August, 2012

# Comparative Study of Cryo -Treated Steel

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**Abstract**— It is well known that most important problems faced by many industrial machine parts are the wear and tear which increases the cost of production and wasted time for the replacement process. Now-a-days cryogenic treatment would be regarded as one of the most important processes in the field of industries, and it is the ultra modern type of processing to make the metals more resistant to wear and more durable. Cryogenic treatment is an additional process to conventional heat treatment process. It involves freezing of materials at cryogenic temperatures to enhance the physical and mechanical properties of materials. This paper describes about different materials property such as their life span in an industrial application and their treatment cost. Peculiarity of this technique is its environmentally friendly nature which produces no waste during the process. In cry-treatment, main aim is to convert retained austenite to martensite. Due to this conversion, all properties of the material increases. In a proper heat treatment process, there is a transformation of 85% of retained austenite to martensite and by the application of supplementary cryo-treatment process only transformation of an addition of 8 to 15%. Here investigation is to compare about cost and durability after and before cryogenic treatments. In this treatment, ultra-cold temperatures i.e. below -310°F, will greatly increases the strength and wear life of all types of automobile/aerospace components, castings and cutting tools. In addition, other advantage includes reduced replacement & maintenance of tools and components, reduced vibrations, rapid and more uniform heat dissipation, and improved conductivity.

**Index Terms**— Cryogenic process; Martensitic transformation; Austenitic transformation; Tool steel; Crankshaft; Tool life; Tool cost

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## 1 INTRODUCTION

The widespread cryogenic technology is an established process for the production of tool steel for the most different technical applications [1-4]. As is known, the quality of cryo-treated steel is influenced strongly by the characteristics of microstructural transformations between Austenite & Martensite. At the beginning of 20th century some experiments of cryogenic treatment on steel started and popularly many investigations are going on to get most efficient materials [5-6]. Cryo-treatment is especially important for progressive dies, where cumulative tolerances are critical. Ultimate goal of cryo-treatment is to improve wear resistance, fatigue life, and minimize residual stress. Residual stresses are uneven and located variously throughout the structure. Stresses exist in parts from the original steel forming or forging operation, and additionally as a result of the many different machining operations to finish the part [7]. Stress is the enemy of the steel, if it is not imparted in a uniform manner. Cryogenic processing will not in itself harden metal like quenching and tempering. It is not a substitute for heat-treating. It is an addition to heat treatment process. During production of steel component, austenite retained in the step of quenching process. Austenite is a soft phase which is a solid solution of carbon and iron [8]. This untransformed austenite is brittle and lacks dimentional stability, which allows the metal to break more easily under loads. To eliminate austenite, the quenching temperature has to be lowered up to subzero temperature. In this temperature austenite phase is transformed slowly into a highly organized grain structure called martensite. Martensite phase having body centered tetragonal crystal structure [9].


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Martensite is a finer and harder material that brings high wear resistant and better dimensional stability that is very desirable in carbon steels. Cryogenic treatments can produce not only transformation of retained austenite to martensite, but also can produce metallurgical changes within the martensite. The martensitic structure resists the plastic deformation mush better than the austenitic structure, because the carbon atoms in the martensitic lattice lock together the iron atoms more effectively than in the more open-centered cubic austenite lattice. Fully martensite steel results a much improved part or tool with no cracking, warping, or any other cryogenically-imposed-defect. Gears [10], engine & transmissions [11], and disc brakes run cooler [12], HSS cutting tools and dies [13] are among the most frequently recommended applications for cryogenic treatment. Cryogenic treatment of tool steel gives many advantages, which are described as:

- **(i)** Transforms almost all soft retained austenite to hard martensite,
- **(ii)** Increases abrasive wear resistance,
- **(iii)** Increases tensile strength, toughness and stability,
- **(iv)** Decreases residual stresses,
- **(v)** Creates a denser molecular structure,
- **(vi)** Decreases brittleness,
- **(vii)** The result is a larger contact surface area that reduces friction, heat and wear [14],
- **(viii)** Forms micro fine carbide fillers to enhance large carbide structures [15],
- **(ix)** Increases durability or wear life,
- **(x)** Used for coated as well as uncoated tool steel [16],
- **(xi)** A better conductor giving the metal better electrical conductivity [17].
- **(xii)** Reduction of ideal time of machine parts for replacement.

## 2 EXPERIMENTAL PROCEDURE

A well-insulated chamber is used for achieving ultra cold temperature. Liquid nitrogen (LN2) is used as the cryogen in this process. LN2 is converted to gas before enter in to the chamber. It is a computer controlled process the system is controlled with proven cooling curves programmed to the computer. Any other required cooling curves may be easily programmed into the processor. The tool parts (Crankshaft components) to be processed are placed in a processor. Tool parts are gradually cooled with nitrogen gas to -320º F. Computer controlled processing ensures accurate tempering cycles and assuring that the dangers of cracking from too rapid cooling/heating are eliminated. That temperature is maintained for at least eight hours. The length of time varies by material and desired results. After completion of cooling cycle tool parts are slowly warmed back to room temperature. Then the object is heat with temperatures of 100º F to 400º F depending on the desired final product and the item is gradually returned to room temperature. The complete process takes a minimum of 24 hrs to a maximum of 7 days. The entire cycle of cooling and tempering can be known from Figure-1.

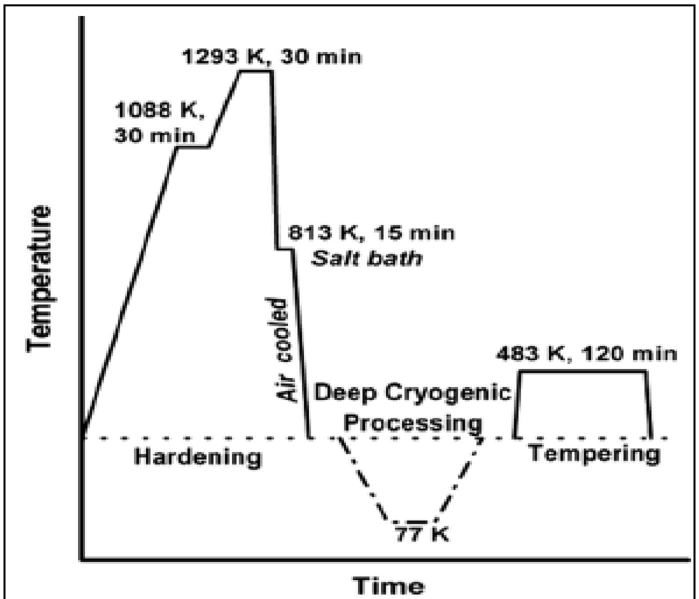


Fig. 1. Total heat treatment process indicating cry-treatment of tool parts.

## 3 Results and Discussion

Crankshaft parts are treated by cryogenic process and the investigations are carried out, based on analysis between before cryo-treatment & after cryo-treatment. It is observed that retained austenite is transformed to martensite in first treatment in heat-treated steels creating a more uniform grain structure and homogenous steel. This provides for a tougher and more durable material as the voids and weaknesses of an irregular grain/crystal structure are eliminated [18]. In many steels, the transformation of austenite to martensite is complete when the part reaches room temperature. Subsequent cryo-cooling can cause additional transformation of the soft austenite to hard martensite. However, it is possible also to transform all of the retained austenite in the steel by appropriate elevated-temperature tempering treatments that carry the added benefit of reducing the brittleness of the martensite. Transformation of retained austenite at low temperatures in tool steels generally is believed to be dependent only on temperature, not on time [19]. Further, tempering of cryo-treated components becomes tougher and better which can resist impact than that of un-tempered martensite. Secondly, cryogenic treatment of high alloy steels, such as tool steel results in the formation of very small carbide particles dispersed in the martensite structure between the larger carbide particles present in the steel. This is a strengthening mechanism which is analogous to the fact that the concrete made of cement and large rocks is not as strong as concrete made of cement, large rocks and very small rocks i.e. Coarse sand [20]. The small & hard carbide particles within the martensitic matrix help support the matrix and resist penetration by foreign particles in abrasion wear. The reported large improvements in tool life usually are attributed to this dispersion of carbides in conjunction with retained austenite transformation. The treatment calls for a precise temperature control during the processing, usually up to one-tenth of one degree, necessitating elaborate controls and sophisticated instrumentation. Freshly formed martensite changes its lattice parameters and the c/a ratio approaches that of the original martensite. Etta (η) carbide precipitates in the matrix of freshly formed martensite during the tempering process. This η carbide formation favors a more stable, harder, wear-resistant and tougher material [21]. This strengthens the material without appreciably changing the hardness (macro hardness). The other major reason for the improvement is stress relief. figure-2 described about the tool life of different crankshaft components. Here observation carried out among Carbide insert face milling, Carbide insert U drilling, Carbide insert CNC turning, HSS center drill.

Figure-3 shows crankshaft component costs by comparing before & after cryo-treatment. Cyo-treatment process also promotes the precipitation of small carbide particles in tool steels and steels with proper alloying metals of the non-cryo-treated parts. So cumulative cost can reduce.

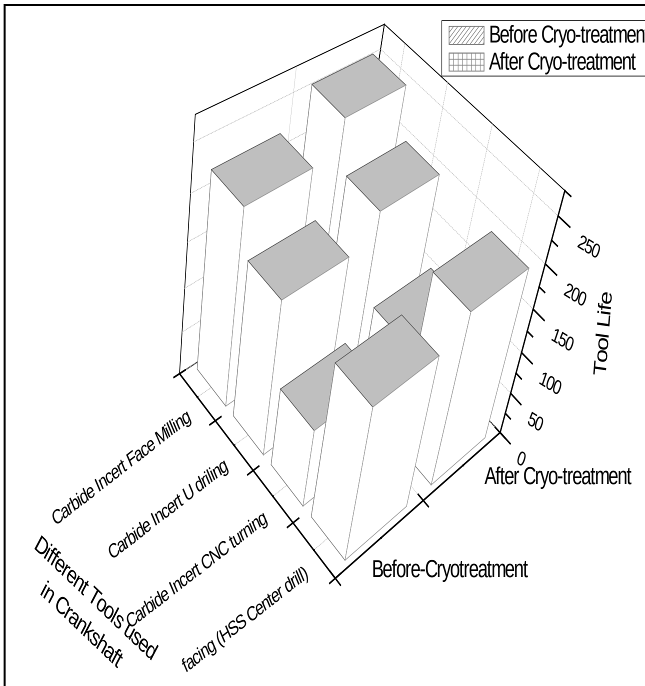


Fig. 2. Comparision of tool life in between before-cryo-treated and after-cryo-treated process.

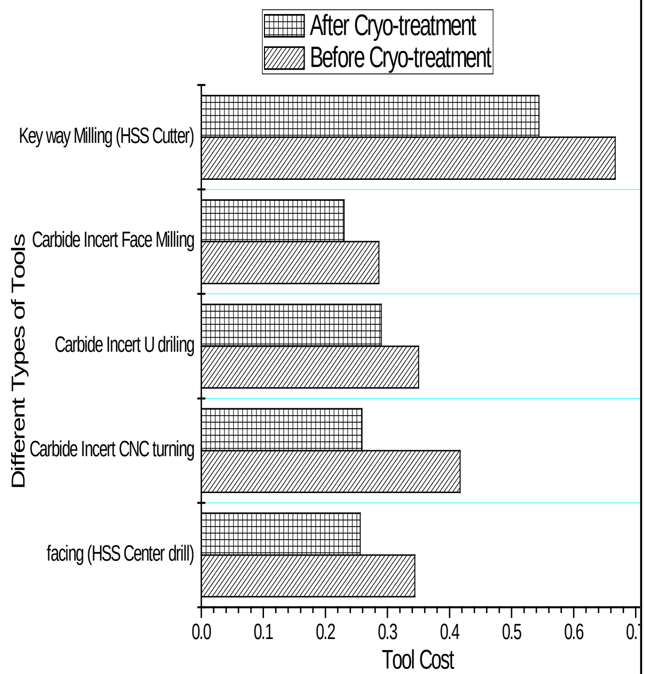


Fig. 1. Comparision of cumulative cost of crankshaft component between before and after cryo-treatment.

## 4 CONCLUSIONS

Cryogenic treatments accelerate the decomposition of martensite which modifies the precipitation behavior of secondary carbides. In general, sub-zero treatments refine the size of the secondary carbides, increase their amount and population density, and lead to their more uniform distribution in the microstructures. By this technique specially hardness, wear resistance, corrosion resistance, toughness etc. increases. Cryogenics materials will be part of the dynamic future. We must not only continue to make incremental improvements in present materials but develop whole new technologies of manufacturing and processing for to achieve the highest performance in cryogenics materials field. Cryogenics-based technologies have applications in wide variety of areas as metallurgy, chemistry, power industry, medicine, rocket propulsion and space simulation, food processing.

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