Chapter 69
Effect of Tempering Temperature on Microstructure, Texture and Mechanical Properties of a High Strength Steel

Pradipta Kumar Jena
Defence Metallurgical Research Laboratory, India

K. Siva Kumar
Defence Metallurgical Research Laboratory, India

A.K. Singh
Defence Metallurgical Research Laboratory, India

ABSTRACT

This work describes the microstructure, texture and anisotropy in mechanical behavior of a high strength steel in various tempered conditions. The microstructures and mechanical properties change considerably with varying tempering temperatures. The material exhibits low in-plane anisotropy and low anisotropic index in terms of yield strength and elongation with increase in tempering temperature. The anisotropy of the material displays similar behavior to that of the yield strength.

1. INTRODUCTION

For long, steels have been used as armour due to their high strength combined with good toughness and low cost. Generally, quenching and tempering are well-established means to achieve strengthening in steel. Considerable knowledge exists on the effect of alloy compositions and the heat treatments on mechanical properties (Barbacki et al., 1998; Lee et al., 1999; Srivastava et al., 2006; Ray et al., 2003; Dhua et al., 2001). Heat treatments of steels exhibit a range of mechanical properties. As a result, the

DOI: 10.4018/978-1-5225-1798-6.ch069

same material can be used in many applications. Tempering of steel at lower temperatures achieves higher strength and hardness, and it is used in armour applications. On the other hand, higher tempering temperatures achieve lesser hard steels with increased toughness levels, which find application in structural parts in armoured vehicles.

The mechanical behavior of quenched-and-tempered steel depends strongly on its microstructure. There are several well-known phases in steel such as ferrite, pearlite, bainite, martensite and austenite. Each of them has different mechanical properties (Carlson et al., 1979; Chai et al., 1987, Callister, 1994). For example, martensite phase exhibits the highest level of strength in steel however, it displays limited ductility due to stress associated with it (Briant et al., 1979; Kwon et al., 1988; Horn et al., 1978). Tempering of martensite introduces phase changes in steel. Tempering at lower temperatures results in decomposition of martensitic phase to low carbon martensite and ε carbide. With increase in tempering temperature, martensite further decomposes to ferrite and cementite.

It is well known that the crystallographic texture can significantly affect the mechanical properties of the rolled materials (Hsun et al., 1980). As a matter of fact, specific textures have been deliberately produced in steel sheets and utilized advantageously in commercial applications. However, the effect of texture on the properties of hot rolled, quenched and tempered plates has been less explored. In an earlier investigation on 5 Ni armour steel, Hu et al. (1980) have demonstrated that the ballistic performance of the strongly textured plates is substantially superior to that of the random textured plates of the same hardness.

A combination of (112) + (111) texture has displayed higher ballistic performance in comparison to (110) and (111) type textures. It has been observed that the intensity of the texture also influences other mechanical properties like through thickness tensile and compressive strength, impact energy, fracture toughness and fatigue life. The present work thus describes the effect of tempering temperature on the microstructure, texture and mechanical properties of a high strength steel.

2. EXPERIMENTAL

The chemical composition of the steel is given in Table 1. The steel was industrially hot rolled to a thickness of 25 mm. Samples were again hot rolled at a temperature of 1100°C to 5 mm from the initial thickness in a laboratory rolling mill. The specimen was deformed 10% in each pass and rolling direction was kept strictly unidirectional. After each pass, the sample was kept back into the furnace to re-attain the rolling temperature.

Samples of 150 x 150 mm cross section were cut and subjected to heat-treatment for modifying the microstructures and mechanical properties. For getting different quenched and tempered martensite phase, samples from the hot rolled plates were austenitised at 910°C and held at this temperature for 12 minutes followed by quenching in oil to get a fully martensitic phase. The austenitisation temperature has been taken from the previous heat treatment studies on this steel (Jena et al., 2010). The plates were then im-

Table 1. Analytical chemical composition of the experimental alloy

Material	Chemical Composition (wt.%)
Steel	0.3–0.35 C, 0.2–0.3 Si, 0.5–0.7 Mn, 1.4–1.7 Cr, 1.5–2.0 Ni, 0.3–0.5 Mo, 0.1–0.2 V, 0.02 Al, balance Fe

Related Content

Bioconversion of Waste Materials for the Production of Polylactic Acid to Alleviate Carbon Footprint

Debbie Dominic, Nurul Alia Syufina Abu Bakarand Siti Baidurah (2025). *Building a Low-Carbon Society Through Applied Environmental Materials Science (pp. 269-284).*

www.irma-international.org/chapter/bioconversion-of-waste-materials-for-the-production-of-polylactic-acid-to-alleviate-carbon-footprint/361690

Theoretical Assessment of the Mechanical, Electronic, and Vibrational Properties of the Paramagnetic Insulating Cerium Dioxide and Investigation of Intrinsic Defects

Mohammed Benali Kanounand Souraya Goumri-Said (2014). *Handbook of Research on Nanoscience, Nanotechnology, and Advanced Materials (pp. 431-446).*

www.irma-international.org/chapter/theoretical-assessment-of-the-mechanical-electronic-and-vibrational-properties-of-the-paramagnetic-insulating-cerium-dioxide-and-investigation-of-intrinsic-defects/107975

Investigation of Influence of Quenching and Annealing on the Plane Fracture Toughness and Brittle to Ductile Transition Temperature of the Zinc Coated Structural Steel Materials

M. Ramesh, Rajnish Gargand Garimella V. Subrahmanyam (2017). *International Journal of Surface Engineering and Interdisciplinary Materials Science (pp. 33-42).*

www.irma-international.org/article/investigation-of-influence-of-quenching-and-annealing-on-the-plane-fracture-toughness-and-brittle-to-ductile-transition-temperature-of-the-zinc-coated-structural-steel-materials/192113

Development of High Performance Polymer Composites by Additive Manufacturing

Pradeep Kumar G. S., Sachith T. S., Sasidhar Jangam, Shivakumar S.and Gurumoorthy S. Hebbar (2023). *Development, Properties, and Industrial Applications of 3D Printed Polymer Composites (pp. 220-238).*

www.irma-international.org/chapter/development-of-high-performance-polymer-composites-by-additive-manufacturing/318981

Optimization of Process Parameters on the Mechanical Properties of Semi-Solid Extruded AA2017 Alloy Rods

Shashikanth Ch, G Venkateswarluand Davidson M J (2019). *International Journal of Materials Forming and Machining Processes (pp. 1-14).*

www.irma-international.org/article/optimization-of-process-parameters-on-the-mechanical-properties-of-semi-solid-extruded-aa2017-alloy-rods/233624