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Technical Report

Effect of cryogenic treatment on the tensile behaviour of En 52 and 21-4N valve steels at room and elevated temperatures

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ABSTRACT

This experimental study investigates the effects of cryogenic treatment on the tensile behaviour of En 52 and 21-4N valve steels at room and elevated temperatures. The materials are subjected to shallow cryogenic treatment (SCT) at 193 K and deep cryogenic treatment (DCT) at 85 K and the tensile behaviour is compared with that of the conventional heat treatment (CHT). The high temperature tensile test is conducted at 673 K (400 °C) and 923 K (650 °C) for the En 52 and 21-4N valve steels respectively. The ultimate tensile strength of the En 52 and 21-4N DCT samples show an enhancement of 7.87% and 6.76% respectively, over the CHT samples tested at the elevated temperature. The average yield strength of the En 52 DCT samples has an improvement 11% than that of the CHT samples when tested at room and elevated temperatures. The deep cryogenic treatment conducted at the optimized condition shows 7.84% improvement in the tensile strength for the En 52 valve steel and 11.87% improvement for the 21-4N valve steel when compared to the strength of the samples without the cryogenic treatment. A scanning electron microscopic analysis of the fracture surface indicates the presence of dimples and microvoid coalescence on the grain facets and interfaces of the cryo-treated specimens. The fracture surface of the deep cryo-treated 21-4N valve steel specimen shows a complete intergranular fracture with deep secondary cracks between the grains. On comparing the results of the percentage elongation, the cryo-treated samples show a smaller reduction in the elongation than that of the CHT samples. It is concluded that the precipitation of fine secondary carbide through cryogenic treatment is the reason for the improved strength and the reduction in elongation.

1. Introduction

Over the past few decades, interest has been shown in the effect of low-temperature treatment on the performance of steels. Low-temperature treatment is generally classified as either "sub-zero treatment" at temperatures down to about 193 K (−80 °C), or "deep cryogenic treatment" at liquid nitrogen temperature (−196 °C) [1]. The basic cryogenic treatment consists of a gradual cooling of the component until the defined temperature, holding it for a given time (soaking time) and then progressively leading it back to room temperature, and tempering it to decrease the brittleness of the martensite [2]. Depending on the alloy composition of the metals and the pre-hardening cycles, the benefits reaped are increased strength, greater dimensional stability or microstructural stability, improved wear resistance and relief of residual stress [3]. Molinari and Pellizzari [4] mentioned that greatest improvement is obtained by carrying out the deep cryogenic treatment between quenching and tempering. Baldissera and Delprete [3] mentioned that the improvement of mechanical properties of cryo-treated tool steels can be ascribed by the complete transformation of the retained austenite into martensite, precipitation of fine carbides, and removal of residual stresses. Various studies showed that after deep cryogenic treatment, the mechanical properties of tool steels, carburized steel and bearing steels etc. have improved on the whole [2,4,5,8]. Zhirafar et al. [1] investigated the effects of the cryogenic treatment on the mechanical properties of AISI 4340 steel. Mechanical tests, including rotating fatigue, impact and hardness were carried out after various heat treating conditions, and the results were compared. It was found that the fatigue limit of the steel improved after the cryogenic treatment and tempering; this was attributed to the higher hardness and strength of the material due to this treatment.

Harish et al. [5] studied the effect of shallow cryogenic treatment (SCT) at 193 K and deep cryogenic treatment (DCT) at 77 K on the microstructure of En 31 bearing steel. It is concluded from the micrographs, that the cryogenic treatment should be followed by tempering to promote secondary carbide precipitation, which is essential for hardness augmentation and wear resistance improvement. Xiong et al. [6] reported that the ultimate tensile strength, yield strength and elongation of the cryogenic treated magnesium alloy added with zirconium have improved to 38%, 57% and 280% respectively, as compared to those of the same alloy without

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