Study on Wear Performance of GS-18NiMoCr36/42CrMo Friction Pair

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Abstract. GS-18NiMoCr36 steel was used to prepare fixed pin with different hardness. The rotating ring with hardness of 53HRC was prepared by 42CrMo steel. Under the different load conditions, MR-H3B high-speed ring on block wear tester was used to study the influence of different hardness matching friction pair wear performance. The results show that with the increase of load, the weight loss of wear has the law of increasing-decreasing-increasing. The form of wear is oxidation wear - adhesive wear - oxidation wear - adhesive wear. As the hardness of the fixed pin increases, the weight loss of wear tends to decrease, and the hardness of the material can be improved within a certain hardness range, which can significantly improve the wear resistance.

1. Introduction
The large tonnage four-wheeled belt travel mechanism mainly includes a roller, a drive wheel, a guide wheel, a carrier roller and a track shoe. The main failure mode of the four-wheel belt is wear, concentrated in the following contact parts: the guide wheel and the track link section; the roller and track section; the sprocket and track section [1, 2]. These contact points are typical rolling friction wear. With the increase of surface friction, the rolling friction resistance increases rapidly [3]. It is especially important to study the effects of different loads on the wear characteristics of friction pairs. In recent years, GS-18NiMoCr36 (hereinafter referred to as G18) has been widely used in large-tonnage track shoes due to its good heat treatment properties and toughness, and 42CrMo is used in the manufacture of wheel bodies [4, 5]. The author simulates the influence of different loads on the G18/42CrMo friction pair on the MR-H3B high-speed ring block wear tester, and provides data support for the performance study of the whole four-wheel system.

2. Materials and methods
G18 round steel were cut into fixed pins of size 12mm×12mm×19mm by wire-cutting. It is quenched and tempered by different temperatures before grinding. The hardness is 26HRC, 36HRC and 46HRC respectively.

For the test, 42CrMo steel is a round bar with a size of Ф60mm. After machining, a circular ring grinding sample (hereinafter referred to as rotating ring) is obtained, the thickness is 13mm, the outer
diameter is 49mm, and the inner diameter is 30mm. The composition of G18 steel and 42CrMo steel used in the test is shown in Table 1.

The ring block wear test was performed using a MR-H3B high speed ring block wear tester (the device schematic is shown in Figure 1.). The load is selected from 100N, 300N, 600N and 1000N, the rotation speed is 100r/min, and the time is 60min. The fixing pin and the rotating ring were ultrasonically cleaned with absolute ethanol before and after the test, and weighed using an electronic balance with an accuracy of 0.1 mg to calculate the weight loss of the worn sample. Three groups were matched for each set of matching tests, and the weight loss of wear was averaged using the results of the three groups. The worn surface of the worn sample was cleaned and dried, the worn surface was analyzed by a scanning electron microscope, and the micro-area composition of the worn surface was analyzed by using EDS.

Table 1. The composition of G18 steel and 42CrMo steel

| Grade | C  | Si  | Mn  | Cr  | Ni  | Mo  |
|-------|----|-----|-----|-----|-----|-----|
| G18   | 0.21 | 0.31 | 0.83 | 0.52 | 0.74 | 0.58 |
| 42CrMo| 0.415 | 0.248 | 0.572 | 0.97 | /   | 0.16 |

Figure 1. Schematic of MR-H3B high speed ring block wear tester

3. Results and discussion

3.1. Effect of load on wear performance of friction pair

The test results of the ring block wear of different hardness pin and ring friction pair samples under different load conditions are shown in Table 2.

According to the results in Table 2, the weight change curves of the fixed pin and the rotating ring are wearing shown in Figure 2 and Figure 3 under different load conditions. At 100N~300N, the wear weight loss of pin and ring increases significantly when the load increases, taking the hardness of fixed pin (26HRC) as an example, the wear weight loss increased from 76.1mg to 189.6mg, which increased by 2.5 times. When the load is 600N, the weight loss of the fixed pin (36HRC) is reduced from 185.6mg to 89.7mg, wear resistance increased by 51%. When the load is increased to 1000N, the wear loss of the friction pair is significantly reduced. It can be seen from Table 2 that the wear weight loss of the fixing pin is always higher than the rotating ring’s. In general, the wear resistance of high hardness materials is higher than that of low hardness materials. This is consistent with the soft abrasive wear law. For the low and medium hardness fixed pins of 26HRC and 36HRC, the fluctuation curve of the grinding loss weight changes greatly. The magnitude of change was 115.5mg (26HRC) and 130.9mg (36HRC), indicating that the load has a significant effect in the wear process. And for the higher hardness sample of 46HRC, the weight loss of the pin changes slowly, the change range is only 44.2mg.

Ring-block wear simulates a relative sliding frictional wear process of a line contact, usually explained by the "adhesion-mechanical meshing" theory. Since the microscopic state of the friction surface between the friction pairs is uneven, the friction only occurs where the convex peak and the
convex peak between the friction surfaces are exactly opposite each other [6, 7]. In general, when the fixing pin (26HRC, 36HRC) with low hardness and good plasticity is ground against a high-hardness rotating ring (46HRC), the hard micro-protrusion on the ring presses and cuts the pin to cause plastic deformation of the pin contact surface, and eventually the deformation of the deformed area causes wear. Therefore, the wear resistance of the material can be improved by increasing the hardness of the fixing pin.

Table 2. Grinding loss weight of friction pairs under different loads

| Load/N | The hardness of pin/HRC | The hardness of ring/HRC | Weight loss of pin/mg | Weight loss of ring/mg |
|--------|-------------------------|--------------------------|-----------------------|-----------------------|
| 100    | 26                      | 53                       | 76.1                  | 25.7                  |
|        | 36                      |                          | 54.7                  | 21.7                  |
|        | 46                      |                          | 29.7                  | 21.3                  |
|        | 26                      |                          | 189.6                 | 107.4                 |
| 300    | 36                      | 53                       | 185.6                 | 107.7                 |
|        | 46                      |                          | 73.9                  | 49.6                  |
|        | 26                      |                          | 139.6                 | 37.0                  |
| 600    | 36                      | 53                       | 89.7                  | 41.7                  |
|        | 46                      |                          | 51.2                  | 24.8                  |
|        | 26                      |                          | 173.5                 | 82.9                  |
| 1000   | 36                      | 53                       | 165.2                 | 84.4                  |
|        | 46                      |                          | 68.8                  | 60.8                  |

In this test, when the load is increased from 300N to 600N, the wear of the friction pair decreases greatly due to the formation of oxidation layer with high hardness. When the load continues to rise to 1000N, the temperature rise of the friction pair intensifies. In addition to the formation of oxidation layer between the contact surfaces of the friction pair, a high-temperature softening layer will also be formed under the oxidation layer. At this time, the stress between the friction pairs is extremely large, and the bearing capacity of the softened layer is insufficient, which leads to the peeling of the oxidation layer with high hardness and brittleness on the surface due to brittle cracking, and the wear amount is increased.

Figure 2. Effect of different loads on the wear performance of fixed pins
Figure 3. Effect of different loads on the wear performance of the rotating ring

3.2. Analysis of wear trace morphology of ring-block wear

Figure 4 shows the wear scar morphology of the fixed pin under different loads. The EDS energy spectrum analysis results of different regions in Figure 4 are shown in Table 3. It can be seen from Figure 4(a) that only a small amount of the surface of the wear scar is peeled off, and the wear debris is formed by the external force. From the EDS analysis results of the two regions A and B, it can be seen that the particles are oxides, and the surface of the wear scar is also an oxide. At this time, the oxidation wear is mainly dominant. With the EDS results of regions C and D, it can be seen from Figure 4(b) that the load is increased from 100N to 300N, the oxide film is peeled off, and it is broken into oxide particles under the action of the load. Oxide particles of different sizes are distributed on the surface of the wear scar, resulting in an increase in the roughness of the wear surface and aggravation of wear. At this time, the adhesive wear is dominant. As shown in Figure 4(c), when the load is 600N, combined with the EDS analysis result (the region of E and F), the surface re-generates the oxide film due to the increase in temperature, reduces the friction coefficient, and reduces the wear amount. There are shallow furrows on the surface of the wear scar and typical adhesive wear morphology. It can be seen from Figure 4(d) that when the load is 1000N, cracks appear on the surface of the wear scar. The oxide particles formed by the rupture of the oxide film are pressed into the crack.
Figure 4. Wear scar morphology of the fixed pin under different loads

Table 3. EDS results for different regions in Figure 4

| Element | Region | O wt.% | O at.% | Cr wt.% | Cr at.% | Fe wt.% | Fe at.% |
|---------|--------|--------|--------|---------|---------|---------|---------|
| A       |        | 41.63  | 71.35  | /       | /       | 58.37   | 28.65   |
| B       |        | 34.51  | 64.76  | 0.84    | 0.48    | 64.65   | 34.76   |
| C       |        | 45.02  | 74.06  | 0.77    | 0.39    | 54.21   | 25.55   |
| D       |        | /      | /      | 1.02    | 1.09    | 98.98   | 98.91   |
| E       |        | 14.26  | 36.72  | 1.03    | 0.81    | 84.71   | 62.74   |
| F       |        | 41.91  | 71.55  | 0.83    | 0.43    | 57.27   | 28.01   |
| G       |        | /      | /      | 1.11    | 1.19    | 98.89   | 98.81   |
| H       |        | 44.28  | 73.47  | 0.95    | 0.48    | 54.78   | 26.04   |

During the increase of the load, due to the conversion of mechanical energy, a temperature rise occurs between the contact surfaces of the friction pair. When the load increases to a certain extent, the temperature between the contact surfaces of the friction pair raises rapidly, and the oxide layer is formed due to the high temperature between the contact surfaces. The thermal conductivity of the oxide layer is lower than that of the metal matrix, which exacerbates the temperature rise of the contact surface. A denser, thicker dense oxide layer is formed between the faces. Studies have shown that the instantaneous temperature (flash temperature) between the metal contact surfaces under high stress can be as high as 1000°C [8]. The high temperature on the one hand exacerbates the oxidation of the contact surface, increases the thickness of the oxide layer, and on the other hand, it softens the metal in contact areas due to high temperature. Due to the high hardness of the oxide layer, the substrate can be well protected and has a certain anti-wear effect. The ability of the softened metal to resist stress deformation is significantly reduced, resulting in rapid wear. Therefore, the influence of temperature rise on wear resistance of friction pair is complex, which is generally a combination of the two different wear mechanisms mentioned above.

4. Conclusion
(1) As the load increases, the weight loss of wear has the law of increasing-decreasing-increasing. When the hardness of the fixed pin is 36HRC, the wear weight loss is the lowest at 100kN, only 54.7mg, and the wear weight loss is 89.7mg when the applied load is 600kN, the wear resistance is increased by 52.6% compared with 300kN, and the wear resistance is increased by 45.7% compared to 1000kN.

(2) As the hardness of the fixed pin increases, the weight loss of wear tends to decrease. In all the results, the wear weight loss of the rotating ring is smaller than that of the fixed pin.
(3) At 600kN, the oxide film is re-formed due to temperature. The oxidation film reduces the friction coefficient, which results in the loss of wear weight of the friction pair.

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