Reducing Wear with Deep Cryogenics

A breakthrough cold thermal process that's fast, low cost, green, and effectively heats up.

By Jack Cahn, Deep Cryogenics International

MINING EQUIPMENT OPERATES AT the intersection of material fatigue, impact, abrasive wear, and corrosion. To improve the wear life of components usually requires a trade-off between material choice, heat treatment, and surface coatings. Although operators demand increased uptime and lower maintenance, higher cost is frequently a barrier.

The problem: abrasive wear

Common solutions include weld overlays, high velocity thermal sprays, and hardfacing, but heat-affected zones (HAZ) often precipitate chromium carbides across grain boundaries or at the bond interface, causing intergranular corrosion, hydrogen embrittlement, and material separation.

Overlay solutions are not chosen for gears, shafts, and internal components because of tight dimensional tolerances, required mechanical core strength, and needed uniform grain structure to resist strain hardening.

Higher yield, increased tensile, and abrasion-resistant material for skip plates, mill liners, bucket teeth, and crusher cones are available but they're costly, sometimes offer only limited improvement, and require a vender tie-back. A low-cost, permanent, and effective alternative is needed.

The solution: deep cryogenics

Deep cryogenics (DC) is a cold-temperature process that reduces corrosion, wear, fracture, and fatigue in metal items by 20 to 70 per cent. Thermo-kinetic exchange occurs during a prolonged time and temperature exposure to -190˚C dry-nitrogen vapor (Figure 1), imparting mechanical improvement.

The process is attracting attention in several areas – from government R&D agencies and universities to OEM's and end users of paste pumps, SAG mills, bucket teeth, crusher cones, bearings, shafts, nozzles, gears, and hauler vehicles.

The benefits of deep cryogenics

The primary metallurgical changes resulting from DC are a three to seven per cent reduction in retained austenite and a conversion to martensite, refinement in grain structure, and the emergence of primary and secondary eta carbides that provide wear protection. Both destructive and non-destructive testing show that DC:

- Increases tensile and yield strength in carbon- and bearing-steel alloys by 10 to 20 per cent.
- Reduces corrosion in high-carbon steel by 20 to 60 per cent (Figures 2 and 3).
- Lowers wear effect on low and high carbon steels by 30 to 70 per cent.
- Improves surface finish contact area by up to 50 per cent (Figure 4).

Industrial applications include mining, oil and gas, power generation machining, and transportation. Deep cryogenics addresses the greatest challenge facing all manufactured items – extending operational life by making things last longer.

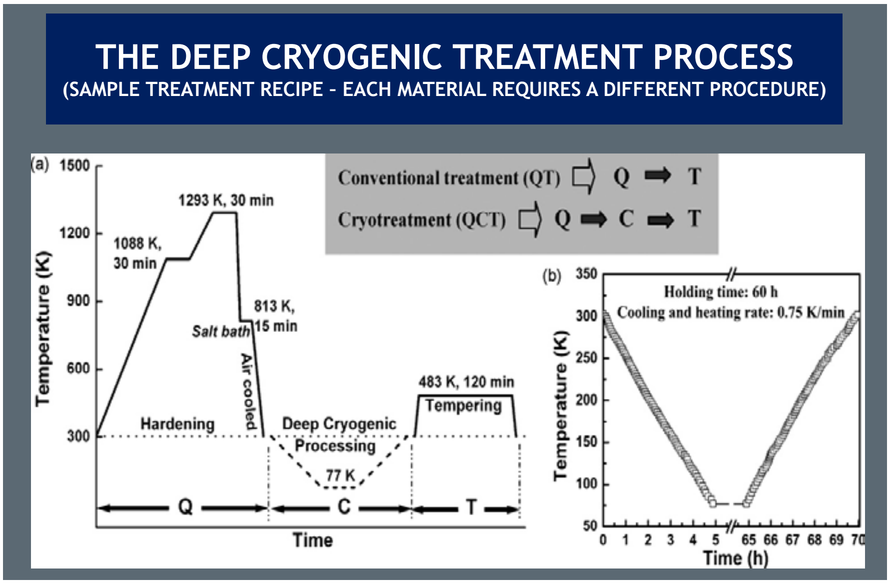

Figure 1.

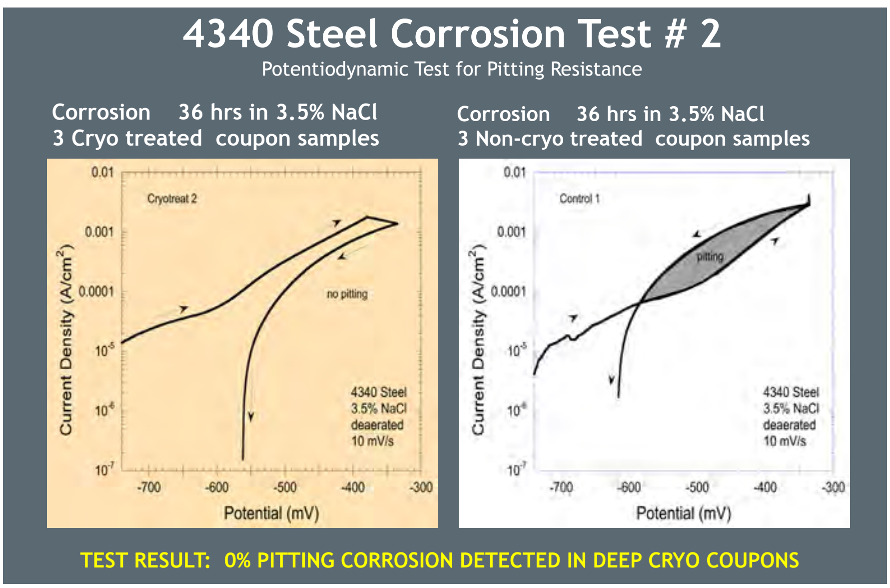

Figure 2.

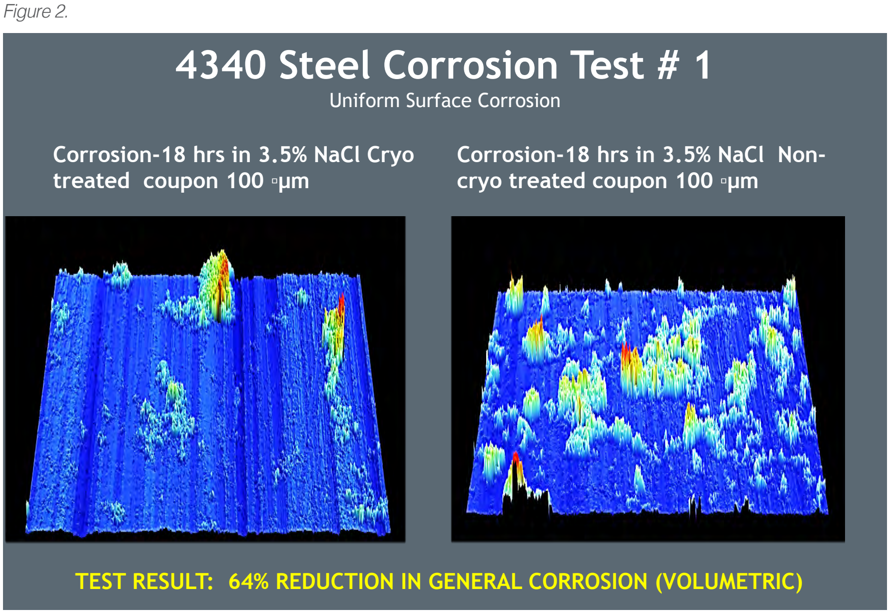

Figure 3.

How it works

Items are placed in a specially designed tank where they are slowly cooled from room temperature down to -190ºC, cold-soaked in a dry nitrogen atmosphere for 12 to 40 hours, and then slowly returned to room temperature.

Then they undergo one to three annealing steps to eliminate hydrogen embrittlement and to add ductility. In steel, the process transforms the softer, retained austenite into more durable martensite and fine carbides precipitate throughout the microstructure. These carbides cement the metal matrix without reversal when the item returns to room temperature. Unlike surface treatments, such as welding, cladding, plating, or HV depositions, deep cryogenics is a through core diffusionless process.

DC takes three days to complete, costs roughly 10 per cent of the original item, doesn't change part size, and allows hundreds of parts to be treated simultaneously – with part weight up to thousands of pounds. DC is non-toxic, uses no chemicals, and generates no environmental waste. The process is scalable to large industrial use and is supported by over 25 years of scientific research. DC treated parts can be authenticated, tested, and certified using existing ASTM destructive and non-destructive test methods.

The process generally follows heat treatment and does not substitute for it, although many parts too big to heat treat can be DC treated for a 40 to 120 per cent gain in wear life.

Prior obstacles to technology adoption

Despite multiple attempts using electron microscopy and nano-characterization, the science behind the deep cryogenic phenomena is still unknown, causing mixed reaction within the heat treat community, in spite of positive field results and test data. Although heat treatment has been around for over 10,000 years (since the first caveman fire-hardened a spear), DC launched in the 20th century when nitrogen gas was separated, chilled, and liquified. Like electric cars, the newness of this process may explain the recent adoption.

Industry qualification

Qualification agencies DNV-GL and Lloyd's have both issued proposals charting the future application of this technology. Because use of DCT doesn't change sources of supply, material type, manufacturing method, dimensional tolerance, or even end use, qualification time can be compressed in the traditionally conservative mining and energy industries. A key benefit is that DCT can be added to existing manufacturing processes without changing, modifying, or eliminating any of the prior steps.

History and equipment

DCT has evolved greatly since WWII, when Clarence Zener experimentally poured liquid nitrogen on aircraft forging dies in primitive attempts to increase wear life. These early experiments often initiated fatigue cracking and die fracture due to thermal shock, but some survived with double the wear life. Zener knew he was on to something, but the war ended and his project was mothballed. Forty years later, the process emerged again with technology advancements, including digital-controlled LN2 supply, use of dry-nitrogen vapor, PID optimization, and in-situ annealing capability.

Current status

The technology has shown that specific time and temperature formulas are required to optimize wear resistance and fracture toughness per alloy. To commercialize the process, an industrial customer should work with a DC provider that can offer both on-site R&D and test lab capability to accelerate development. There is currently a single company in Canada that provides on-site DC treatment, test and R&D, and certification capability – soon with scale-up treatment capacity up to 60,000 kg.

Opportunities

Numerous mining assemblies, such as crushers, grinding mills, hauling rigs, slurry pumps, and gearboxes, are an excellent match for improvement by deep cryogenics. But in many cases, DC will also allow the substitution of low-cost carbon steel for expensive superalloys and tungsten-carbide products – providing extended life at a significantly reduced cost.

Summary

Deep cryogenics allows end users to sharply reduce the wear and corrosion effect on mining equipment. The technology has come of age with the introduction of engineering-based acceptance standards, known destructive / non-destructive test methods, large-size tanks, and certification protocols. This step-change in thermal treatment of metals will reduce operational downtime, lower maintenance / capital-replacement cost, and increase net profitability. After many years on ice, it's a technology that has finally arrived. M

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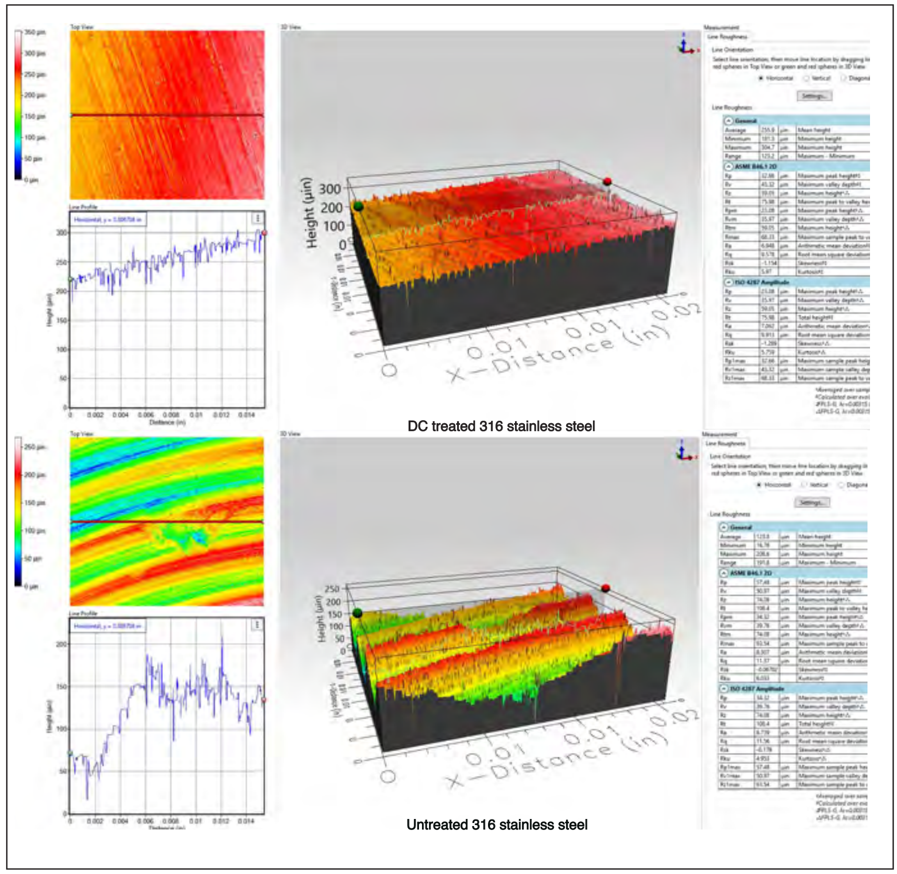

Figure 4.