hammond adds that the system was tested and didn't need to preheat spur gears, internal gears and helical gears. Tests will be done on worm gears, but he says he doesn't expect the system to need to preheat those either.

Also, the system can emit a single frequency, either medium or high. So, it can treat a range of part configurations and variations and can be used for other applications, like tempering after hardening.

Hammond says the system is suited for in-house and commercial heat treating operations. He adds that the first system was sold to a commercial heat treating company in Europe.

Assuming the power supply unit can generate up to the 450 kW range, the whole system—the power supply unit, part-handling equipment and quenching/cooling machine—takes up 140 square feet.

Hammond says the system's drawback is probably cost. A typical system can cost \$250,000–\$650,000, depending on the complexity of the part-handling system and process-monitoring equipment.

Hammond adds: People may think the power supply unit is expensive—if they think of it as one power supply. If they think of it as two, then the unit doesn't look so pricey. ✪

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