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Cold and Cryogenic Treatments

Thermal treatments can involve heating *or* cooling. When it comes to low-temperature processes, there is a distinction made between subzero, or cold treatment, to -84°C (-120°F) and deep cooling, or cryogenic treatment, to -195°C (-320°F). A question many designers, metallurgists and heat treaters ask is: Can these treatments be used for anything besides converting retained austenite to martensite? In other words, are performance enhancements achievable with materials such as aluminum, brass, bronze, carbide, cast iron, copper, stainless steel (austenitic and martensitic), steel and titanium, as well as tool steels? And is trial and error on a case by case basis still necessary? Let's learn more.

The basics

The concept of changing the properties of metals through the use of low temperature had its origins in this country back in World War II when the life of steel cutting tools was improved by immersing them in liquid nitrogen prior to being placed in service. Today, the technique most commonly used involves gradual changes in temperature. Of course, anyone familiar with a Siberian winter might speculate that the Russians have been testing the theory of cryogenics for a very long time. Because the mechanisms involved have been poorly understood, more research is needed. Today, the technique most commonly used involves gradual changes in temperature rather than direct immersion. It is a fact that exposure to very low temperatures does produce permanent changes in materials. Reported benefits include:

- Increased fatigue resistance
- Precipitation of fine carbides
- Increased abrasion resistance
- Change in vibrational dampening
- Increased electrical conductivity
- Stabilization and reduced warpage
- Transformation of retained austenite

Tempering is necessary after treatment, especially on hardened steels. Cold and cryogenic processes affect the entire part. Thus, subsequent manufacturing steps, such as machining, can be performed after treatment without loss of properties.

Applications

Cryogenics has found its way into a number of product applications (Fig. 1), including some that are unique. For example, musical instruments have better tonal quality and sports equipment (e.g., tennis rackets, golf balls and clubs, baseball bats and firearms) show better performance in distance, accuracy and life. Even flags are treated to prevent their colors from fading and panty hose to reduce the risk of tearing.

Cryogenic treatment of brake pads and rotors (Fig. 2) in automotive applications is said to improve service life. In police cars, where a combination of high speeds and frequent braking translates to brake-component replacement around 8,000 miles, cryogenic processors report having extended the time between replacement of these components consistently up to 24,000 miles. The brake rotor is a pearlitic cast iron (Fig. 3).

In another example, connecting rods made of 300M alloy steel used in certain V8 racing engines are processed in custom designed heat treatment/cryogenic treatment cycles to hardness values (approx. 42 HRC) generally thought too hard/brittle for the application. These components are able to withstand repetitive stress of reversing the piston direction at the top of its stroke at over 9,600 rpm.

Bearings	Engine blocks	Knives
Brake rotors	Extruders	Lifters
Cams & camshafts	Gears	Piston rings
Clutches	Granulators	Punches
Crankshafts & rods	Gun barrels	Push rods
Cutters	Hammermills	Reamers
Cylinder heads	Heads	Shear blades
Dies	Hobs	Slicers & slitters
Drill bits	Inserts (carbide)	Valve springs
End mills	Intake manifolds	Welding electrodes

Fig. 1. Selected products that are given a cold/cryogenic treatment to enhance performance

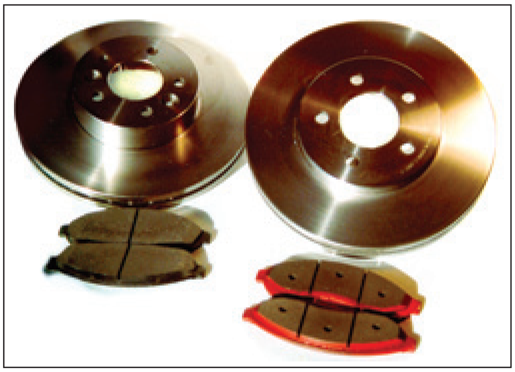

Fig. 2. Automotive brake pads and rotors. Courtesy of Controlled Thermal Processing Inc. (www.metal-wear.com)

Fig. 3. Pearlitic structure of a cryogenically treated gray cast iron brake rotor; 100×; 2% nital etch. Courtesy of Controlled Thermal Processing Inc.

Documented improvement

A scientific study [1] conducted to investigate the wear resistance and microstructural changes of quenched and tempered alloy tool steels, followed by either cold treatment (−60°F, or −50°C) or cryogenic treatment (−300°F, or −185°C) produced some interesting results. An almost identical volume fraction of retained austenite was found using x-ray phase analysis in samples austenitized at approximately 1875°F (1025°C) and treated using one or the other low-temperature process. However, cryogenic-treated specimens had improved (sliding) wear resistance (Fig. 4). The wear rate of as-quenched samples was greater than those of cold- and cryogenic-treated specimens at sliding distances of 656 ft (200 m). At double and triple these distances, cold-treated samples had almost the same wear rate as the as-quenched samples. However, cryogenic-treated specimens had a smaller wear rate than the as-quenched samples and cold-treated samples for any sliding distance.

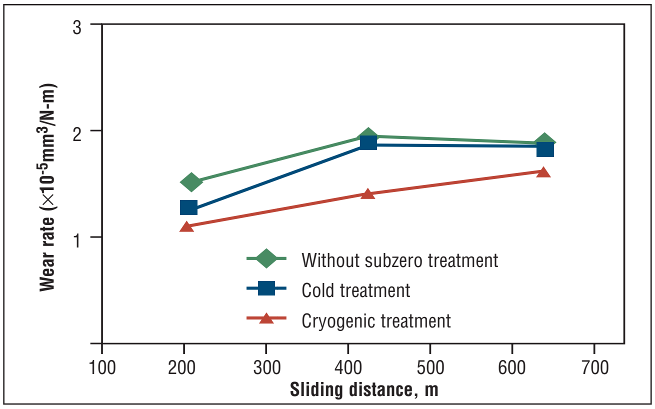

Fig. 4. Wear rate versus sliding distance [1]

The volume fraction of retained austenite was also analyzed for samples austenitized at 1875 and 2000°F (1025 and 1095°C). As-quenched samples had about 12% retained austenite compared with approximately 6% for cold- and cryogenic-treated specimens. Cold treatment drastically reduced the volume fraction of retained austenite, while cryogenic treatment only reduced it slightly relative to cold treatment.

Conclusions

This research shows cryogenic treatment increased (sliding) wear resistance dramatically, especially at high sliding speed, and the cryogenic-treated specimens had minimum wear rates. The microstructure was also dramatically different between cold- and cryogenic-treated samples. Unlike cold treatment, cryogenic treatment promotes preferential precipitation of fine eta-carbides. It is assumed that the formation mechanism of eta-carbides involves the expansion and contraction of iron or substitutional atoms, allowing carbon atoms to shift slightly due to lattice deformation as a result of cryogenic treatment. The contribution of cryogenic treatment to wear resistance is believed to be precipitation of fine eta-carbides, with enhancements in strength and toughness of the martensite matrix rather than the removal of retained austenite.

Cold and cryogenic treatments are not a cure-all. However, they are gaining in popularity. For this reason, many heat treatments include this step as a logical continuation of the heat treating process, as well as to add a measure of safety to product performance. However, a thorough review of the design is imperative to ensure that the correct heat treatment for the material has been specified and the use of cold or cryogenic treatment produces tangible, documented benefits. **IH**

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