Analysis of Wear Mechanism and Influence Factors of Drum Segment of Hot Rolling Coiler

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Received April 21, 2012; revised October 26, 2012; accepted November 22, 2012

Abstract: Because the work environment of segment is complex, and the wear failures usually happen, the wear mechanism corresponding to the load is a key factor for the solution of this problem. At present, many researchers have investigated the failure of segment, but have not taken into account the compositive influences of matching and coiling process. To investigate the wear failure of the drum segment of the hot rolling coiler, the MMU-5G abrasion tester is applied to simulate the wear behavior under different temperatures, different loads and different stages, and the friction coefficients and wear rates are acquired. Scanning electron microscopy(SEM) is used to observe the micro-morphology of worn surface, X-ray energy dispersive spectroscopy(EDS) is used to analyze the chemical composition of worn surface, finally the wear mechanism of segment in working process is judged and the influence regulars of the environmental factors on the material wear behaviors are found. The test and analysis results show that under certain load, the wear of the segment changes into oxidation wear from abrasive wear step by step with the temperature increases, and the wear degree reduces; under certain temperature, the main wear mechanism of segment changes into spalling wear from abrasive wear with the load increases, and the wear degree slightly increases. The proposed research provides a theoretical foundation and a practical reference for optimizing the wear behavior and extending the working life of segment.

Key words: friction coefficient, wear rate, micro-morphology, wear mechanism, wear resistance

1 Introduction

The segment is a key components of the hot rolling coiler, and fits with the wedge set, core shaft and others during working process, so that the steel strip is coiled and discharged[1–2]. Because of the complex structure and the harsh working environment of the segment[3], the wear failures usually happen, affecting the production quality and reducing produce efficiency. So the effective measurements are needed to be proposed to improve the wearing condition during working, and the rounded analysis of worn reason and right judgment of wear mechanism are the basement of the analysis[4]. In recent years, many domestic and foreign researchers investigated the wear of segment, the work included the load distribution, the wear losses of failure parts and some recommendations for increasing the abrasive resistance of the segment. These approaches alleviate the wear of the segment to some extent[5–8]. But the integrality and profundity of the influence factors are not considered sufficiently, the studies about the wear mechanism and the influence of working condition upon the wear degree are rarely reported.

A large number of observation and testing analysis on wear failure of segment showed that the main wear of the segment takes place at the contact inclined plane, different coiling process and different strip size can cause the variety of the wear degree. Otherwise, the wear losses of the segment are different in coiling process and discharging process. In order to analyze the friction and wear behavior of segment under different working conditions, a series of experiments were carried out.

2 Wear Examinations

The experiment material is ZG42CrMo. Fig. 1 shows the heat treatment of the material, which was used to get the similar microstructure and performance to the segment. After the experiment, the hardness was HB240. The friction and wear tests were carried out on the MMU-5G high-temperature-end wear tester. The material of the upper specimen is ZG42CrMo, its main part is the
cylinder with 13 mm outer radius, 10 mm inner radius, 14 mm high, HB240 hardness, surface roughness \( R_a < 1.6 \mu m \). The under specimen is a disc, with diameter 43 mm, high 3 mm, and the material is 40CrNiMoA, with hardness HB260, and surface roughness \( R_a < 1.6 \mu m \).

\[
\begin{array}{ccc}
\text{Annealing} & \text{Normalizing} & \text{Tempering} \\
930 \degree C \pm 10 \degree C & 930 \degree C \pm 10 \degree C & 660 \degree C \pm 10 \degree C \\
(\geq 1 \text{ h} / 25 \text{ mm} \pm 2 \text{ h}) & (\geq 1 \text{ h} / 25 \text{ mm}) & (\geq 1 \text{ h} / 25 \text{ mm}) \\
\text{Furnace cooling} & \text{Intensive cooling with the fan} & \text{Air cooling} \\
\end{array}
\]

**Fig. 1.** Heat treatment of material

The friction surface was lubricated with lithium grease, with the grade of mep-2t. The specimens were cleaned in acetone applying ultrasonic for 15 min and dried before and after wear, then weighed by an electronic balance with the accuracy 0.1 mg, as a result, the wear losses of the specimens could be calculated. Each experiment under special load, velocity and temperature was repeated two times at least, and the average datum and the wear losses were used for analyzing the wear rate.

The formula \( W = V / PL \) was used to calculate wear rate, where \( W \) is the wear rate, \( V \) is the wear volume loss (wear mass loss/density), \( P \) is the normal load and \( L \) is the sliding distance\(^{[9]}\).

Other parameters in the experiment are shown in Table 1.

**Table 1.** Setting parameters of experiment

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Temperature ( T/\degree C )</th>
<th>Normal load ( F/N )</th>
<th>Speed ( n/(r \cdot \text{min}^{-1}) )</th>
<th>Time ( t/\text{min} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Room, 90, 150, 210</td>
<td>2469</td>
<td>91</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>2069, 2269, 2469</td>
<td>91</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2669, 2869</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>75</td>
<td>78</td>
<td>120</td>
</tr>
</tbody>
</table>

After the test, scanning electron microscope(S-4800) attached with EDS was used to observe and analyze the surface morphology and chemical composition of worn specimen.

**3 Results and Discussions**

**3.1 Friction and wear properties**

Fig. 2 shows the variation of the friction coefficient versus time at different temperatures in test 1. One can see that, under the same normal load, the friction coefficient of the material reduces with the increasing of the contact temperature, and the amplitude is greatly.

Fig. 3 shows the wear rates of upper specimens under different working conditions in test 1. As is shown in the figure, the wear rate reduces with the increasing of the temperature.

In actual working process, the internal surface temperature of the segment is different due to different coiling temperatures and cooling processes. Otherwise, the temperature increases gradually because of the accumulated heat during the continuous heat coiling. As analyzed in test 1, in the working temperature range of segment, the higher the temperature, the lower the wear degree of internal surface.

**Fig. 2.** Variations of friction coefficient versus time at different temperatures in test 1

**Fig. 3.** Wear rates of upper specimens at different temperatures in test 1

**Fig. 4.** shows the variation of the average friction coefficient versus load under different working conditions in test 2. One can see that, under the load range of 2069–2869 N, friction coefficient of the material reduces with the increasing of the load, and the amplitude is very small.

**Fig. 4.** Variation of average coefficient of friction versus normal load in test 2