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EFFECT OF QUENCHING MEDIUM AND TEMPERING TEMPERATURE ON MICROSTRUCTURE AND HARDNESS OF JIS SUP 9 STEEL

(PENGARUH MEDIA PENDINGIN DAN TEMPERATUR TEMPERING PADA MIKROSTRUKTUR DAN KEKERASAN BAJA JIS SUP 9)

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ABSTRACT

JIS SUP 9 steel is one of the materials commonly used for suspension components in motorized vehicles with medium carbon steel base material. It must have good hardness and toughness so that failure does not occur during operational. This research was conducted to increase the hardness of JIS SUP 9 Steel through a heat treatment and various quenching media. The heat treatment was carried out with 830-880ºC temperature with a holding time of 7 minutes then cooled using water and oil. After treatment, tempering was carried out with a holding time of 7 minutes and then cooled in room temperature. Hardness testing was carried out using Microhardness Vickers and then the microstructure was observed using an Olympus Metallurgical Microscope. The results show that heat treatment followed by rapid cooling increases the initial hardness of JIS SUP 9 (229 VHN) steel. The decrease in hardness after the tempering process will be higher with increasing tempering temperature. The results of the microstructure of the sample without heat treatment showed pearlite and ferrite phases. After heat treatment, tempered martensite, residual austenite and carbide phases appear. It can be concluded that changes in the microstructure affect the hardness of JIS SUP 9 steel.

Keyword: Hardness; Heat Treatment; JIS SUP 9 Steel; Microstructure; Quenching Media.

ABSTRAK

Baja JIS SUP 9 merupakan salah satu material yang biasa digunakan untuk komponen suspensi pada kendaraan bermotor dengan bahan dasar baja karbon medium dengan persentase karbon antara 0.5-0.6%. Material ini harus memiliki kekerasan dan ketangguhan yang baik agar tidak terjadi kegagalan pada saat pemakain operasional. Penelitian ini dilakukan untuk meningkatkan kekerasan dari Baja JIS SUP 9 melalui proses perlakuan panas dan variasi media quenching. Perlakuan panas yang dilakukan pada percobaan ini yaitu hardening dengan *temperatur diatas 830-880ºC dengan waktu penahanan 7 menit kemudian didinginkan menggunakan media pendingin air dan oli. Setelah proses hardening dilakukan proses tempering dengan waktu penahanan 7 menit kemudian didinginkan dengan udara pada suhu ruang. Pengujian Kekerasan dilakukan menggunakan Micro Hardness Vickers kemudian dilakukan pengamatan struktur mikro menggunakan Olympus Metallurgical Microscope. Hasil pada percobaan ini menunjukan bahwa perlakuan panas diikuti dengan pendinginan cepat menaikan kekerasan awal dari baja JIS SUP 9 (229 VHN). Penurunan kekerasan setelah proses tempering akan semakin tinggi dengan naiknya temperatur tempering. Hasil struktur mikro pada sampel tanpa perlakuan panas menunjukan fasa perlit dan ferit. Setelah dilakukan perlakuan panas muncul fasa martensit temper, austenite sisa dan karbida. Dapat disimpulkan bahwa perubahan struktur mikro mempengaruhi kekerasan pada baja JIS SUP 9.*

Kata Kunci: Baja JIS SUP 9; Kekerasan; Media Pendingin; Perlakuan Panas; Struktur Mikro.

INTRODUCTION

In the automotive world, it is necessary to pay attention to comfort and safety in terms of driving when choosing which vehicle to use apart from the design and acceleration aspects. To support this, a good suspension system is needed so that comfort and safety in terms of driving can be obtained perfectly (Hou, J. et al. 2022). The system is made of spring and damper steel components which are located between the wheels and the vehicle body. Steel are consists of iron as the basic element and carbon as the main alloying element. The carbon content in steel was varied depending on the grade.

The function of carbon in steel is as a hardener by preventing dislocations from shifting in the crystal lattice of iron atoms, which induces a reconstruction (Hachet, G. et al. 2020). When the carbon reach iron lattice, they move following and accommodate screw dislocations (Nematollahi, G.A. et al. 2016). In reality, automotive suspensions often experiences problems such as cracking due to overload, or shock loads which causes its fatigue life to decrease (Andoh, P. Y. A. et al. 2022). This reduces the efficiency value of the spring steel.

Along with the development of material selection, spring steel has also reduced its usage in for suspension (Das, S. et al. 2020). This makes spring steels have switched functions for the manufacture of sharp weapons such as machetes or swords because they are considered to have good hardness (Jiang, H. et al. 2022). Several studies has been conducted to enhance the microstructure and mechanical properties of steel, one of the method is by using pack carburizing method (Karim, A. et al. 2022).

JIS SUP 9 steel is one of the spring steels type commonly used for suspension components in motorized vehicles (Chandra, H. et al. 2018). The manufacture of JIS SUP 9 steel with a moderate carbon composition (0.55%) begins with machining for the manufacture of spring steel components in general. The carbon content means that JIS SUP 9 categorized as medium carbon steel. Normally, the carbon percentage of steel consists of 0.30-0.60%. Heat treatment is a combination process between heating and cooling of a metal or alloy in its solid state in a certain period of time which is intended to obtain certain properties in metals or alloys (Banerjee, 2017). The hardness of steel is highly dependable on the heat treatment temperature. Tensile and fatigue properties are also can be modified by heat treatment (Morri, A. et al. 2022).

When using JIS SUP 9 steel as suspension or sharp weapons, hardness and toughness needs to be considered. In the Hardening method, temperature variation exceeding 800ºC and holding time of heating above the critical temperature limit will change the microstructure to hard martensite structure after a rapid cooling process. The quenching media can be varied such as water, vehicle oil, and vegetable oil (Lenzi, F. et al. 2019). Martensite has good hardness but highly brittle. The brittleness can be reduced by tempering. The tempering method with a temperature of 420ºC can increase the toughness and slightly reduce the hardness of martensite. This means the selection of hardening and tempering temperature greatly affect the hardness and toughness of the material, as well as the cooling media needs to be considered so that the quality of the material can be optimized (Zheng, C. et al. 2019). The changes in the hardness of the spring steel material with temperature variations means that the hardness aspect is an interesting research. The quenching media that has been used for steel includes water, oil, sodium hydroxide, brine, caustic soda, liquid nitrogen, and circulated air. Both of water and oil are mostly used even in industrial scale since they were easily obtainable and less risk compared to other media.

Based on the statements above, this study was conducted to analyze the effect of Heat Treatment temperature variations and quenching media on the hardness and microstructure of JIS SUP 9 Steel.

MATERIAL AND METHOD

The JIS SUP 9 steel was obtained from LTC Glodok, North Jakarta, Indonesia. The steel were cut into 13 pieces with the dimensions of 2.5 x 2mm. Uneven surface from cutting was then grinded with silicon carbide paper until it has smooth edges. Resulting specimen were shown in Figure 1.

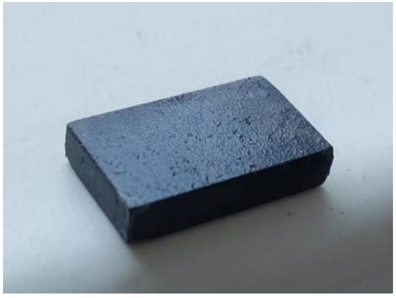

Figure 1. JIS SUP 9 steel.

The quenching media are consisting of tap water and used engine oil, both were obtained from Cikarang, West Java, Indonesia Variations in this study, which consists of: (1) Heat Treatment Temperature, (2) Tempering Temperature, and (3) Quenching Media was shown in Table 1.

Table 1. Variations of Heat Treatment Temperature and Quenching Media

Name	HT Temp. (°C)	T Temp. (°C)	Quench Media
UT		Untreated	
830-NT-W	830	-	Water
830-NT-O	830	-	Oil
830-T340-W	830	340	Water
830-T340-O	830	340	Oil
830-T380-W	830	380	Water
830-T380-O	830	380	Oil
830-T420-W	830	420	Water
830-T420-O	830	420	Oil
855-T420-W	855	420	Water
855-T420-O	855	420	Oil
880-T420-W	880	420	Water
880-T420-O	880	420	Oil

The JIS SUP 9 steel was heated in muffle furnace with holding time of 7 minutes. The temperature variation used in this study is 830°C, 855°C, and 880°C dues to maximum temperature limitation of 900°C. It was followed by rapid cooling by various quench media. After that, the specimen undergoes tempering, which involves secondary heating with temperature variations conformed to Table 1 above. Heat treated specimens were tested its hardness using Vickers Hardness Tester at PT INTEC Instruments, Karawang, West Java, Indonesia. The hardness of the specimen (VHN) was calculated using equation (1) by dividing the load (P) with the average of indentation diagonal (d).

$$VHN = \frac{1.854\,P}{d^2} \quad (1)$$

The microstructure of specimens were analysed using Olympus Microscope (Magnification 500X) at Heat Treatment Laboratory, Department of Metallurgical Engineering, Institut Teknologi Sains Bandung, West Java, Indonesia.

RESULTS AND DISCUSSION

Hardness Test Results

The hardness value of specimens in Table 1 were presented in Figure 2 below.

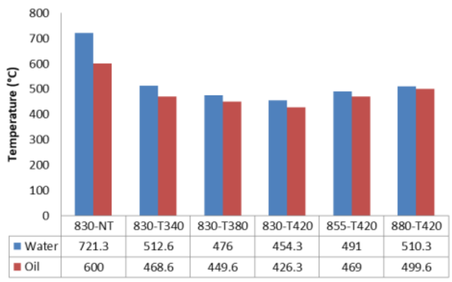

Figure 2. JIS SUP 9 steel.

The hardness value of untreated specimen was 229 HV. After heat treatment in furnace, there is an increase in hardness which indicates the formation of martensite. This phase has hardness value of approximately 600 VHN (Garcia-Mateo et al. 2003). In this study, the hardening process temperature were varied at 830°C, 855°C and 880°C. The highest hardness results were at 880°C (510.3 HV) and the lowest hardness value at 830°C (473 HV), using water as quenching media and tempering process at 420°C. This indicates that higher hardening temperature increased the hardness.

This is due to the rapid cooling process transform the austenite phase to martensite phase, while tempering transform the martensite into martensite temper. The hardness of specimens 830-NT were within that hardness range of the martensitic phase in both quenching media. The phase is formed in the hardening process which is carried out at temperatures above the A3 line in Fe-Fe_3C phase diagram and a transformation occurs from the pearlite phase to the austenite phase. The tempering process is carried out after the rapid cooling process which aims to reduce the mechanical properties, especially hardness to reduce the brittleness and increases the toughness of the steel.

Microstructure Observation Results

The micostructure of untreated JIS SUP 9 showed the formation of pearlite and ferrite (Figure 3). Ferrite is a soft, weak and ductile phase, and also pure iron with a body centered cubic (BCC) crystal structure. This structure can be identified since the untreated sample still has ferromagnetic characteristics. The basic structure of pearlite is a lamellar structure composed of layers of ferrite and cementite.

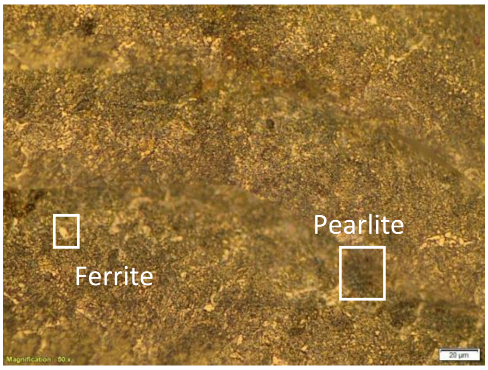

Figure 3. Microstructure of untreated JIS SUP 9 (Magnification 500X).

Figure 4 and 5 shows the presence of martensite and retained austenite. The martensite formed was needle-like phase, which indicates the brittleness of the sample is still high.

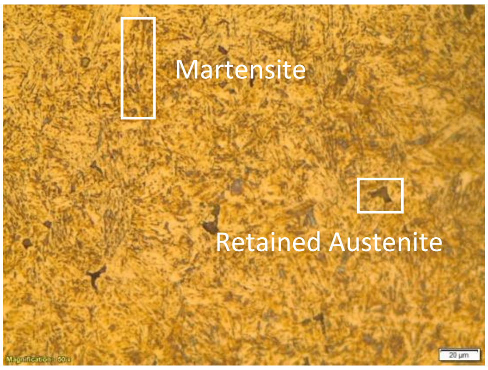

Figure 4. Microstructure of 830-NT-W (Magnification 500X).

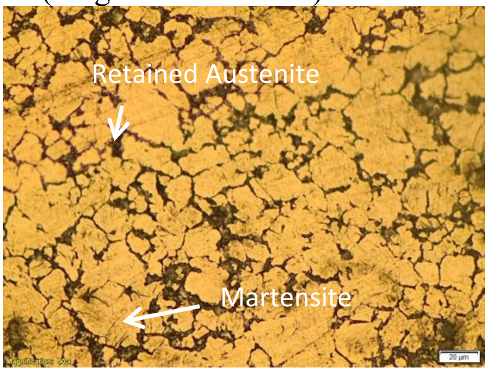

Figure 5. Microstructure of 830-NT-O (Magnification 500X).

The microstructure of JIS SUP 9 heat treated at 830ºC in water and oil cooling medium followed by tempering at 340ºC and 380ºC were shown in Figure 6-9.

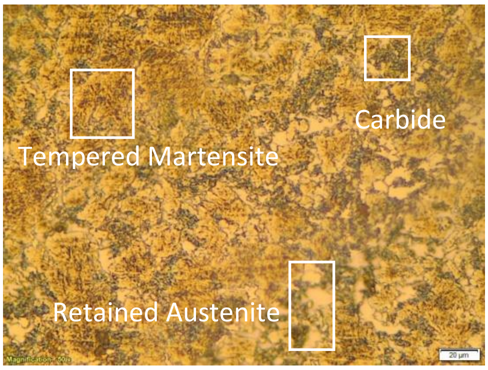

Figure 6. Microstructure of 830-T340-W (Magnification 500X).

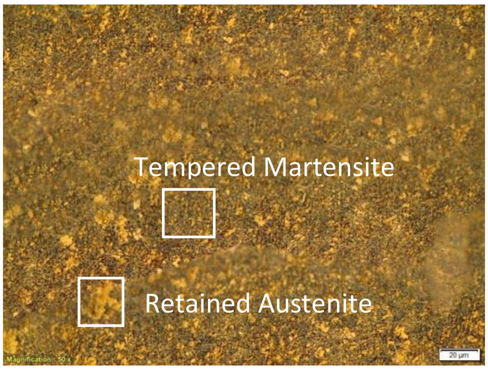

Figure 7. Microstructure of 830-T340-O (Magnification 500X).

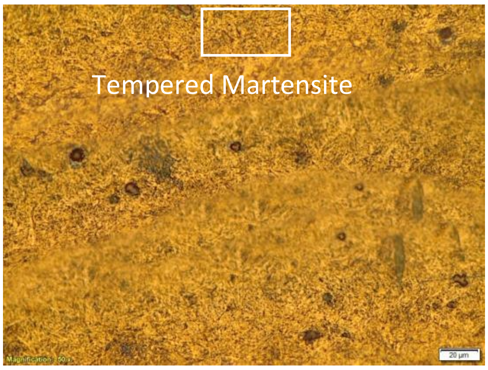

Figure 8. Microstructure of 830-T380-W (Magnification 500X).

Figure 9. Microstructure of 830-T380-O (Magnification 500X).

Tempered martensite phase appears as a result of rapid cooling accompanied by tempering, while carbide appears due to heating at austenite temperature, the compounds contained in the steel do not dissolve to form carbides.

There is austenite remained due to homogeneity of the structure. The increase in temperature was followed by appearance of large amount residual austenite. Microstructure at 340°C tempering was dominated by coarse tempered martensite which is brittle and hard. Microstructure of 380°C tempering is dominated by the remaining austenite phase which has ductile properties. The carbide phase and tempered martensite phase in oil cooling medium were formed less than the water-cooling medium followed by domination of residual austenite phase. This happens because the heat absorbance of oil was slower than the water cooling medium, which means that the formation rate of martensite is also slower.

There is large amount of martensite phase transforms into tempered martensite phase during the tempering process and the presence of a carbide phase affects the hardness of JIS SUP 9 steel. This means that water as quenching media produces higher hardness compared to the oil cooling subjected to heat treatment and tempering.

The microstructure of JIS SUP 9 at hardening temperatures of 830°C, 855°C and 880°C in water-cooled and oil media followed by tempering at 420°C was shown in Figure 10-15. There were differences in the size and number of phase grains at each temperature variation.

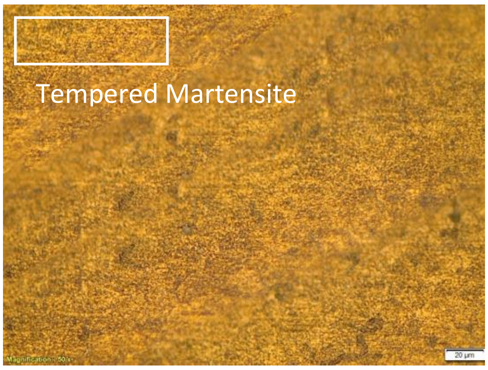

Figure 10. Microstructure of 830-T420-W (Magnification 500X).

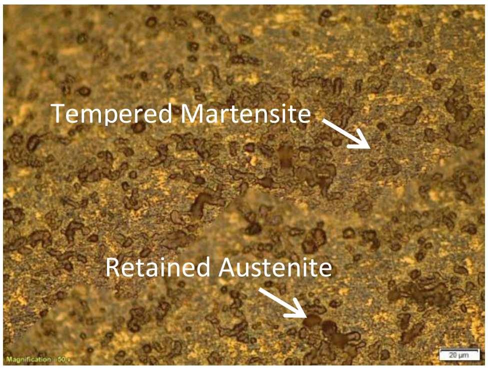

Figure 11. Microstructure of 830-T420-O (Magnification 500X).

Figure 12. Microstructure of 855-T420-W (Magnification 500X).

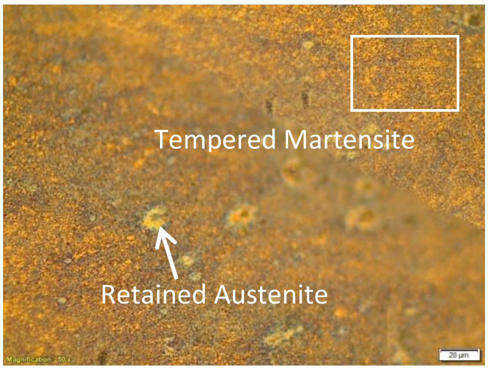

Figure 13. Microstructure of 855-T420-O (Magnification 500X).

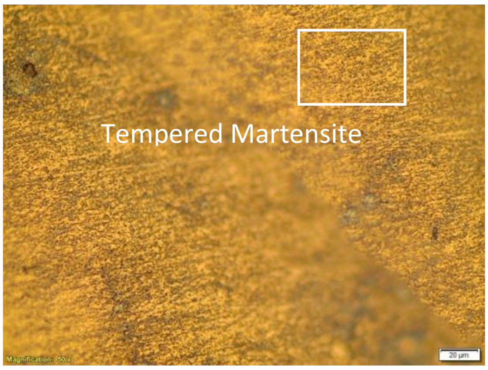

Figure 14. Microstructure of 880-T420-W (Magnification 500X).

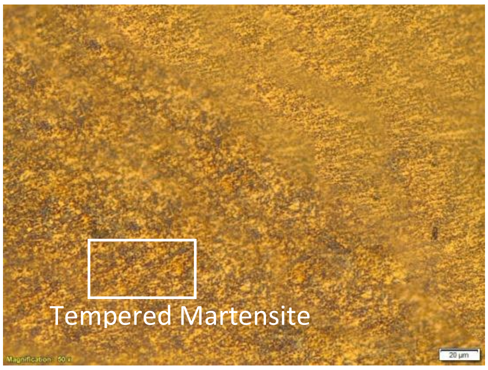

Figure 15. Microstructure of 880-T420-O (Magnification 500X).

The tempered martensite phase is obtained from a rapid cooling process accompanied by a tempering, while carbide can be obtained due to heating at austenite temperature, the carbon compounds contained in the steel do not dissolve to form carbides.

Residual austenite appears due to the homogeneity of the structure at the austenite temperature. Tempering is carried out with the aim of reducing residual stresses, increasing the toughness and ductility of steel that has undergone martensite hardening. During the tempering process, the hardness and strength will decrease. At hardening temperatures of 830ºC and 855ºC the most formed phases are coarse tempered martensite which is brittle and hard and residual austenite which has ductile properties, while at 880ºC it is dominated by Temper Martensite and also carbide phase. Increase in heat treatment temperature was followed by increased in hardness but the ductility and toughness of JIS SUP 9 were decreased.

CONCLUSION

This study concludes that the hardness of JIS SUP 9 can be increased with heat treatment. The rapid cooling can produce martensitic microstructure that has high hardness but low toughness, compared to formation of pearlite and ferrite in untreated specimen. The toughness can be increased using tempering method which resulted in slightly decrease of hardness value. Water as quenching media produce higher hardness in specimen compared to Engine Oil.

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