Cryogenic Treatment Review

Cryogenic treatment is primarily performed for dimensional stability and improved wear resistance in specific applications. There have been many claims that cryogenic treatment, performed as a part of the heat treatment cycle, leads to improved performance characteristics. A large amount of research has been done, but the results show a fair amount of variability. However, results have proven advantageous, even dramatic, for improved wear life of metal parts, particularly in abrasive wear applications, after cryogenic treatment.

The application of cryogenic treatment for improved wear life is dependent on part chemistry and function. The most common use for cryogenic treatment is for tools and dies, particularly those with high carbon contents, such as: A2, D2, and 440C. The information below is criteria to help you make a decision on specifying cryogenic treatment for a particular application.

Facts

1. Cryogenic treatment transforms retained austenite to martensite, which increases hardness.
   - This may or may not increase wear resistance and/or part life depending on the application. Retained austenite adds toughness to the structure, which enhances impact and fatigue resistance, both of which are important properties in many types of wear applications. Tough/ductile austenite inhibits crack initiation and blunts crack propagation. But increased hardness or “deformation resistance” resulting from cryogenic treatment often does result in increased abrasive wear resistance for many applications.

2. Retained austenite can transform to martensite under strain-induced conditions.
   - This can lead to dimensional instability in processing or service because there is a volume increase associated with the phase change of austenite to martensite. The problem is particularly acute with grinding, where retained austenite and its propensity to result in grinding cracks is a major concern in the gear industry. Thus, cryogenic treatment to eliminate retained austenite is highly desirable to avoid strain-induced distortion of parts.

3. Cryogenic treatment will amplify distortion.
   - If distortion is present after quenching, cryogenic treatment will make it worse. This means that from a “cryogenic standpoint” marquenching or vacuum gas quenching are desirable because both tend to minimize quench distortion.

Metallurgical Thought-To-Be Truths

4. The martensite that transforms from retained austenite during cryogenic treatment is structurally different than the "bulk martensite" that formed from the high temperature quench.
    - Tempering after cryogenic treatment initiates the preferential precipitation of fine eta-carbides only in the martensite formed from retained austenite transformation. Only epsilon-carbides are precipitated within the bulk martensite.
    - Eta-carbides enhance wear resistance by adding strength and toughness to the martensitic matrix. Note the use of the word toughness; this is an important attribute used to describe retained austenite and its contribution to wear resistance in certain specific applications.

5. Interrupted cooling before complete transformation can "stabilize" retained austenite.
    - Stabilization reduces the ability of austenite to transform to martensite. Therefore, it is highly desirable to perform cryogenic treatment of steel as an integral part of the heat treatment cycle, as Solar does.

6. Cemented carbide wear improvement due to changes at microvoids.
    - The results of one study showed that only abrasive wear resistance (not hardness or other typically measured mechanical properties) was improved by cryogenic treatment. With cryogenically treated cemented carbide, "plastic flow" may take place at defects (microvoids that are points of stress concentration) due to shrinkage on cooling, which results in residual compressive stresses on the surface of the voids on return to room temperature. Such stress reduces the effectiveness of the defects in lowering the localized strength of the material and this situation results in the reduction of abrasive wear.

The Most Marketed Benefits

7. 1. Improved dimensional stability and improved service performance.
    - Gun barrels, automotive racing parts - including engine blocks and heads - intricate parts to be EDM and numerous others, even including aluminum bats, and golf clubs and balls, report enhanced performance.
    - Musical instruments purport improved sound quality.
    - Try it…you might like it!

Summary

Cryogenic treatment is primarily performed for dimensional stability and improved wear resistance. Wear resistance is very application specific, but significant improvement in wear resistance has been realized for certain applications using cryogenic treatment, and most notably for tool and die steels. Just trying cryogenic treatment may lead to the discovery of improved performance for a particular application.

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