EFFECT OF AUSTEMPERING TEMPERATURES ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF A BEARING STEEL

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Abstract: In this study, the effect of austempering temperatures on microstructure and mechanical properties of AISI 52100 steel, which is commonly used in producing bearings, was investigated. AISI 52100 steel specimens were austenitized at 950 °C for 30 min and then were quenched into a salt bath held at three different austempering temperatures (250°C, 275°C and 300°C) and austempered for various times (15 min, 30 min, 60 min and 120 min). Microstructural constituents were characterized by using optical microscope. Impact toughness and hardness tests were conducted to determine the mechanical properties of AISI 52100 steel. Experimental results showed that, enhancement of the impact toughness of AISI 52100 steel depends on the bainitic structure. The selection of austempering temperature constitutes a key parameter to obtain superior impact toughness – hardness combination in AISI 52100 bearing steel.

Keywords: AUSTEMPERING TEMPERATURE, AISI 52100 STEEL, BAINITE, IMPACT TOUGHNESS.

1. Introduction

AISI 52100 steel is the high carbon and low chromium containing steel which most widely exploited material for ball-bearing applications and automotive and bearing industry [1-4]. The universal popularity of this steel in the mentioned applications arises from the attractive combination of low cost, high hardenability, high hardness (61–63 HRc), high yield/tensile strength (2000/2200 MPa), and good machinability and formability [5].

The conventional heat treatment processes used in the manufacture of rolling bearings are normally specified to produce a martensitic structure in high carbon bearing steel [2-4]. AISI 52100 steel is routinely used in hardened and tempered condition with a predominantly tempered-martensitic microstructure that provides adequate abrasion resistance and mechanical properties at room temperature [3-6].

Recent studies showed that the mechanical properties of the AISI 52100 steel can be improved by isothermal heat treatments such as austempering [3-5, 7-10]. The austempering temperature and austempering time have great significant influence to control of the mechanical properties of AISI 52100 steel [7-10].

Akbosglu and Edmonds [4] have demonstrated that bearing steel with bainitic microstructure provides improved resistance to wear and hydrogen embrittlement as compared to that in martensitic condition. It is known that tensile strength, impact toughness and hardness can be simultaneously increased by austempering of the AISI 52100 steels [7-9].

The present study attempts to determine the austempering parameters (austempering temperature and austempering time) for AISI 52100 steel to achieve optimum impact toughness and hardness.

2. Experimental Details

Cylindrical rod specimens of 15 mm diameter and 55 mm length of AISI 52100 steel having a nominal composition of 0.979%C, 0.238%Si, 0.356%Mn, 1.487Cr, 0.026%P, 0.031%S and rest Fe (in wt%). The initial microstructure of specimens have fully pearlitic matrix in hot rolled condition. Specimen were austenitized at 950°C for 30 min followed by instantaneous transfer to a salt bath for austempering at 250°C, 275°C and 300°C, for different time periods ranging from 15 to 120 min. Following austempering, specimens were water quenched to room temperature. Summary of heat treatments schematically represented in Fig.1.

Fig. 1 Schematic representation of the heat treatments.

3. Experimental Results and Discussion

3.1. Microstructural examination

AISI 52100 steel microstructures has fully pearlitic matrix in as received condition (see Fig 2.a).

Fig.2.b to Fig.2.d illustrate the optical micrographs of the specimens austempered for constant austempering time (30 min) conditions for all three austempering temperatures (250°C, 275°C and 300°C). The microstructures after heat treatments contain martensite + bainite and retained austenite. Dark laths are bainite, dark brown regions are martensite and white/gray regions are retained austenite in microstructures.
It is apparent that the bainite volume fraction increases, while both the retained austenite and martensite volume fraction decreases with increasing austempering temperature (see Fig. 2.b-d). Bainite volume fraction is 10%, 30% and 45% for 250°C, 275°C and 300°C austempering temperatures, respectively.

3.2. Effects of austempering temperatures

Fig. 3 shows the impact energy variations and Fig. 4 shows the changes in the hardness values with austempering temperature in AISI 52100 steels austempered for different times, respectively. According to Fig. 3, increasing the austempering temperature improves the impact toughness for all austempering times. It is clear that the impact toughness values of the specimens which were austempered at 250°C and 275°C were lower than those of austempered at 300°C. It can be explained the volume fractions of bainite and martensite. At constant austempering time the higher austempering temperatures produces more bainite volume fraction in austempered AISI52100 steel (see Fig. 2.b-d).

Moreover, impact toughness properties are expected to be further improved due to the upper bainitic microstructure in austempered AISI52100 steels.

Experimental results indicate that the volume fraction and of bainite and martensite is important parameters affecting the impact toughness and the hardness. In addition, higher amount of bainite is essential in order to improve impact toughness. Moreover, it has been shown that controlling the bainite, martensite and the retained austenite volume fractions can further influence impact toughness of austempered AISI 52100 steels. The austempering temperatures more effective than austempering time to control of the bainite volume fraction in AISI 52100 steels.

The hardness decreased with increasing austempering temperatures (see Fig. 4). It can be attributed to higher bainite volume fraction at high austempering temperatures.

3.3. Effects of austempering times

Fig. 5 represents the impact energy variations with austempering time in AISI 52100 steels austempered at each three austempering temperature. After 30 min., the impact toughness remained almost unchanged at 300°C due to nearly completion of
bainitic reaction. But however, the impact toughness values increased with increasing austempering time for specimens austempered at 250°C and 275°C. It is apparent that the bainite volume per cent increases, while both the austenite and martensite volume fraction decreases with increasing austempering time.

Experimental results showed that the austempering time has great influence on the impact toughness of AISI 52100 steel. There is a good agreement in existing literature [7-9].

![Graph showing variation of impact toughness with austempering time.](image)

**Fig. 5** Variation of the impact toughness with austempering times.

Fig. 6 shows the changes in the hardness values with austempering time in AISI 52100 steels austempered at each three austempering temperature. The hardness of austempered AISI 52100 steel decreased with increasing austempering time. It can be attributed to higher bainite volume fraction at higher austempering times.

![Graph showing variation of hardness with austempering time.](image)

**Fig. 6** Variation of the hardness with austempering times.

Fig. 7 shows the impact toughness versus hardness values of austempered AISI 52100 steels. The best combination of hardness and impact toughness obtained is at 300°C austempering temperatures for 30 min, 60 min and 120 min austempering times.

![Graph showing relationship between hardness and impact toughness.](image)

**Fig. 7** Relationship between hardness and impact toughness in austempered AISI 52100 steel.

4. Conclusion

The following conclusions could be drawn from this study;

- Bainite + martensite duplex microstructures can be produced in AISI 52100 steel via combination of austempering and quenching processes.
- Bainite + martensite duplex microstructure yields in high levels of hardness (55-64 HRc) and enhanced impact toughness (24-54 Joule).
- Austempering temperatures are more effective than austempering time to control the bainite volume fraction in AISI 52100 steels.

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References