Cryogenic tempering delivers better cutting tool durability

Steel materials that typically retain austenite after an ordinary heat treatment, exhibit greater wear resistance and dimensional stability after cryogenic treatments.

300° Below Inc.

Edited by Diane L. Hallum

Deep cryogenic processing is dramatically enhancing metalworking tool life and workpiece life by relieving residual metal stress and creating a stronger, denser, more-uniform microstructure. Residual stress develops in steel during the initial steel forming or forging operations and from machining operations required to finish a piece. This residual stress can result in part warpage if the part heats up during service.

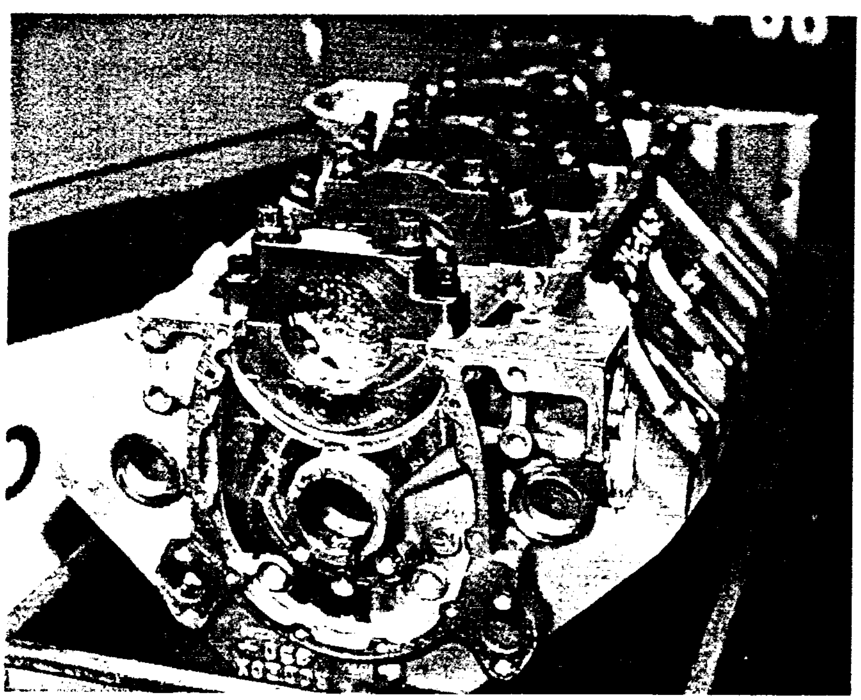
A workpiece expands due to heat generated during processing operations. If a part is prevented from expanding, stresses build up within the microstructure of the material. Once cool, these stresses are called residual stresses. The complex nature of expansion and contraction results in an uneven distribution and level of residual stress in a given part.

Accurate deep-cryogenic processing of metals using computer-controlled thermal contraction and expansion decreases residual stress, homogenizing and stabilizing the microstructure. The process also increases the durability or wear-life of tool steels through carbide precipitation within the steel microstructure, making it significantly stronger, more coherent, and dense.

Today, cryo-processing is used for new and used as well as for sharp and dull tools including end mills, drill bits, inserts, punch dies, press dies, forging dies, circular slitters, cutters, gears, hobs, and engine components. In specific applications it increases tool steel life over 300%. It isn't unusual to increase the life of carbide inserts 400 to 600% with the process.

Uniform temperature changes are key

Properly controlled, dry cryogenic processing physically transforms a steel part's microstructure into a more refined, uniform substructure that is stronger. 300° Below Inc., Decatur, Ill., builds and



This all-aluminum Chevrolet short-block V-8 racing engine saw an increased lifespan of 500% after a cryogenic treatment. The treatment included the engine block, crankshaft, rods, pistons, piston rings, piston pins, bearings, heads, intake, camshaft, push rods, rocker arms, valve springs, valves, and lifters.

markets the Model 925 Cryostatic Processor to treat tools and metals by controlling temperatures within $\frac{1}{2}$° F by manipulating flashed liquid nitrogen.

President Peter Paulin explains, "Cryogenic temperatures near -300° F are required to effect a complete molecular change in most alloy steels, making all the retained austenite turn to martensite, a denser, more-refined mix with a smaller and more uniform microstructure than austenite."

The computer on a cryogenic processing system duplicates an optimal cooling curve for a given part size and shape within $\frac{1}{10}$ of 1° F, so the temperature of a mass descends at an even, slow rate. This computer-controlled process is repeatable time-after-time.

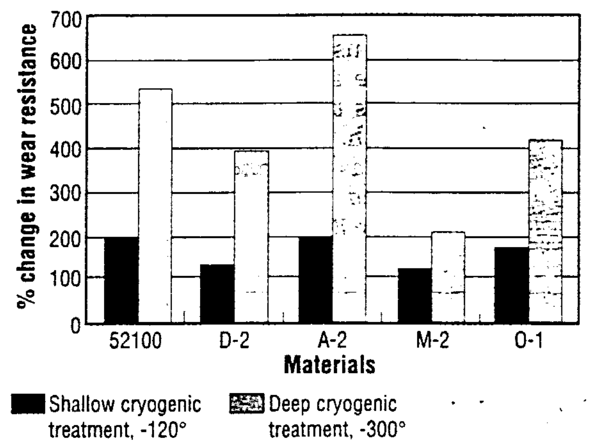
The process does not expose the material to liquid nitrogen, thus eliminating the risk of thermal shock. Cutting tools are cooled very slowly, held at a -300° for a preset time, then slowly allowed to return to room temperature. The process is electronically computer-controlled to a precise timetable allowing the cutting tools to adjust to the progressively cooler environment before returning to ambient temperature.

A major aircraft manufacturer forecasted its savings could reach $5 million just from using six cryogenically treated cutting tools. This is due to the high durability and wear resistance of the cold-treated tools. Tool life increased 96%, while resharpening required $\frac{1}{3}$ the stock removal required previously to restore tool geometry.

Manufacturers have experimented with cold-treatment by applying dry ice to heat-treated metals. However, this kind of shallow cold-temperature treatment, which drops temperatures only to -110°, is ineffectual unless performed as part of the initial heat-treatment cycle.

Heat-treating gives steel its hardness, toughness, wear resistance and ductility. In most steels, heat treatment can leave 15% retained austenite. Cryogenic treatment can transform 8 to 15% of the retained austenite to martensite.

Steels that undergo austenitic changes during heat treatment show marked wear resistance after cryogenic treatments.



Deep cryogenic treatment induces a microstructure having fine carbide precipitates in a martensitic matrix. This structure has high resistance to abrasive wear. The fine carbide particles support the martensite matrix, minimizing the likelihood that sections of the substrate will be dug out during a cutting operation and cause abrasion. When a hard asperity or foreign particle is pressed onto the tool's surface, the carbides further resist wear by preventing the particle from plowing into the surface.

After oil quenching to 68° F, an O-1 steel remains fully austenitic. Quenching an M-1 steel from 222° F to 212°, then tempering at 1,045° leaves 11% retained austenite. Additional improvements in tool life and performance are possible if this retained austenite is transformed to martensite using a cold treatment.

Fabricators of racing engines find the cryogenic process improves engine life, as well. Engines push the edge of the envelope for temperature, vibration, and strength. Many engines are routinely destroyed when run at these boundary conditions.

Cryogenic processing of engine blocks and components at -300° F opens the envelope farther by providing a measurable, permanent refinement to the grain structure and reducing residual stresses.

These characteristics resulted in an engine that went into the world's fastest gas-powered Harley-Davidson motorcycle. Butch Hixson, owner of Hixson Engines, Gibson City, Ill., cryogenically treated a small-block Chevrolet engine that operated at 8,000 to 8,500 rpm for the entire racing season without any breakage. In addition, normal cylinder wear would be 0.002 to 0.003 in. The engine showed less than $\frac{1}{4}$ of 0.001 in. of wear.

Past mistakes

Cryogenics got a bad name when first introduced after a connecting rod company treated the parts by immersion into liquid nitrogen. This kind of immersion creates stress. Contrastingly, stress relieving takes place when the entire mass is cycled slowly at less than 1 degree per minute through a wide temperature range.

If the rate of temperature change is slow enough, thermal compression and expansion take place uniformly from the core to the surface, releasing internal stresses. The result is a thermally stabilized, homogeneous material. This process takes more than a day to keep the entire mass in equilibrium through the temperature cycling.

A study conducted by Louisiana Technical Institute's mechanical engineering department supports increased life claims for deep cryogenic processing. Their scientists found that metal samples processed at -320° F exhibited wear resistance two to five times greater than that for samples processed at -120° F. ■