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Rolling Contact Fatigue Properties of SAE 8620 Steel after Case Carburizing

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Abstract: Rolling contact fatigue (RCF) properties of SAE 8620 steel after case carburizing have been investigated under two contact stresses of 4.0 and 5.5 GPa. Results show that the RCF life ranges from 2.5×10^{6} to 3×10^{7} cycles under the contact stress of 5.5 GPa, while it can be more than 1×10^{8} cycles under the contact stress of 4.0 GPa. The rated fatigue life L_{10} (lives with the 10% failure) is also drastically shortened from 9.8×10^{6} to 5.4×10^{5} cycles when the contact stress is increased from 4.0 to 5.5 GPa. Theoretical calculations and fractographs show that the maximum shear stress and the contact area increase with increasing the contact stress, making RCF tend to occur earlier.

Key words: case hardening steel; carburizing; rolling contact fatigue; contact stress; SAE 8620 steel

Case hardening steels are widely used for important components, such as power transmission gears of automobiles and industrial machines, due to the combination of high hardness in the case and good toughness in the core. Recently, transmission gears with smaller size and less mass are highly required to meet the increasing demand of automobiles capable for energy saving and pollution reduction, which may result in higher loads for the gears. Thus, it is necessary to study the properties of case hardening steels under higher stress levels. Rolling contact fatigue (RCF) is one of the common failure modes of transmission gears[1]. It is reported that RCF properties of bearing steels under the high contact stress of 5.3−5.8 GPa are quite different[2-6]. However, few studies on RCF properties of case hardening steels for gears under higher stress levels have been reported in literatures. This study aims to compare RCF properties of case hardening steel under the contact stresses of 4.0 and 5.5 GPa.

1 Experimental

A commercial SAE 8620 steel has been used as the experimental material, and its chemical composition is listed in Table 1. Hot-rolled bars with the diameter of 100 mm were machined into specimens for RCF tests. The specimens were 52 mm in outer diameter, 30 mm in inner diameter and 10 mm in thickness, as shown in Fig. 1.

Table 1 Chemical composition of the experimental steel

mass%

C	Si	Mn	S	P	Cr	Ni	Mo
0.20	0.29	0.79	0.017	0.013	0.54	0.46	0.15

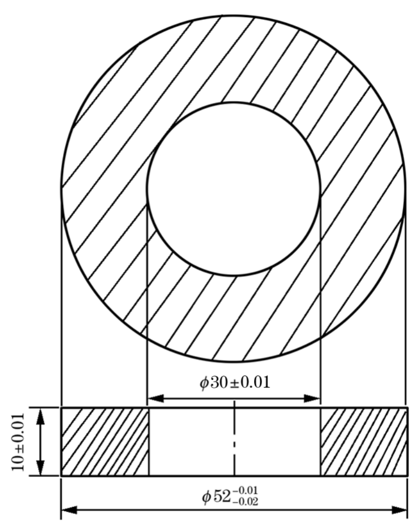

Fig. 1 Dimensions of specimens for rolling contact fatigue tests (unit: mm)

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The specimens were carburized first at 1 203 K for 7 h with a carbon potential of 1.0 mass%, and then at a lower temperature of 1103 K for 0.5 h with a carbon potential of 0.8 mass%, oil quenched, followed by tempering at 453 K for 2 h, as shown in Fig. 2. After heat treatment, the specimens were surface ground for RCF tests.

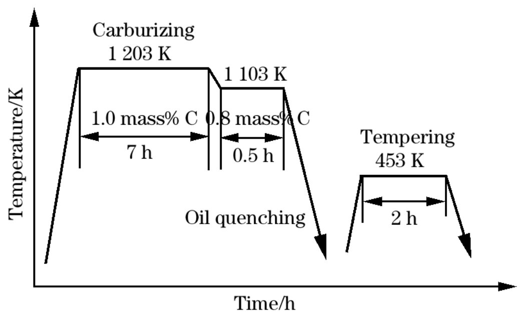

Fig. 2 Schematic illustration of carburizing and heat treatment process

RCF tests were conducted on a thrust-type machine of JP-52 with the cyclic speed of 2 800 r/min under the contact stresses of 4.0 and 5.5 GPa, respectively, at room temperature, as shown in Fig. 3. The load P was selected according to the following equations given in Chinese national standard GB/T 10622:

$$P=\left(\frac{p_0 \cdot \alpha \cdot \beta}{852.6}\right)^3 / (\sum \rho)^2 \tag{1}$$

$$p_0=\frac{852.6}{\alpha \cdot \beta} \times \sqrt{P(\sum \rho)^2} \tag{2}$$

where, p_0 is the maximum contact stress; α and β are constants; and ρ is the principal curvature between specimens and accompany testing specimens. This contact test was regarded as a pure rolling and slide was negligible. When spindle rotated, the specimen kept still, and balls revolved and rotated, driven by friction. Then, a rolling track appeared at the surface of specimens. When a pitting or spalling with the length of more than 0.5 mm formed, a vibration signal was propagated to an automatic control instrument through transducer, and then the test stopped automatically. The test was stopped when the specimens did not fail at a life more than 10^8 cycles. RCF limits were obtained in accordance with the Chinese standard GB/T 10622-89. The balls in contact with specimens were made of AISI 52100 steel, with the diameter of 9.525 mm, and spindle oil No. 5 was used as the lubricant.

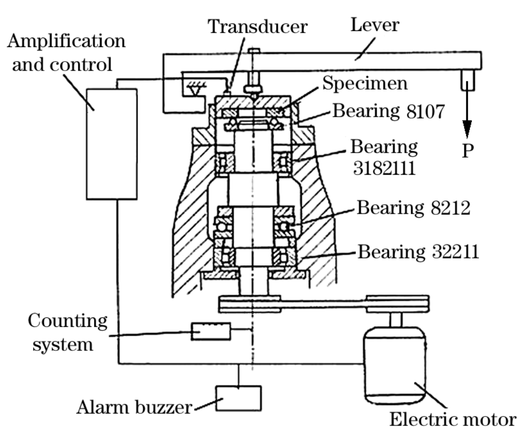

Fig. 3 Schematic illustration of rolling contact fatigue test machine

Fractographs of the specimens were observed on an S-4300 type scanning electron microscope (SEM) attached with energy dispersive X-ray analysis (EDX), operated at 15 kV. Microstructure of the carburized surface was observed by means of optical microscope after etched in 2 vol.% nital. In-depth microhardness was tested by an FM300 type digital microhardness tester.

2 Results and Discussion

2.1 Microstructure and hardness distribution

Fig. 4 shows martensitic microstructure at carburized case surface of the SAE 8620 steel after etched in 2 vol.% nital. It is composed of acicular martensite, retained austenite and some carbides, as usual for carburized case[7].

The in-depth hardness at the cross-section of RCF test specimen after carburization is shown in Fig. 5. It can be seen that the hardness of the carburized case was much higher than that of the matrix (about 450 HV). The hardness value of 550 HV is defined as the threshold value for carburized case according to ISO 2639; therefore, the effective carburized case depths were 1.2 mm for the steel. The peak hardness in the carburized case was about 780 HV, located at the distance of 0.2 mm from the surface of

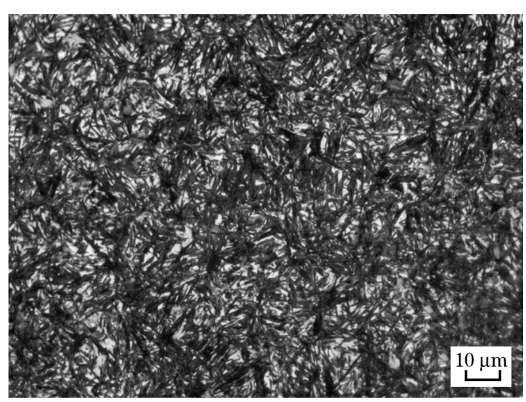

Fig. 4 Optical micrograph at carburized case of experimental steel