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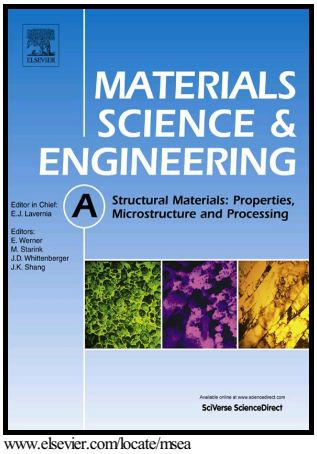

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Microstructural characterization, strengthening and toughening mechanisms of a quenched and tempered steel: Effect of heat treatment parameters

Bo Jiang[a, *], Meng Wu[a], Mai Zhang[b], Fan Zhao[a], Zhigang Zhao[c], Yazheng Liu[a, *]

[a]*School of Materials Science and Engineering, University of Science and Technology Beijing, Beijing 100083, China*

[b]*School of Advanced Engineering, University of Science and Technology Beijing, Beijing 100083, China*

[c]*Fushun Special Steel Co. Ltd., Fushun 113001, China*

[*]Corresponding author. Tel.: +86 010 62333174. *E-mail address*: jiangbo@ustb.edu.cn (Bo Jiang)

[*]Corresponding author. Tel.: +86 010 62334939. *E-mail address*: lyzh@ustb.edu.cn (Ya-zheng Liu)

Abstract: A quenched and tempered steel for a large bearing ring was investigated. The heat treatment experiments were designed by using the L_9 (3^4) type orthogonal form. Based on these conditions, a better combination of mechanical properties was obtained. The results showed that the quenching and the tempering temperatures were the most influential factors on the strength and toughness. The dislocation strengthening and the solid solution strengthening of the dissolved alloying carbides are the main mechanisms of increasing the strength by decreasing the tempering temperature and increasing the quenching temperature, respectively. The stripped carbides and long chain carbides strongly influence the differences in the tensile strength of the steels under different processes. The toughness AKv at -20 ºC was increased by 42.2 J when the quenching temperature increased from 800 to 900 ºC. The stripped undissolved carbides at lower quenching temperature promoted crack propagation and cleavage fracture and thus decreased the toughness of the steel. The AKv was increased by 47.4 J when the tempering temperature increased from 550 to 650 ºC. The long chain carbides distributed along the grain boundary and the martensitic laths with a high density of dislocations at the lower tempering temperature decreased the toughness. Oil quenching can improve both the strength and toughness by refining the martensitic microstructure.

Key words: Quenching, Tempering, Strength, Toughness, Carbide.

1. Introduction

An excellent combination of strength, toughness and hardenability of steel has always been desired for use in large equipment, for example, the large bearing ring of a tunneling boring machine (TBM). A number of studies have been conducted on the microalloying method in order to improve the comprehensive properties [1-3]. It has been reported that the combined addition of the C and Ni elements can not only improve the strength and hardenability but also guarantees the toughness. In addition, the heat treatment parameters including the quenching temperature, the quenching agent, the tempering temperature and time are also vital for the final microstructure and the mechanical properties. Lee's report [4] on the 4340 steel showed that the distribution of the