

CRYOGENIC TECHNIQUE FOR PROCESSING STEEL TREATMENT

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Abstract:

Cryogenics or deep freezing have been around for quite some time. There is documented research from as far back as the 1930's where German companies used it on components of jumbo aircraft engines. Cryogenic processing had its US origins in the 1940s. Cold treatments or sub zero treatments are done to make sure there is no retained austenite during quenching. Cryogenics is a relatively new process and to eliminate retained austenite, the temperature has to be lowered, but one that using correct procedures can bring substantial economic benefits. In cryogenic treatment the material is to be deep freeze temperatures of as low as -185°C (-301°F). The austenite is unstable at this temperature and the whole structure become martensite. This is the region to use cryogenic treatment. Processing is not a substitute for heat treating if the product is properly treated or if the product is over heated during remanufacturing or if it is over stressed during use. Cryogenic processing will not in itself harden metal like quenching and tempering, it is an additional treatment to heat-treating. The benefits of this process includes; reduction of abrasive and adhesive wear, improved machining properties resulting from the permanent change of the structure of the metal, reduction of the frequency and cost of tool remanufacturing and reduction of likelihood of catastrophic tool failure due to stress fracture. In the present study, the cryogenic technique is applied by exposing the steel to deep freezing environment (-320°F) for 24 hours and slowly raised to room temperature. The results are correlated with standard results. Cryogenic processing makes changes to the structure of the materials being treated and dependent on the composition of the material, it performs three things; viz. retained austenite turned to martensite, carbide structures are refined and stress is relieved.

Key words: Cryogenic Treatment, Steel, Martensitic Transformation, Retained Austenite.

Introduction:

Considering the wide uses of steel, it is surprising to many people that there is still much we do not know about it. This paper will review what is known about cryogenic tempering and future research plans to improve our understanding of these important phenomena [1-4]. Cryogenic tempering takes place in a chamber, where the materials are gradually lowered in temperature. Shallow cryogenic tempering is performed at about -120°F (-85°C) for 10 hours or so, whereas deep cryogenic tempering takes the material below -300°F (-185°C) for more than 24 hours. The materials are then slowly raised to room temperature and usually annealed at about 300°F (149°C) for several hours. Only deep cryogenic tempering has shown to give the greatest improvement in wear resistance. Controlled experiments and industry experience have demonstrated that many materials benefit from this treatment. Increased wear life and better corrosion resistance, while at the same time maintaining or even improving toughness have been observed. However, few materials benefit more than tool steels. Tool steels that are deep cryogenically treated will typically last more than 50 % longer than as quenched specimens. In addition, tool steels have been studied extensively to understand the cryogenic phenomena. Therefore, I will discuss the present understanding of the cryogenic tempering in these metals [5]. Even the ancients knew that the rapid quenching of steel from elevated temperatures made it harder. We now know that this rapid quenching produces a metastable phase in steel called martensite. This transformation process is rapid and diffusionless. To form martensite the steel must initially be in the face center cubic (FCC) form of iron called austenite (γ). To establish austenite in the steel, one typically has to “soak” the steel at temperatures above 750°C . There is another form of iron called ferrite. If the steel is ferritic (α), it cannot form martensite. In figure-1, there is a description of transformation with temperature.

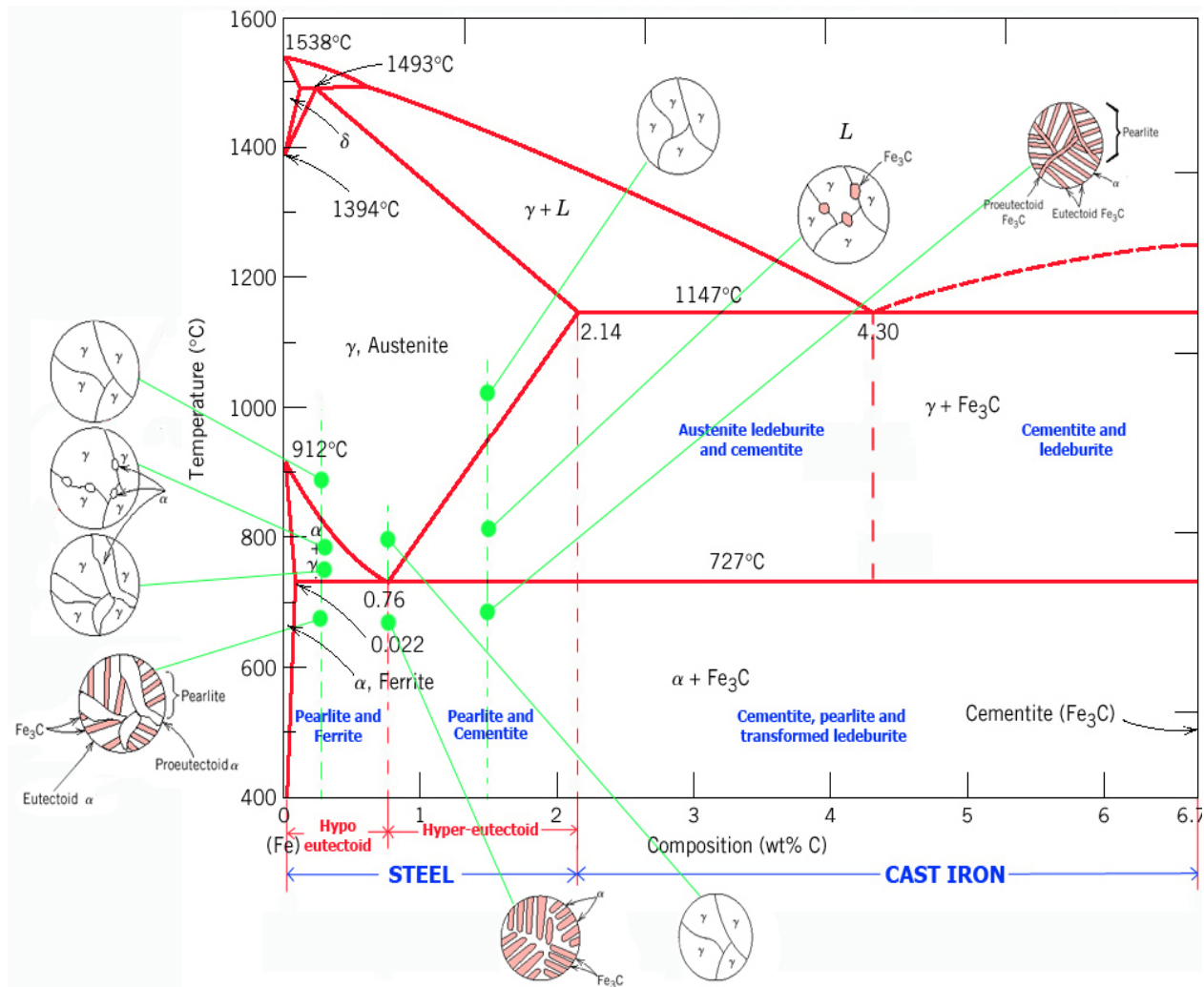


Figure 1. The steel phase diagram.

The martensite reaction occurs as the FCC austenite transforms to a BCT (body centered tetragonal) martensite. Carbon atoms are trapped in interstitial sites during the rapid transformation. See Figure 3. As the carbon content increases a greater number of carbon atoms are trapped. If the temperature quench is not rapid, stable pearlite, bainite and other constituents can form.

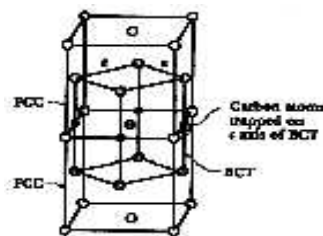


Figure 2. Martensite crystal structure.

Experiment, Result & Discussion:

As the steel is quenched, the martensite starts to form at a given temperature for the material. This temperature is called the martensite start temperature (M_s). To completely form martensite, the martensite finish temperature must be reached before pearlite and cementite can start to form. This mechanism can be seen on a time-temperature-transformation chart (TTT chart) shown below.

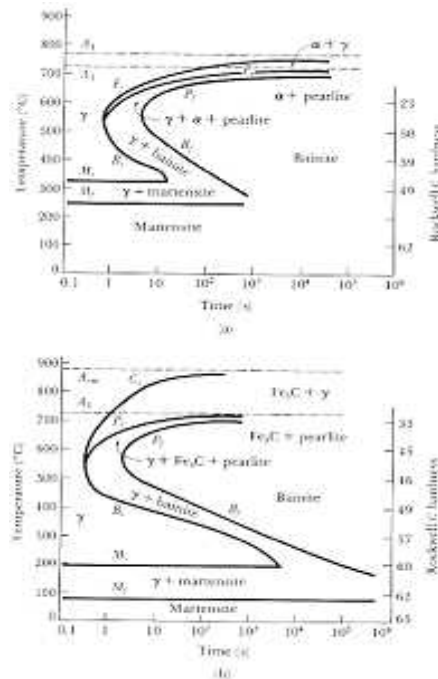


Figure 4. TTT Diagrams for (a) 1050 and (b) 10110 steels

The addition of carbon reduces the temperature at which martensite stops forming as we can see in the above TTT charts. The M_f temperature is the temperature at which 100 percent of the martensite has formed. M_f for 1050 steel (0.5% carbon) is 245°C, whereas it is 85°C for 10110 steel (1.1% carbon). The presence of other alloying materials such as manganese, chromium and vanadium tends to reduce the M_f temperature and provides the added benefit of suppressing the formation of pearlite and bainite. The combination of the carbon and the alloying metals can reduce M_f to below room temperature, with no possibility of other constituents forming. The TTT below, for A2, shows this effect.

Meng et al [6] proposed that the dominant mechanism for enhancing wear in tool steels is eta carbide formation. Their work is experimentally well supported and the analysis of eta carbides was performed with transmission electron microscopy. Their conclusions, from experiments, were:

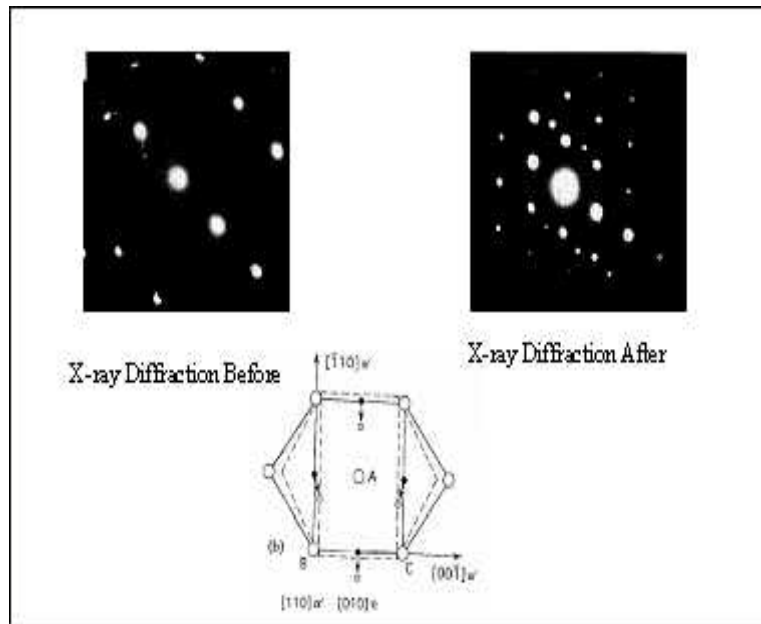


Figure 8. Cryogenic tempering appears to cause a movement of carbon atoms in the steel molecular structure as shown in the diagram. The results are evident in the before and after x-ray diffraction pattern.

Conclusion:

The dramatic improvement in wear resistance in deep cryogenically treated tool steels, with no loss in toughness is most likely explained by the formation of molecular eta carbides and the formation of fine cementite particles in the final tempered structure. It would appear that the conversion of additional martensite, although often present, is probably a secondary mechanism. This understanding also supports the increase wear resistance in materials that don't readily form martensite.

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