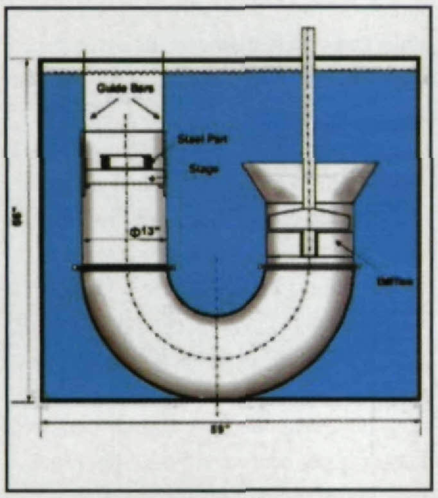
Welcome to* Revolutions, *the column that brings you the latest, most up-to-date and easy-to-read information about the people and technology of the gear industry.* Revolutions *welcomes your submissions. Please send them to* Gear Technology, P.O. Box 1426, Elk Grove Village, IL 60009, fax (847) 437-6618 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.

Intensive Quenching

Every heat treater knows that the greater the part cooling rate during quenching, the better the part performance. However, the conventional wisdom with heat treated parts is that quenching a part too quickly will result in harmful tensile and residual stresses, greater distortion and the possibility of part cracking. But engineers and researchers at IQ Technologies Inc. (IQT) of Akron, OH, are out to prove that controlled, rapid cooling through the martensite range can actually result in higher quality hardened steel with beneficial compressive residual surface stresses on a through hardened part.



A specially designed quench tank keeps water or salt/water solution moving over the quenched part.

IQT's IntensiQuench℠ process has been used successfully to quench splined shafts, sprockets and other steel parts, such as coil springs, torsion bar samples, bearing products and gear blanks. It can also be applied to gears, says IQT President Joe Powell, but some applications may require special modification of the quenching equipment. Results of the process have been validated in hundreds of laboratory and field experiments, which demonstrate improvements in mechanical properties, microstructure, compressive residual stress and part lifetime when compared with parts quenched in oil using traditional methods.

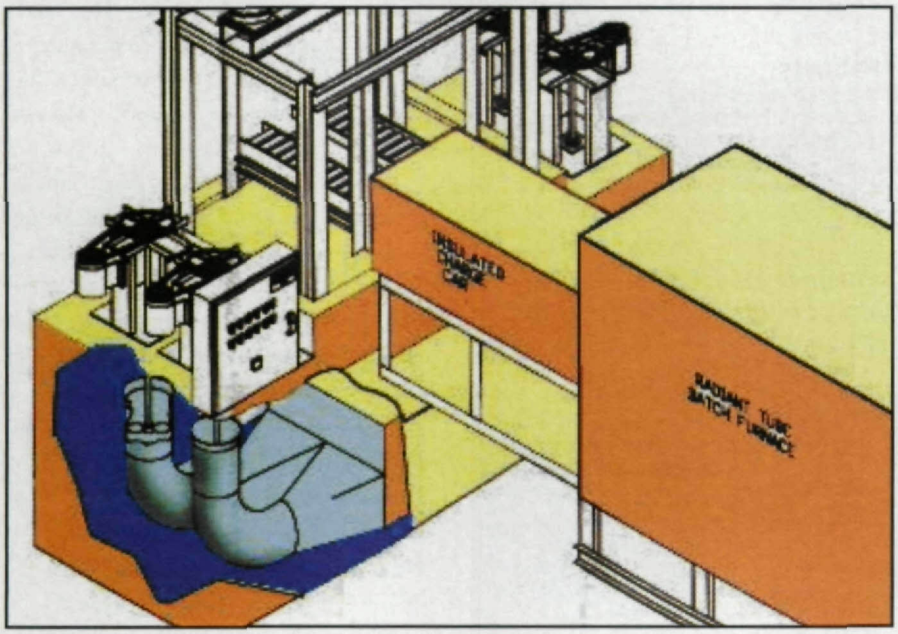
During conventional quenching, martensite forms first in the thinner sections of a part, since those sections cool more rapidly than the thicker sections. The difference in cooling rates results in distortion and possible cracking. The IntensiQuench process uses a highly agitated quenchant (usually water) to cool the part rapidly but uniformly, according to Powell. Moreover, the process quenches parts three to six times faster than other methods, without the usual distortion, he says.

The unique, 6,000-gallon quench tank is equipped with four 18-inch impellers rotated by 10-hp variable speed motors to keep the water or salt/water solution moving over the part. In addition, the quench tank is equipped with a temperature and concentration control system to ensure the proper conditions of the cooling medium.

Those controls are essential, because one of the keys to the IntensiQuench process is to interrupt the cooling of the part at the critical temperature when compressive stresses on the surface are at their maximum. The part is then held at that temperature, allowing the continued, even formation of martensite, resulting in higher uniform surface compression and increased strength in the parts.

Depending on the application, the beneficial surface compressive stresses created through the process can sometimes take the place of carburization or shot peening, Powell says. He adds that the ability to increase the amount of martensite formed in a given steel allows the part designer to use a less expensive steel or one with lower alloy content and still achieve the same hardness.

The IntensiQuench process relies heavily on sophisticated computer modeling, Powell says. By performing finite element analysis and a series of calculations, the process software can determine



Intensive quenching can be installed in-line with any heat source. Shown above are quench tanks used with a batch furnace.

a part's thermal and stress profiles. That allows the process to accurately predict the critical holding temperature and to achieve the optimum hardened depth with compressive stresses.

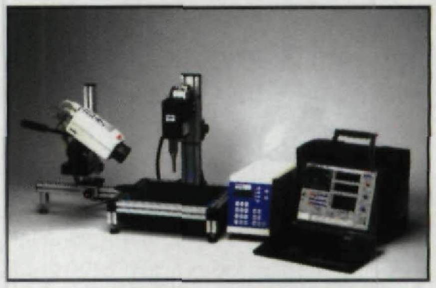
The quenching process can be used with induction, atmosphere, salt, vacuum or any other type of heat treatment, and it has been used successfully with most common steels, Powell says.

Circle 300

NDT Process Finds Cracks By Shaking Parts

An infrared NDT process has been developed that detects closed cracks by forcing their two sides to rub together, then photographing the resulting heat—all in less than a second.

Suitable for quality control, the non-destructive testing technique was developed at Wayne State University in Detroit. A commercially available version of that technology is the ThermoSoniX test station, manufactured by Indigo Systems Corp. of Santa Barbara, CA.



The ThermoSoniX test station finds closed cracks in parts by using ultrasonic energy to force the cracks' sides to rub together, which creates heat, and imaging that infrared energy with the station's camera.

The test station can be used in gear manufacturing to supplement or replace other inspection methods, like dye penetrant, Magnaflux, and visual inspection using a microscope.

To detect cracks, the station directs a pulse of high-frequency sound at a part surface. The pulse lasts 50–200 milliseconds and has a frequency of 20 kHz.

The sound makes the part vibrate. If there's a crack, even a closed crack, its two sides will vibrate as well. But, they won't vibrate in unison. They'll rub, creating heat. The station's infrared camera detects that heat, showing the crack's location on the part surface.

The station can detect temperature changes as small as 0.02°C. The NDT process raises a crack's temperature a few degrees Celsius. Consequently, the cracks look like "explosions," process developer Bob Thomas says.

Also, the process can detect cracks vertical to a part surface—without being perpendicular to them. Vertical cracks can be hard to detect. Process developer "Skip" Favro says looking at a vertical crack is like looking at a knife's cutting edge—"There's not much to see."

Consequently, inspection devices can better detect a crack when they're perpendicular to the crack, so it looks like a sheet, not a line. The ThermoSoniX test station can detect cracks regardless of their orientation to a part surface.

According to Thomas, the NDT process can be automated for high-volume inspection. However, Austin Richards, Indigo Systems' project manager for the test station, explains that the station is mainly intended for hand inspection of low-volume, high-cost parts. The station can be automated to inspect up to 30 parts per second.

The NDT process can inspect metals, like steel and iron, ceramics and composites. "It can do basically any solid," Thomas says.

Richards, who holds a doctorate in physics, estimates the station can detect cracks 4 or 5 millimeters beneath a part's surface and likely can inspect parts weighing up to 100 kilograms. The station itself weighs 150 pounds and fits on a 3-foot-by-5-foot surface, like a desktop.

For the process to work, a part must be solid and be a good emitter of infrared energy with wavelengths of 3–5 microns. Richards describes that wavelength range as: "A great waveband if you want to see tiny bits of changes in surface temperature."

The station provides real-time displays of cracks. Also, it uses no consumables, as with dye penetrant and Magnaflux, and no radiation, as with X-ray processes.

Also, X-ray imaging can't effectively detect some types of cracks, like compression cracks. During manufacture, a part can crack at high temperature, but that crack can close as the part cools, becoming a nearly invisible compression crack.

The deeper the compression crack is, the more the crack weakens the part. A shallow crack may not weaken a part too much, but any crack can be dangerous because it can grow as the part is used.

As a drawback, the test station can be quite loud. "It's a good idea to wear hearing protection," Richards says.

Also, he describes the station—with its computer, software and camera—as more complicated to set up initially than dye penetrant or Magnaflux is.

"But," he says, "once it's up, it's easy to use."

The station costs about $85,000 and consists of a part platform, a piezoelectric converter that provides ultrasonic energy, a hard metal probe that transmits the energy to the part, a pneumatic actuator that holds the converter, an infrared camera, a mechanical structure that holds the camera, and a computer that controls the station.

"Most of that cost is the infrared camera," Richards says.

A major part of the camera is the detector. That part detects infrared heat. But, it can't do so if it's generating heat itself. Consequently, the detector is cooled by a miniature, closed-cycle helium refrigerator to the temperature of liquid nitrogen—about –350°F.

The camera records a part's image and transmits the 12-bit digital image data to a digital framegrabber, which allows for recording and storing of images in a computer's memory.

As for the cost to operate the station, Richards says: "There's no consumables, you're just buying electricity."

The NDT process was developed by physics professors Favro and Thomas, with electrical engineering professor Xiaoyan Han and their students at Wayne State University. Favro and Thomas are members of the university's Institute of Manufacturing Research.

Favro and Thomas had performed nondestructive testing with infrared cameras for years. They had been using flash lamps to warm a part, then detecting defects as the part cooled. The defects were broken glue joints, corrosion, and delaminations—the popped-apart horizontal layers of a composite material.

Also, that old method detected those defects only if they included air gaps. A defect's gap would reflect heat to the part surface above the defect, making that surface area warmer than the surrounding surface.

"All the kinds of defects we were seeing were parallel to the surface, not perpendicular," says Thomas, explaining that most cracks which people look for in materials are cracks perpendicular, or vertical, to a part surface.

To detect vertical cracks, Favro and Thomas developed another NDT technique and experimented with it in summer 1999. Favro recalls the vertical cracks "lit up like a Christmas tree" using the new process.

They filed for a patent that September. "It happened very fast," Favro says.

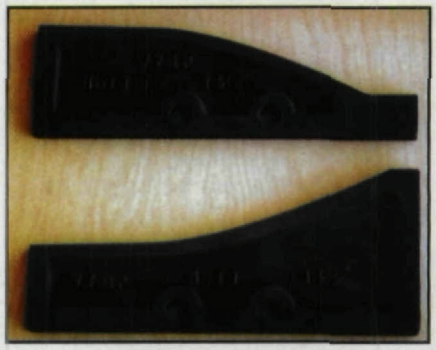
Indigo Systems obtained a license to manufacture products based on Favro and Thomas's technique and developed the ThermoSoniX test station from it.

Circle 301

Vintage Machines Still Producing

Some technologies are worth preserving, says Bennie R. Boxx, president of B&R Machine & Gear in Sharon, TN.

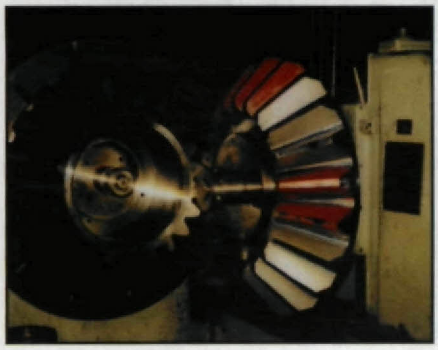
B&R is home to one of America's few remaining model 77GP Gleason Planers, a versatile machine capable of cutting bevel gears up to 80 inches in diameter.



The machine was built in 1917. Since then, the technology for cutting bevel gears has been updated many times. Still, B&R's machine has recently come back into demand, Boxx says.

Much of that demand comes from the steel mill industry, which often requires large bevel gears with pitches as coarse as 0.4 DP. Boxx says that most modern bevel gear machines aren't capable of cutting gears in that pitch range.

B&R uses near-net-shaped forged gear blanks in specialty alloy steels for its large bevel gears. The blanks are machined on the Gleason planers and



then heat treated.

However, running machines that use technology which has been largely forgotten has challenges of its own, Boxx says. One challenge is finding the tooling to make the machines operate. The Gleason planers use top and bottom formers, which are templates used to guide the blades that cut the gear profile. The tooling was originally manufactured by Gleason in standard 14.5- and 20-degree pressure angles.

However, steel mills often require bevel gears with 25- or 27.5-degree pressure angles, Boxx says. When B&R received an order for such gears in 1999, Boxx discovered that the tooling would have to be custom-manufactured.

B&R turned to Trogetec Inc. of Riverton, WY, for help. According to company president Sandor J. Baranyi, Trogetec had never worked with Gleason planers before, but the project was intriguing. "We had the feeling that we could fill the order based on our preliminary design study," Baranyi says. He determined that Trogetec would be able to modify its EZGearPlot version 3.0 software so that it could create the patterns for the formers.

The first time Trogetec created the formers, the process had to be created on the fly. "We didn't have the software yet," Baranyi says, "but we were able to piecemeal it together."

Since that time, Trogetec has released EZGearPlot–GP version 2.0, which, in addition to its gear design functions, is able to create CAD files for manufacturing the formers for Gleason gear planer models 54, 77, 144 and 192. The user enters the gear set's design parameters and the model of the gear planer. "We plug in the data and it goes like a cinch," Baranyi says.

Once the CAD files for the formers are created, the tooling is manufactured from 0.50-inch thick cold-rolled plate using CNC abrasive waterjet cutting technology.

The result is that B&R's Gleason planer is back in business. "Since we started getting the formers made, this machine runs 24 hours a day," Boxx says.

Circle 302

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