Deep-Cryogenic Treatment of Steel: Saves money while improving mechanical properties.

In the field of mechanical engineering we are always looking for ways to improve the mechanical properties of materials. By doing so we can improve the quality of the products we are making, reduce costs to both ourselves and our customers and possibly gain market share by offering a higher quality product.

In the manufacturing of gears for example we seek to achieve a very hard case to reduce wear while maintaining a ductile centre to increase strength. The standard process for doing this is through the traditional heat treatment of steel alloys. In the heat treatment process the alloy is heated to the austenite phase and is then quenched in oil or water. If quenched faster than the critical cooling rate the maximum amount of martensite will result based on the percent carbon in iron. While martensite has a high hardness value it is also very brittle and difficult to use in a practical way. Quenching also causes the build up of residual stress within the material. Tempering is used to reduce this residual stress which can enhance the ductility and toughness of martensite. Tempering involves re-heating the material and allowing carbon atoms trapped by iron to diffuse throughout the crystal structure. Longer tempering times result in softer more ductile steel.

While this is certainly the tried and true method there are some problems with conventional heat treatment processes. For example, in some alloys the temperature at which martensite finishes forming is much lower than room temperature. If that temperature is not reached some retained austenite might be present in the material. Retained austenite causes significant changes in mechanical properties, such as internal stresses that weaken the part. If the part is exposed to extremely low temperatures the retained austenite can transform into martensite with a resulting change in density that causes the part to warp (1 p.5).

The solution to this problem is deep-cryogenic tempering of the parts. "The deep cryogenic tempering process for gears is an inexpensive, one-time, permanent treatment, affecting the entire part, not just the surface. Gears may be new or used, sharp or dull, and re-sharpening will not destroy the treatment (2 p.1)."

The process of deep-cryogenic or freeze tempering is really quite simple. "A Freeze Tempering Process means that the material to be treated is not exposed to any Liquid Nitrogen, which eliminates the risk of thermal shock. The material is frozen through a thermo-dynamic refrigeration cycle. The material is cooled slowly, held for a prolonged period of time 48-60 hours, and allowed to return to room temperature slowly (4 p.1)."

How deep-cryogenic tempering works: by cooling the metal to well below zero the retained austenite will transform into martensite which can then be further tempered after being slowly heated back to room temperature. The effects are very pronounced in tool steels but the process also works well in most steels as well as polymers (5 p.1).

Why cool to -300° F instead of some other temperature? A deep-cryogenic cycle doubles the results of a shallow-cryogenic cycle. After performing separate laboratory tests it was determined that cold treatment improves wear resistance and that the colder the treatment the better. The dry ice or -120° F test showed improved wear resistance of 1.2 to 2 times, depending on the alloy. The deep cryogenic treatment at -317° F showed improved wear resistance of 2.0 to 6.6 times (2 p.2-3).

There are numerous benefits to deep-cryogenic tempering, including increases in tensile strength, toughness, and stability due to the release of internal stresses. The greatest benefit is the increase in wear resistance generally about 200% (2 p.1). The cryogenic treatment of parts can increase product life significantly. According to Controlled Thermal Processing, Inc., a standard punch made of S5 steel is capable of producing roughly 4,000,000 tablets while a cryogenically treated punch is capable of producing roughly 64,000,000 tablets (3 p.1).

Cryogenic treatment can significantly increase the useful life of parts in such a way that the cost of treatment will certainly be offset by the reduction in the cost of time lost due to the breakdown of machines and the replacement of parts. The manufacturing process will become more efficient; production orders can be completed in less time thereby increasing customer satisfaction and perhaps loyalty.

Myths about Cryogenic Processing and Metal Wear:

"Cryogenic processing will make the metal harder and therefore more brittle.

- Although cryogenic processing makes metals more wear resistant, it rarely increases hardness any significant amount. The wear resistance comes from a refined crystal structure, not an increase in hardness (7 p.2-3)."

  "Cryogenic processing has no effect on low carbon steel, cast iron, and non ferrous metals.

  - You don't need retained austenite for cryogenics to have an effect. Very pure silver and very pure copper will react to cryogenic processing. The same is true of copper alloys, low carbon steel and most materials that have a crystalline structure, including plastics (7 p.3-4)."

There are numerous applications for this process which include; Industrial (machine tools, dies, and other products), Motor Sports (engines, valves, rods, pistons, etc.), Sporting goods (softball bats, golf clubs, tennis rackets), Musical Instruments (any instrument not made of wood), Electronics (anything including CD's), Farm Implements (ploughs, shovels, picks, etc.) (6 p.1).

Deep-Cryogenic processing is effective on a variety of materials and has an extensive list of uses. The process is relatively inexpensive and will generate savings to manufacturers and consumers. The change in mechanical properties such as increased tensile strength, ductility, stability, toughness and the decrease in residual stresses and the increase in wear resistance generated by this process by far out weigh any cost associated with the process itself. For customers in a manufacturing setting there will be a direct savings based on longer product life through the reduction in maintenance costs, replacement part cost, and the cost of idle time for employees. This will ultimately result in lower cost to the end users because of the lower cost of production associated with deep cryogenic processing.

Deep-cryogenic processing cannot be used for all materials, but for the materials that do show improvement in mechanical properties deep cryogenic processing is the way to go. New uses for deep-cryogenic processing are being developed everyday and the possibilities are endless. I can't wait to see what the next development will be.

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