FREEZING OUT THE COMPETITION

Cryo treating can be used for coated as well as uncoated tools. (Courtesy: CryoPlus, Inc.)

Cryogenics is an exciting frontier that has already led to major discoveries and holds much promise for the future.

By KATHI BOND

Most companies are looking for a secret that can help them keep a step ahead of the competition — a little edge to run faster, cheaper, and more efficiently than the competitor. That secret is cryogenics.

Cryogenic processing — the deep chilling of tool steel so that the molecular of the metal is brought to "cryogenic stillness" in order to improve wear characteristics — is not a new technology. In the past, toolmakers would bury components in snow banks for weeks or even months to improve their wear resistance. Castings were always left outside in the cold for months or years to age and stabilize. Swiss watchmakers noticed that extreme cold changed the properties of their metal clock parts for the better. They would store them in cold caves and let them freeze during the winter.

DEVELOPED BY NASA

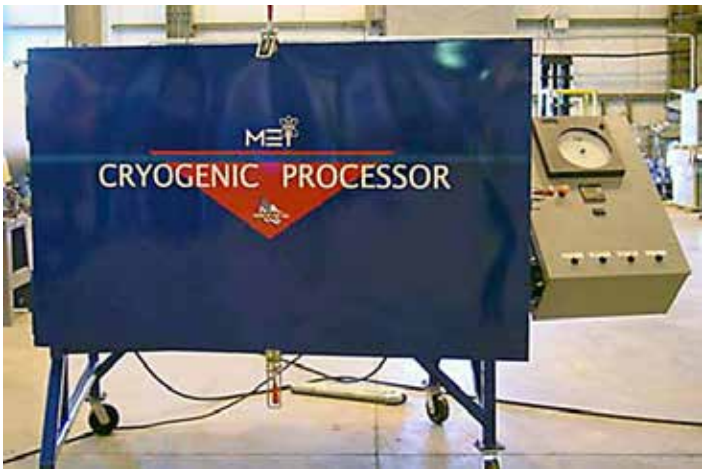
The process was originally developed by NASA. The cryogenic treatments involve cooling temperatures of minus-300° F using liquid nitrogen, replacing dry ice and mechanical refrigeration treatments. Today's dry process is computer controlled, using a prescribed schedule and maintained at minus-300° F for a particular time before slowly returning the parts to room temperature. The dry process means the material is not exposed to any cryogenic liquids, eliminating the risk of thermal shock. A microprocessor is programmed according to size, weight, and configuration of the parts being treated. It controls the flow of the liquid nitrogen into the dispersal system where the liquid is dispersed as a gas, and the boil off vapor is spread throughout the chamber.

Prior to the deep cryogenic step, many tool steels require a preconditioning step consisting of a short temper. Once the temperature reaches minus-305° F the cryogenic process enters the "soak phase," which maintains this temperature for a period to allow for transformation on a molecular level. After being subjected to the deep freeze, the materials must be tempered to about 300° F to retemper the newly formed martensite. This temperature varies for different materials, and the processing time varies for different material cross sections.

CryoPlus uses a controlled dry thermal treatment, designed to more efficiently transfer cold from the liquid nitrogen to the metal parts being treated.

WHY CRYO TREAT?

The purpose of cryogenic treatment is to transform retained austenite and raise the tensile strength of the as-quenched structure. In addition, better dimensional stability is often achieved. This is especially important for progressive dies, where cumulative tolerances are critical. Subzero treatments have as their ultimate goal an increase in wear resistance, improved bending fatigue life, and minimizing residual stress. Stress is the enemy of steel, if it's not imparted in a uniform manner. Stress boundary areas are susceptible to micro cracking which leads to fatigue and eventual failure. Residual stresses exist in parts from the original steel forming or forging operations and additional as a result of the many different machining operations to finish the part. They create a complex invisible random pattern in the steel.



A cryogenic processor. (Courtesy: CryoPlus, Inc.)

Residual stresses are uneven and located variously throughout the structure. Austenite (a soft form of iron) is a solid solution of carbon and iron that is formed during the quenching phase of metal production. Austenite is weak and undesirable because it contains few molecular interfaces to help hold the metal together. When metal is cryogenically treated, the austenite structure is transformed slowly into a highly organized grain structure called martensite, a body centered tetragonal crystal structure. Martensite is a finer and harder material that brings high wear resistance that is very desirable in carbon steels. There may be as much as 40 percent residual austenite in heat-treat ferrous metals. That percentage can be lowered to as little as 1 percent in some cases.

MARTENSITE FORMATION

Martensite is also formed during the quenching phase. There is always a certain amount of martensite present, but prior to cryo, the ratio of strong martensite to weak austenite is less than favorable. This untransformed austenite is brittle and lacks dimensional stability, which allows the metal to break more easily under loads. To eliminate austenite, the quenching temperature has to be lowered. At very low temperatures, austenite is unstable and readily becomes martensite. The result is a much-improved part or tool with no cracking, warping or any other cryogenically imposed defect. Improvement in durability is about 100 percent. The typical increase in strength is 30-50 percent. Another advantage of cryo is the increase in efficiency to dissipate heat. Gears, engines, transmissions and disc brakes run cooler.

Cryogenic processing at minus-300° F can improve performance and increase the life of metal cutting tools, blades, punches, dies, slitters, shears, and knives. Cryo processing increases abrasive wear resistance, raises the tensile strength, and decreases brittleness with only one permanent treatment. There is no advantage to having an item treated more than once. It's not something you can grind off. Subsequent refinishing or regrinding operations don't

affect the permanent improvements of the processing.

Cryogenic treatment changes the entire structure, not just the surface. The only way to reverse the cryo treatment is if you took the tool back up to a critical temperature, such as heat treating. It creates a denser molecular structure and closes the grains structure, resulting in a larger contact surface area that reduces friction, heat, and wear. The net result for the customer is lower manufacturing costs and superior product performance.

HSS cutting tools and dies are among the most frequently recommended applications for cryogenic treatment. This includes, drills, taps, endmills, reamers, broaches, circular saws, chipper knives, router bits, and molder knives.

DEEP VS. SHALLOW TREATMENT

The difference between deep and shallow cryogenic treatment should be considered. Taking a part to minus-120° F for a short period of time is called shallow cryogenics. This method does not transform all of the retained austenite to martensite and does not stress relieve. Deep cryogenics takes the parts to minus-300° F for many hours as LN2 is pumped into a well-insulated chamber at precise time intervals. Beware of those processors who are dipping and dunking parts into a barrel of liquid nitrogen. This will cause stress and fracturing to the part. It must be done gradually and precisely so the metal will be stronger and will not become brittle.

There are many theories as to why cryogenic treatment is effective; actual measurements of results have remained relatively difficult to obtain. Treated tools or parts show no visible change in color, size, or any other property that can be visually detected. A normal metallograph shows no changes nor do common tests like eddy current or ultrasonics. The benefits of the treatment can be supported by numerous examples, but there aren't precise measurements that can prove their effectiveness. Most companies are not willing or able to undertake such testing to quantitatively measure such results. Companies keep their processing techniques a secret to maintain a competitive advantage. This is slowly beginning to change, but the industry as a whole is still reluctant to utilize the process.

Gage blocks, which are used as a length reference for precision measuring devices, are treated to stabilize their dimensions over time. They're made of corrosion resistant steel alloys to prevent growth.

UNDERSTANDING THE TECH

Today's limited acceptance and use of cryogenic treatment is basically attributed to a lack of understanding the technology. Changes to the material micro structure are not visible with a standard laboratory metallograph or any other standard mechanical testing. Material hardness can be improved somewhat — 1-2 points HRC — the variation in hardness throughout the part is reduced. This makes for a more consistent and predictable tool.

When the cryo-treated tool does wear, the degree of wear reportedly is less severe, slower, and more uniform. Therefore, less material must be removed to re-sharpen it. Customers have reported a material removal rate of less than half the normal material removed in re-sharpening. Cryo treating reduces the cost of the product by having longer tool life, less scrap, fewer rejections and above all, less costly downtime. Gains between 50 and 500 percent may occur, depending on the component structure and previous heat-treating.

Every application is unique, and the benefits for each one are application specific. There is no blanket prediction that can be made or previous results used to guarantee the same results for every operation. Each one has to be tested.

Cryogenics is not a substitute for heat treating; instead, it simply adds the finishing touch to the heat-treating process. It completes the austenite-to-martensite conversion in tool steel.

Cryo treating reduces the cost of the product by having longer tool life, less scrap, fewer rejections and above all, less costly downtime.

Durability is the most important criterion used to define the quality of a gear. Cryogenic treatment will provide high quality products with superior performance. It allows an increase in fatigue life, load capacity and wear resistance of gears without an increase in weight or major modifications to component design. Racing teams will reduce costs and often prevent destructive failure. The process is not a coating, but a permanent irreversible change completely through the metal part. Gears may be new or used, sharp or dull, re-sharpening will not destroy the treatment. Potentially every gear that is heat treated is a candidate for the additional service of cryogenic treatment.

UNIFORM GRAIN STRUCTURE

Another benefit of cryo treating is its ability to make the grain structure more uniform, which ultimately improves dissipation of heat-beneficial to the racing industry.

Cryo treating can be used for coated as well as uncoated tools. The coatings actually adhere better. Anodized surfaces or metals, such as aluminum, also obtain longer life. Cryo also creates a better conductor giving the metal better electrical conductivity.

One of the strangest aspects of cryogenic treatment is the thin layer about 0.0001" thick- on the outside of the tool that remains untreated. After this layer is removed by sharpening, the tools will get the added wear resistance

It looks as if cryogenics finally will be getting the attention, in terms of metallurgical research that many of its proponents have been seeking. Cryogenics is an exciting and important frontier that has already led to major discoveries and holds much promise for the future. Deep cryogenic processing is now inexpensive and very cost effective due to recent developments, new cryo processors and computers.

A wide array of items such as racing engines, guns, knives, aluminum softball bats, punches, dies, golf club heads, high end audio equipment, brass instruments, guitar strings, vacuum tubes, CDs, and DVDs all benefit from the cryogenic treatment. New applications are being discovered regularly.

Until more companies commit themselves to taking, recording and making available exact results of cryogenic treatment, the industry as a whole is likely to remain somewhat reserved in its use of the process. Due to the efforts of the Cryogenic Society of America, misperceptions are slowly giving way to the cryogenic technology because of the scientific date and documented case studies. If you're looking for a cryogenic provider, their web page would be an excellent place to start. www.cryogenicsociety.org.

ABOUT THE AUTHOR

Kathi Bond is founder of CryoPlus, Inc., which is based in Wooster, Ohio. She is a member of ASM International, as well as the National Association of Women Business owners and the Association of Women in the Metal Industries. Learn more at www.cryoplus.com.