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EFFECT OF TEMPERING TEMPERATURE ON FATIGUE STRENGTH OF THYSSEN 6582 STEEL

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Abstract. Fatigue tests under rotating bending fatigue testing machine has been carried out to estimate the effect of tempering temperature on fatigue strength of Thyssen 6582 machinery steel materials. The fatigue strength of these materials has been studied as a function of tempering temperature from 100 to 600°C test temperature with time hold up during 20 minute. The initiation and propagation behaviours of micro cracks were investigated on the specimen surface. The results show that the fatigue strength at 100°C was lower than at room temperature as standard specimen. The fatigue strength rates increasing as the tempering temperature increases to 300°C due to crack length occurs on the specimen surface, and then decreasing again with higher tempering temperatures. The ratio of fatigue strength and ultimate stress at 300°C was higher than at all of the tempering temperatures. The effect of tempering temperature on hardness, ultimate strength of material and the relationship between and microstructure are discussed.

Keywords: Fatigue Strength, Machinery Steel, Tempering Temperature, Microstructure, Crack length, Fatigue Test.

1. INTRODUCTION

In the previous, the effect of high-humidity environment on fatigue strength of metal materials such as structure steel and aluminium alloys has been reported [1,2]. The results show that high-humidity environment with ranges from 70 to 90 % RH reduces remarkably in fatigue strength. Thus, a transition of environmental fatigue strength was found with increasing humidity for those metal materials. The effect of specimen size of fatigue strength of HQ705 machinery steel was investigated as a variation of diameter from 8 to 3 mm [3]. Fatigue strength increases as the specimen size decreases to diameter of 3 mm.

In the recent years, the effect of tempering temperature on the mechanical properties and on fatigue strength of materials has extensively studied. The effect of tempering temperature on the mechanical properties was investigated. Increasing the tempering temperature decreases the yield and ultimate tensile strengths, but increases the ductility. However, the ultimate tensile strength decreases at a higher rate compared with increased tempering temperature [4]. The ultimate tensile strength of a C-Mn steel quenched and tempered at temperatures ranging from 150 to 450°C decrease linearly with an increase of tempering temperature, but their yield strength shows no significant variation [5]. The hardness, yields strength and the ultimate tensile strength of HSLA-100 type copper-bearing steels attained peak values after tempering at 500°C. Thereafter, the hardness and strength values dropped continuously, reaching minimum at 700°C [6]. In the present, the effect of tempering temperature on fatigue strength of Thyssen 6582 machinery steel is studied.

2. EXPERIMENTAL

The Thyssen 6582 type of medium carbon and Cr-Mo-Ni tensile strength over 100 kgf/mm^2 was used as the test materials. The chemical composition and the mechanical properties of the steel investigated is presented in Table 1 and 2, respectively. The specimens were machined from bar with diameter of 12 mm. The shape and dimension are shown in Figure 1.

TABLE 1 . Chemical Compositions (wt%) of Thyssen

C	Si	Mn	Cr	Mo	Ni	S	P
0.30-0.38	0.15-0.4	0.4-0.7	1.4-1.7	0.15-0.3	1.4-1.7	0.035	0.035

TABLE 2. Mechanical Properties of Thyssen 6582

Material	Ultimate Strength σ_{ul} (N/mm^2)	Hardness BHN
Thyssen 6582	1380	320

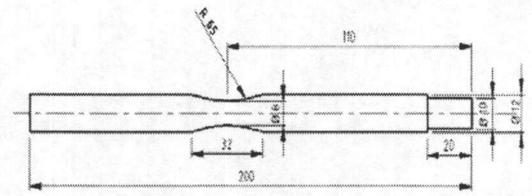

FIGURE 1. Geometry of specimens

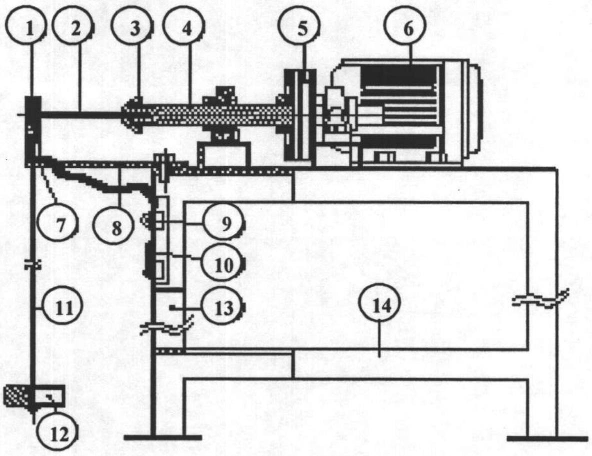

FIGURE 2. Equipment of Fatigue Testing Machine

The size and geometry of the specimens were in accordance with specifications of ASTM E-466. The specimen contains a shallow notch to observe crack initiation. The specimen surface and shallow notch were ground with grade 1200 emery paper and then were buff finished, and tempered in variation with tempering temperature. Six conditions of tempering temperature conditions were chosen as follows100°C , 200°C, 300°C, 400°C, 500°C, and 600°C for 1 hour. After heat treatment, specimens were machined for tension testing. Figure 2 shows the experimental equipment of rotating bending fatigue testing machine. Cracks were observed by a scanning electron microscopy (SEM).

3. RESULTS AND DISCUSSION

3.1 Fatigue strength in variation with tempering temperature conditions.

Figure 3 shows the S-N curve of Thyssen-6582 steel tempered at temperatures raging from 100 to 600°C. The test were carried out in variation with tempering temperature conditions, namely 100°C, 200°C, 300°C,

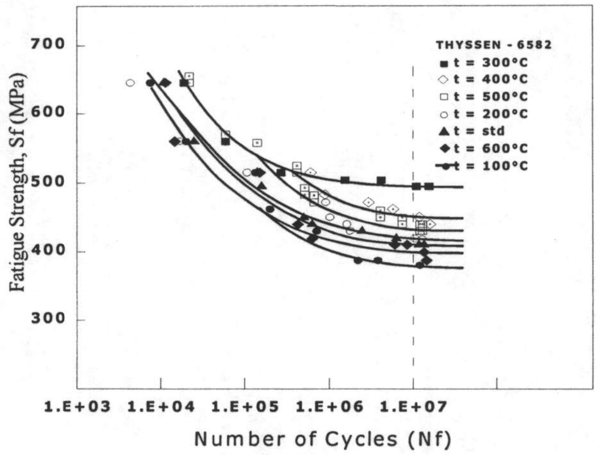

FIGURE 3. S-N curve of fatigue strength of Thyssen 6582 at tempering temperature from 100 to 600°C

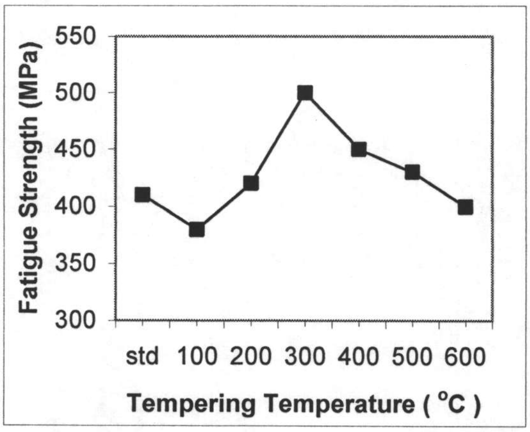

FIGURE 4. Effect of tempering temperature on fatigue strength.

400°C, 500°C, and 600°C. At tempering temperature of 300°C, fatigue strength is higher than that of specimen tempered at temperatures raging from 100 to 600°C. At tempering temperature 100°C, fatigue strength is lower than that of other tempering temperature. In addition, Fig. 4 shows that the effect of tempering temperature on fatigue strength. The fatigue strength of this material without tempering is 410 MPa. At tempering temperature of 100°C, the fatigue strength reduces slightly to be 7.31% and it becomes 380MPa, and then it increases 21.95% becomes 500MPa with increasing temperature reaches at 300°C. Fatigue strength is higher than that of all tempering temperature. Further, increasing the temperatures raging from 300 to 600°C fatigue strength decreased to 24%. Therefore, the fatigue strength increases remarkably at tempering temperature of 300°C and the effect of tempering temperature on fatigue

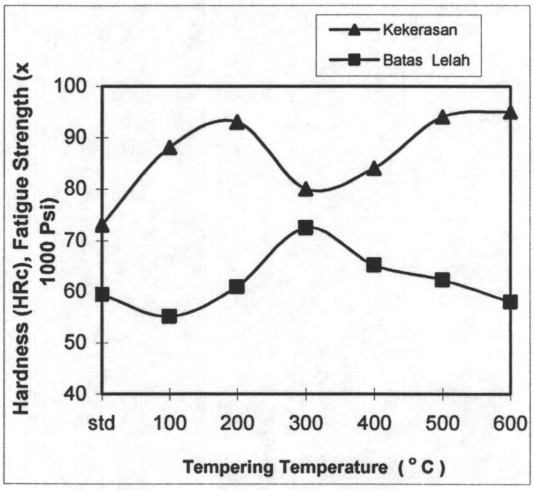

FIGURE 5. Effect of tempering temperature on hardness and fatigue strength of Thyssen 6582 steel.

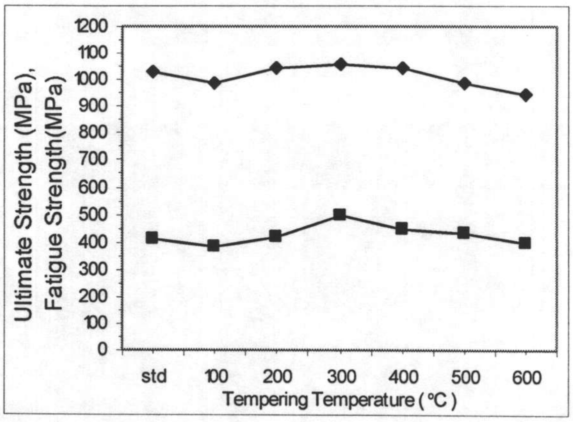

FIGURE 6. Effect of tempering temperature on the ultimate strength and fatigue strength

strength of Thyssen 6582 steel is greater than at tempering temperature ranging from 400 to 600°C.

The hardness and fatigue strength are plotted against the tempering temperature in Fig. 5. The hardness and fatigue strength show significant variation with tempering temperature. Fatigue strength is slightly lower than that of standard specimen without tempering, and it increases up to at 300°C. Effect of tempering temperature at 300°C shows significant increase in fatigue strength and it decreases up to at tempering temperature of 600°C. Inversely, the hardness increases at tempering temperature of 200°C, and it decreases at 300°C. Effect of tempering temperature at raging from 300°C to 600°C shows significant increases in hardness and it shows decrease in fatigue strength.

The fatigue strength and ultimate strength against the tempering temperature are plotted in Fig. 6. Both the

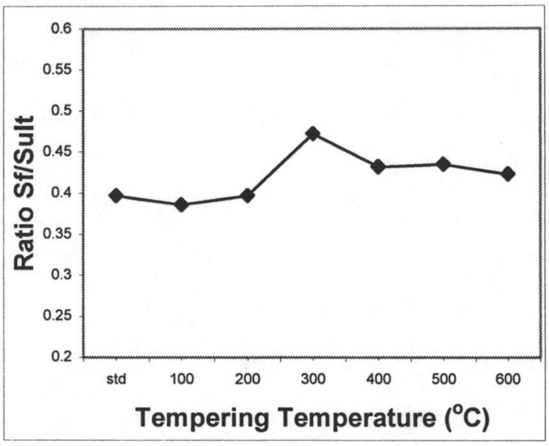

FIGURE 7. The relationship between ratio S_f/S_{ult} and tempering temperature.

uniform curve of the the fatigue strength and ultimate strength increase with an increased tempering temperature. The effect of tempering temperature on the ultimate strength of this steel is slightly almost the same as the effect of tempering temperature on fatigue strength.

Figure 7 shows the relationship between ratio S_f/S_{ult} and tempering temperature. Results show ratio of endurance limits and tensile strength of 0.386 at tempering temperature of 100°C, and ratios of S_f/S_{ult} of 0.472 at tempering temperature of 300°C. Average ratio of S_f/S_{ult} after tempered is slightly below 0.504[7]. Ratio of endurance limits and tensile strength does not show significant variation with tempering temperature.

3.2 *Crack Initiation on the surface specimen in variation with tempering temperature conditions.*

Figure 8 up to 14 shows the photographs of surface cracks in the vicinity of a pioneer cracks on the shallow notch of the specimen, which was fatigued at 10^7 cycles in variation with tempering temperature.

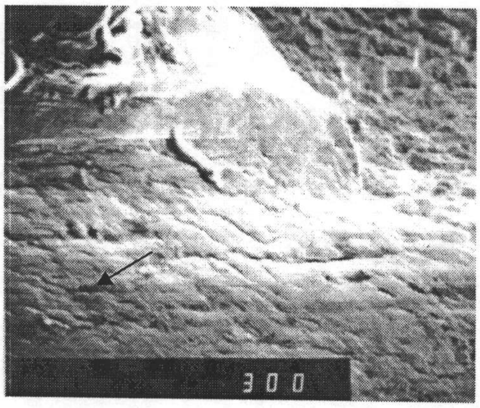

FIGURE 8. SEM micrograph of specimen without tempered without tempering.

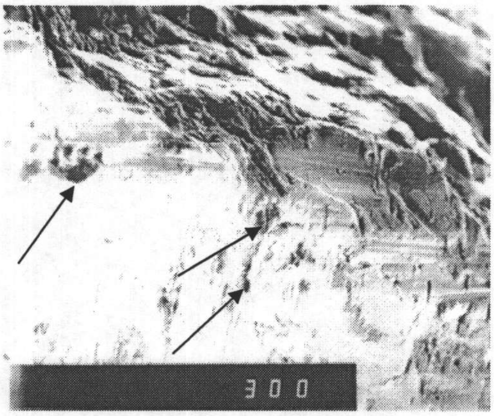

FIGURE 9. SEM micrograph of specimen at tempering temperature of 100°C.

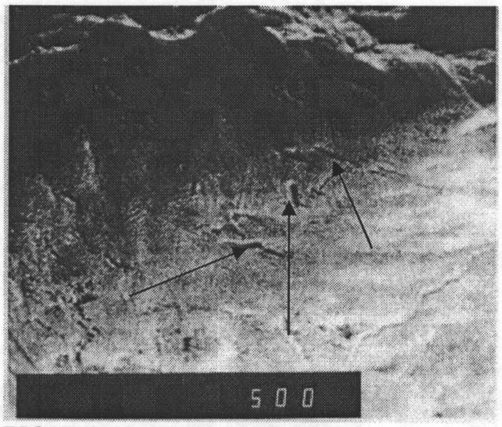

FIGURE 10. SEM micrograph of specimen at tempering temperature of 200 °C

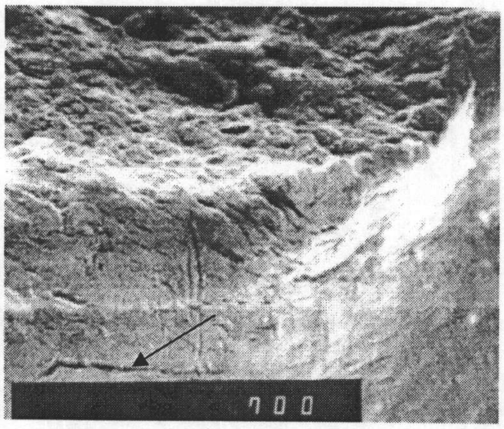

FIGURE 11. SEM micrograph of specimen at tempering temperature of 300°C

An SEM micrograph of specimen without tempered is shown in Fig. 8 where microcracks were found on the surface. The size of the length cracks decrease as the tempering temperature was increased from 100 to 300°C is shown Fig. 10 and 11. When the tempering temperature is higher than 300°C the crack length occurs

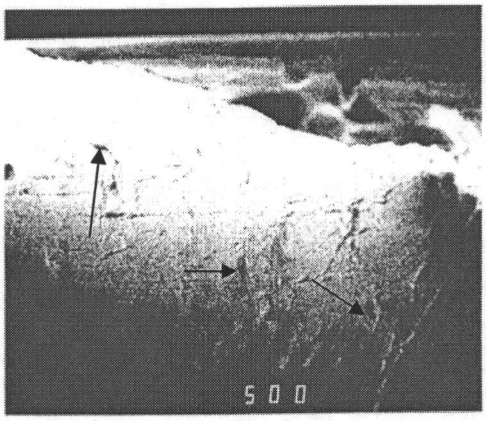

FIGURE 12. SEM micrograph of specimen at tempering temperature of 400°C

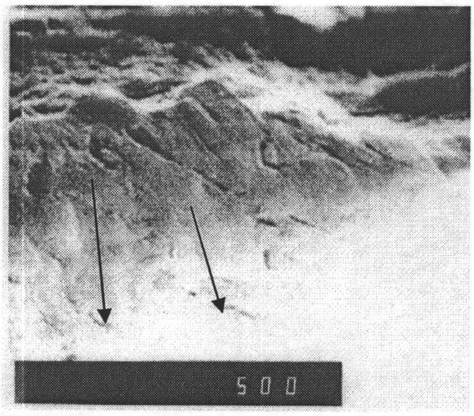

FIGURE 13. SEM micrograph of specimen at tempering temperature of 500°C

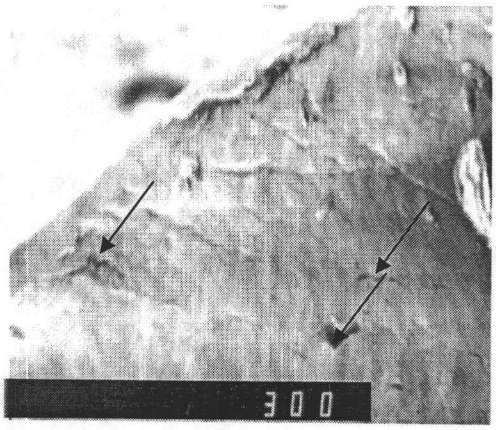

FIGURE 14. SEM micrograph of specimen at tempering temperature of 600°C

on the specimen surface (see, Fig. 12~14). With an increase in the crack length, the fatigue strength of this material decreases due to increase the tempering temperature. Therefore, the fatigue strength of Thyssen 6582 steel increases with increasing tempering temperature when the tempering temperature reaches at tempering temperature of 300°C. As expected, the mechanical behaviour of the steel investigated is quite sensitive to the tempering temperature.

4. CONCLUSION

The effect of tempering temperature on fatigue strength of Thyssen 6582 steel has been studied. The results obtained can be summarized as follows:
(1). The fatigue strength of the samples tempered at temperatures ranging 100 to 300°C increases with an increase of tempering temperature, but the fatigue strength at tempered ranging 400 to 600°C decreases with an increase of tempering temperature.
(2). The microcrack is found at tempering temperature of 300°C, and the reduction of fatigue strength at tempered ranging 400 to 600°C is due to the occurrence of length cracks on the specimen surface.

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