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Effect of Deep Cryogenic Treatment on the Dimensional Stability of Aisi 440c Bearing Steel

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Abstract

The interest of realizing cryogenic treatment on various materials has been increased recently. The dimensional stability of Shallow Cryogenic Treated (SCT) and Deep Cryogenic Treated (DCT) AISI 440C bearing steel compassion with Conventionally Heat Treated (CHT) have been investigated in this paper. Thermo mechanical analysis is carried out using a dilatometer. The temperature of the CHT, SCT and DCT specimens were increased upto 810 oC (1083k) with a constant rate of 5 oC/min from atmospheric temperature. By using Linear Variable Differential Transformer (LVDT) the change in length of the specimens during the experiment is measured. By using these data, Coefficient of Linear Thermal Expansion (α) has been found for all the specimens, and DCT specimen has 8.7% lower than SCT and 14% lower than CHT specimen.

Keywords: Bearing Steel, Deep Cryogenic Treatment, Thermal Expansion Coefficient

1. Introduction

Most of the failures in the engineering applications occur due to material failures. Hence it is needed to devise a method for improving the material properties such as dimensional stability and wear resistant. One of the methods most suitable and least expensive is cryogenic treatment 1-3. Cryogenic treatment process is a value addition process to the conventional heat treatment process which can modify the total cross section of the part manufactured. In cryogenic treatment process, the temperature of the components are brings down slowly up to the cryogenic temperature -196°C and then soaking the components for long hours in the cryogenic temperature, after it is again heated slowly to attain room temperature. Finally, tempering process carried out to reduce the brittleness and reduced residual stresses which were induced during cryogenic treatment4. Cryogenic treatment induced better mechanical properties and microstructure of the steel by increasing the amount of hard martensite through conversion of soft retained austenite in the conventionally heat treated steel^{5.6}. Bearings play a major role in engineering applications it can be used for smooth rotation of the shaft. The bearing failure is a result of high temperature operations, in this case the material properties are changed and the dimensional stability is reduced due to the thermal expansion.

In² studied the dimensional stability of 100Cr6 bearing steel after cryogenic treatement and reported that the DCT specimen has higher dimensional stability than CHT specimen because of finer carbides precipitation. In⁸ analysed the mechanical properties of 80CrMo12 5 tool steel through deep cryogenic treatment process and conclude that DCT samples have marginally higher dimensional stability than CHT sample due to the maximum conversion of the retained austenite to martensite. In² studied influence of cryogenic treatment process on AISI 440C bearing steel material and proved that the deep cryogenic treatment process increases hardness of

the steel through the increase in amount of conversion of more retained austenite to martensite. In 10 studied the effect of cryogenic treatment process over thermal expansion of valve steel and decided that the DCT specimen had higher dimensional stability than CHT specimen due to alloy carbide precipitation and coarsening of grain. In¹¹ analysed the dimensional stability of D2 Tool steel using Navy C ring and concluded that DCT has high shape distortion than CHT because of large thermal stresses during quenching. In¹² studied the role of cryogenic treatment process on ball bearing and judged that the diameter of the ball variation and surface damages were reduced through cryogenic treatment process. Through this literature survey, the cryogenic treatment process improves dimensional stability of bearing steel materials has been proved.

2. Experimental Procedure

The elemental analysis of the given steel is analysed through Optical Emission Spectroscope (OES), the results confirmed that the steel is AISI 440C bearing steel. The chemical compositions following as weight percentage are C 0.93%, Cr 16.94%, Mn 0.4%, Si 0.74%, Mo 0.45% remaining Fe. In this study the specimens of size 10 mm diameter and 20 mm length were machined and grouped into three groups. For one group of specimens Conventional Heat Treatment process (CHT) done as per ASM standards¹³, for another group of specimens Shallow Cryogenic Treatment process (SCT) done and for the third group of specimen Deep Cryogenic Treatment process (DCT) done.

2.1 Conventional Heat Treatment

During Conventional Heat Treatment process (CHT) as per ASM standards the specimens are preheated to 760° C. Then the specimens are heated to austenitizing temperature 1010° C and held at the same temperature for about an hour. Then for hardening, the steel is quenched in oil which is at room temperature. Finally tempering is done at 200° C for 30 minutes.

2.2 Shallow Cryogenic Treatment

During Shallow Cryogenic Treatment process (SCT), the specimens after hardening but before tempering were placed in a freezer which temperature is maintained -80°C (193K) and soaked for 5 hours. After soaking the

specimens brings back to room temperature by heating . Tempering process done in 200° C for 30 minutes.

2.3 Deep Cryogenic Treatment

During Deep Cryogenic Treatment process (DCT), the specimens after hardening are cooled slowly from atmoshperic temperature to cryogenic temperature -196°C (77K) in 1.2°C/min cooling rate, and soaked for 24 hours. The specimens are brings back to room temperature in the heating rate of 0.6°C/min. After DCT process, the tempering is done at 200°C for 30 minutes to reduce the residual stresses. For cryogenic treatment process liquid nitrogen is used as cryogenic fluid.

2.4 Thermo Mechanical Analyses

In thermo mechanical analysis, the dimensional variation of the specimens was mainly measured by heating specimens at constant heating rate. The dimensional stability of AISI 440C bearing steel is studied in dilatometer. The dilatometer is an instrument which can able to measure the thermal expansion and contraction of the specimen by using Linear Variable Differential Transformer (LVDT) as per ASTM standard E831. The specimens for thermo mechanical analysis is 10 mm diameter and 20 mm length are machined and divided into three groups, one group involved in CHT process, second group involved in SCT process and the third group involved in DCT process. The specimens being treatment were placed in an enclosure with probe contains displacement sensor with temperature sensor which is contact with the specimen. The 20 mN force was applied over the probe to ensure the contact with the specimen. The specimens are heated at the rate of 5°C/min up to 810°C (1083K) ing from room temperature. The coefficient of linear thermal expansion (α) is calulated by the formula.

$$\begin{split} \alpha &= \Delta L \ / L \times \Delta T \\ where \\ \Delta L &= Change \ in \ the \ length \ of \ the \ specimen \\ L &= Original \ length \ of \ the \ specimen \\ \Delta T &= Change \ in \ temperature \end{split}$$

3. Results and Discussion

In thermo mechanical analysis the thermal expansion of the specimens are measured through LVDT and listed in Table 1. The graph drawn for coefficient of linear thermal expansion (α) at 810°C (1083K) temperature for CHT specimen, SCT specimen and DCT specimen are shown in Figure 1 to Figure 3 respectively. The coefficient of thermal expansion of AISI 440C bearing steel is very low for DCT specimen when compared to CHT and SCT specimen. It proved that the DCT specimen has higher dimensional stability compared to CHT and SCT specimen. For CHT specimen initially thermal expansion coefficient is more up to 75°C, then stabilizing starts with 100°C and maintained same value up to 810°C. in case of SCT specimen the thermal expansion coefficient is stabilized from 50°C and it is constant up to 810°C in case of DCT specimen, it follow the similar trend of SCT specimens. Comparatively the thermal expansion coefficient for DCT specimen is lower than that of CHT and SCT specimen because of the amount of retained austenite transformantion to martensite and carbides precipitation is maximum in DCT specimen.

Table 1. Result of thermo mechanical analysis

Specimen type	Expansion (mm)	coefficient of thermal expansion
CHT	0.178	1.21E-5
SCT	0.176	1.14E-5
DCT	0.163	1.04E-5



Figure 1. Coefficient of thermal expansion of CHT specimen.

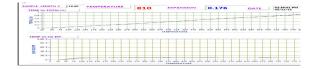


Figure 2. Coefficient of thermal expansion of SCT specimen.



Figure 3. Coefficient of thermal expansion of DCT specimen.

4. Conclusion

AISI 44°C bearing steel subjected to DCT, the coefficient of thermal expansion of DCT specimen is 14% lower than CHT specimen and 8.7% lower than SCT specimen which indicates that the dimensional stability of the DCT specimen is better than SCT and CHT specimen. The analysis reveals that the increase in dimensional stability of DCT and SCT specimen are because of maximum conversion of retained austenite into to martensite and precipitation of carbides.

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