

Influence of rotational speed on friction and wear properties of 35CrMo/GCr15 friction coupling

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Abstract—The effect of rotational speed on the friction and wear properties of 35CrMo/GCr15 was studied under the condition of boundary lubrication. The speed was set as 400r/min,800 r/min,1200r/min,1600r/min,and the load were 200N. Working time was 120min.The ring block friction and wear testing machine were used for testing. The surface morphology changes of wear specimen were analyzed by scanning electron microscope (SEM). The results showed that the main form of the wear of the material was different with speed different. When the rotating speed was low, the wear was mainly abrasive wear, and the wear was mainly adhesive wear at high speed. When the speed was 800r/min, the wear rate was minimum, and the friction coefficient also was minimum. It shows that when the load was constant, the speed was too high or too low, would make the wear and tear intensified.

1. Introduction

In recent years, compressor, oil pump and other machinery used needle roller bearings without inner ring. The needle roller and shaft formed in direct contact with friction. The shaft material was 35CrMo, and the commonly used materials for needle GCr15. So the study of 35 CrMo /GCr15 friction performance of friction pair was of great significance. It could improve the working life of bearing and shaft .

At present, there are a lot of research on this subject. Literature 1 thought that the surface roughness of material had impacted on the tribological properties of 35CrMo/GCr15 friction pairs. And experimental results showed that the roughness had an optimum value, and the wear rate was the lowest. The influence of load and temperature on the friction pair of 35CrMo / GCr15 was studied in literature 3. The experimental results showed that the load was proportional to the friction coefficient. However, the increase of temperature would also affect the friction coefficient of the material.The influence of different surface hardness of 35CrMo on the contact fatigue was studied in Literature 4. The result showed that high hardness would increase the surface hardening rate. At the same time, it also would affect the surface fatigue strength. In literature 8, the effect of plastic contact area on the sliding wear behavior of 35CrMo/GCr15 friction pairs is studied. It was considered that the decrease of contact area was caused by the fatigue pitting of the surface of friction pairs. At the same time, the wear rate increases sharply . In literature 9, the friction and wear properties of 35CrMo materials were improved by surface coating method. In literature 7, the hardness and wear resistance of the alloy were increased by laser cladding on the surface of 35CrMo. The literature 11 had studied the fretting friction behavior of



35CrMo by using a self-made test machine. It also analyzed the fretting wear mechanism and surface damage.

Through the analysis of the above literature, we found that many factors had affected the tribological properties of 35CrMo materials. Such as surface hardness, surface roughness, load, temperature, etc. In addition, the surface treatment process could also improve the ability to wear. However, there was no analysis of the impact of speed. In this paper, four different speeds were set up under the fixed load. The experimental results were analyzed and compared to find the best speed. In order to further studied the theoretical basis for the improvement of the service life of rolling bearing with 35CrMo as raw material.

2. Experiment process and Method

2.1 Experimental equipment and Experimental materials

In order to simulate the needle roller and shaft of the rolling friction. This experiment selected MRH-3 high-speed ring block wear test machine to simulate the movement of the friction pair. The basic principle of the friction and wear testing machine is shown in Figure 1:

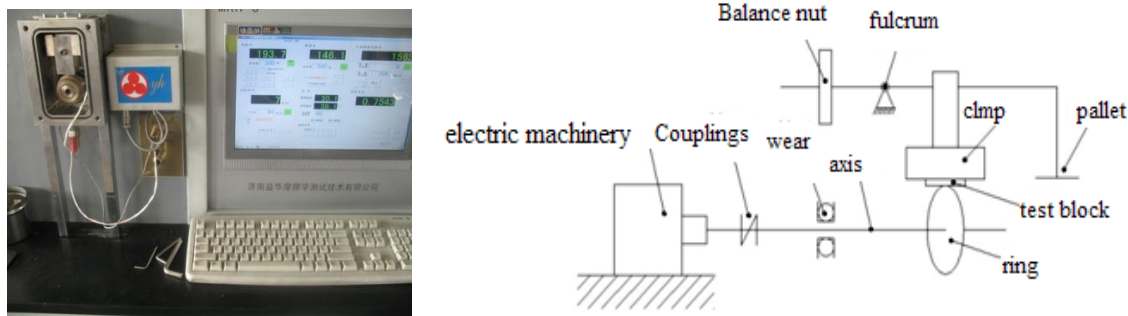


Figure 1 MRH-3 type multifunctional friction testing machine and its working principle

The 35GrMo material is made of size: 19.05mm * 12.32 mm * 12.32mm of the rectangular block, the hardness is about 120 ~ 150HBS; The chemical composition is shown in table 1, The GCr15 material made of size: 49.22mm * 13.06mm steel ring, the surface roughness of about 0.63 μm , hardness of 210 ~ 220 HBS. The content of the material is shown in table I. Set the speed of the four groups, respectively: 400r/min, 800r/min, 1200r/min 1000r/min, 1600r/min. The experiment was carried out with five samples in each group, and then the average value was obtained.

Table I CHEMICAL COMPOSITION OF SAMPLE MATERIAL

Name	C	Cr	Ni	Si	Mn
35CrMo	0.9-1.05	1.35-1.7	≤ 0.3	0.15-0.3	0.25-0.4
GCr15	0.3-0.4	0.9-1.15	≤ 0.03	0.17-0.4	0.4-0.7

2.2 Experimental Process

Grease evenly on the surface of the friction pairs before the test, the test is carried out in the process no longer add any lubricant. In room temperature environment, no corrosion, no dust. According to the actual working conditions, the friction pairs in the 5 groups were loaded with 200N, and each group was tested for 120 minutes. Then start the test machine, in the 50 r/min speed rotation for 3 minutes, during the period not to load, to ensure that the contact can be formed in a uniform lubricant film, and then smoothly to the test load to the specified value.

The samples in acetone solution before and after the test are cleaned by ultrasonic wave for about 10 minutes, After drying in the oven, the quality of the sample was measured by PING FA-1004 HANG (precision 0.1mg) electronic analysis balance. Using optical reading microscope to measure the width of the surface grinding mark. Then the surface morphology of the material was observed by JSM-5600LV scanning electron microscope.

3. Results analysis and Discussion

3.1 The influence of rotating speed on the friction coefficient

Under different rotational speed, the quality of the measured before and after wear, real-time friction coefficient values, the measured data in order. The results are shown in table II

Table II FRICTION COEFFICIENT OF THE SAMPLE BLOCK AT DIFFERENT SPEED

rotation rate (r/min)	Quality before wear (g)	Quality after wear (g)	Wear quality(g)	Mass wear rate ($\times 0.0001$)	Average friction coefficient
400	23.6844	23.6528	0.0316	13.342	0.1264
800	23.6670	23.6658	0.0012	0.507	0.0672
1000	23.4627	23.4598	0.0029	1.236	0.1158
1200	23.6929	23.6875	0.0051	2.247	0.1718
1600	23.6875	23.6844	0.0031	1.309	0.1511

By figure 2 can be seen obviously, speed is significant for the influence of the average friction coefficient. Relationship between speed and average friction coefficient are shown in Fig 3. In 400 ~ 800 r/min, the average friction coefficient is inversely proportional to the speed. At 800 r/min, the minimum value is reached. In 800 ~ 1200 r/min, the friction coefficient is proportional to the rotational speed. In 1200 ~ 1600 r/min, the increase of rotational speed, the friction coefficient showed a slow decreasing trend. Due to the curve slope is in 1200 ~ 1600 r/min are much smaller than between 400 ~ 800 r/min. It shows that the influence of rotational speed on the friction coefficient is not obvious when the speed is 1200 ~ 1600 r/min, but the friction coefficient is still high.

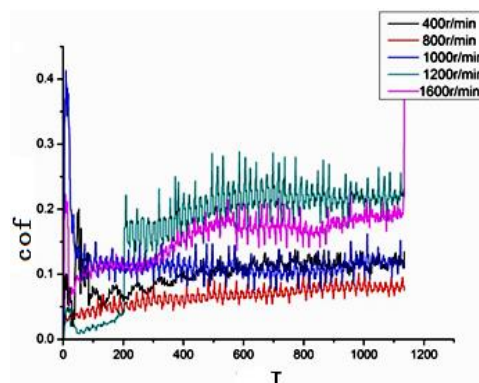


Fig. 2 curve of friction coefficient with time under different rotating speed

Overall, the impact of high speed on the friction coefficient is greater than low speed, low speed is conducive to reducing friction. Exist in the whole experiments, the optimal speed range, minimal effects on the friction coefficient, which is about 600 ~ 1000 r/min. This is because, under the high speed, the friction heat fast, make the friction pair surface temperature increases rapidly, the lubrication film is easy to be destroyed, lubricating film bearing function is lost, make direct contact with the metal and metal, the state of dry friction, so the friction coefficient is higher. However, due to the high viscosity of the grease, at low speed, the grease is not easy to form a continuous uniform lubricating film, so the friction coefficient is relatively high. But relatively and friction coefficient under high speed, is still relatively low. Between the rotating speed is 1200 ~ 1600 r/min, the coefficient of friction and a downward trend. This is mainly because with the increase of speed, temperature, on the surface of the friction pair surface may have softened. Under high temperature is 35CrMo block can rapidly on the surface of a layer of molten film on the surface of the molten lubrication, friction pair contact, changing factors such as the synergy of the friction coefficient of friction pair has been effectively reduced.

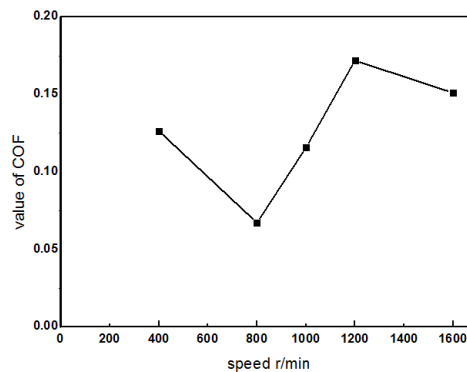


Fig. 3 Relationship between speed and average friction coefficient

Through experiments, it is found that the speed of 600 ~ 1000r/min is the best range, which is due to the formation of continuous uniform lubrication film at this speed. At the same time, because of the low speed, the heat generated by the surface temperature is limited, lubricating film on the surface of the friction pair is not easy to be destroyed, so the friction pair has been in fluid lubrication state, low friction coefficient.

3.2 The influence of rotating speed on the wear rate

Relationship between speed and wear rate are shown in Fig 4. As can be seen from Figure 4 the relationship between the wear rate and speed, the speed in the 400 ~ 800r/min and the curve is more steep, the wear rate is proportional to speed. The wear rate of 400r/min is about 26 times that of 800r/min, which shows that the speed of the rotating speed on the wear rate is larger than that of the wear rate.

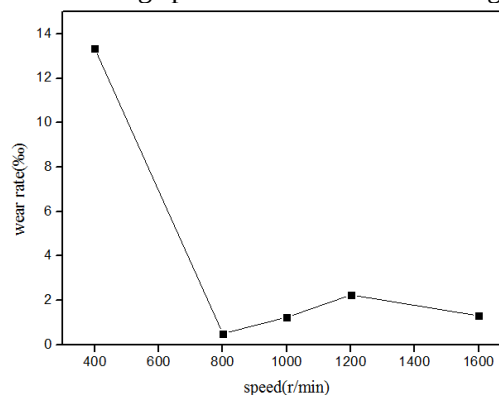


Fig. 4 Relationship between speed and wear rate

During 800 ~ 1600 r/min, with the increase of speed, the wear rate of change is not obvious, basically stable in a certain range, and overall is in a low condition, in the speed range, is conducive to reducing wear. Through Figure 4 shows that when the speed is 800r/min, the wear rate is minimum, which is consistent with the average friction coefficient of the speed. Overall, 35CrMo material under the high speed of the wear resistance is good, especially the speed of over 800 r/min, the wear rate increases as the speed and has been in a relatively low level, and the speed of change on the influence of the wear rate is not big.

Analysis reason, generated by the friction wear, figure 3 and figure 4 and comparison, the change trend of wear rate and rotating speed, the tendency of the average friction coefficient and speed has been. Lower wear rate on the high side, it is because at low speeds, grease on the surface of the friction pair is not easy to form homogeneous lubricating film, in the early wear and tear, the oxide film on the surface of the block, damages, was quickly try ring and direct contact, makes the high friction coefficient, wear rate is bigger also. And under the high speed, while friction coefficient is higher, but due to high

temperature and hardening effect, higher surface hardness, lower wear rate. After observing the wear surface of the test loop, the shine is obvious.

3.3 Surface morphology analysis

The wear of the specimen under the scanning electron microscope (SEM), observe the changes in their morphology, the results shown in figure 5.

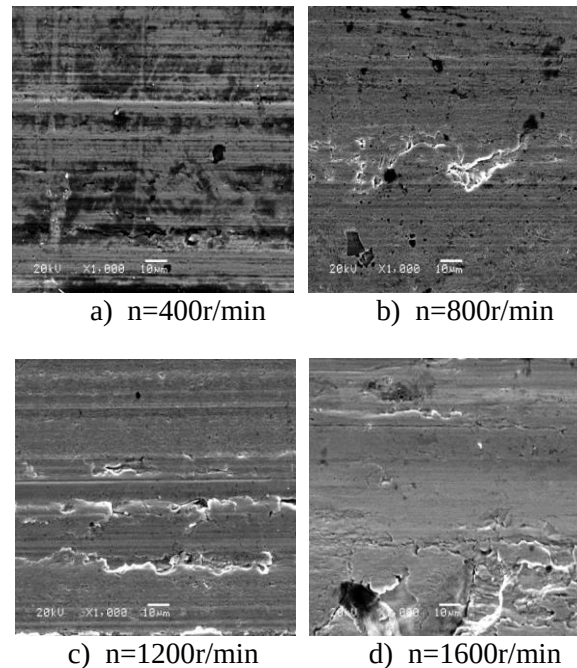


Fig 5 the shape of the surface of the block after wear under different rotational speed

As can be seen from the figure 5, after wear under different rotational speed of 35CrMo block surface topography. From the figure 5 (a) shows that at the speed of 400r/min, the test block surface has more obvious gully, showed that the main wear and tear of the plough wear. From figure 5 (b), figure 5 (c), 5 (d) it can be seen that with the increase of rotational speed, scratches on the surface of the material, but the trace of the adhesive wear more and more obvious, with traces of burns. When the rotating speed of 1600 r/min, sample piece of visible surface spalling pit, you can also see significant fatigue crack, in addition to the adhesive wear occurred in the process of wear and tear, also produced a fatigue wear. This is because the faster the relative sliding velocity, the greater the friction heat, the temperature rise, the greater the lubricant viscosity decline, the lubrication film thinning, lubrication, boundary lubrication, it is easier for direct contact with the metal agglutination, and adhesive wear. In addition under the high speed of 1600 r/min, when two sliding surfaces touch each other, soft on the surface of the micro convex body is easy to deformation, and under the action of repeated under varying

stress fracture occurs, formation of wear debris, the hard surface under the action of micro convex body, soft surface layer the overall plastic deformation will occur. 35CrMo block hardness less than GCr15 ring, so the sample surface will appear scratches. because of higher speed, so in the same time, the number of cycles is more, after a certain number of reciprocating motion, the surface layer of plastic deformation accumulated to a certain extent, it produced a crack. Lubricating oil into the surface crack under pressure, when try to ring and the crack surface contact, will exert a certain load, thus oil were closed within the crack, oil pressure rising, accelerate the crack propagation, as bends to the surface of crack, peeling, off, on the sample surface wear pit.

4. Conclusion

- (1) Under the condition of boundary lubrication, high speed, the surface temperature rise sharply, will cause friction pair surface glue, mainly adhesive wear, And Speed is more obvious when 1600r/min.
- (2) The speed is too low, the friction pair surface due to the fall of impurities or tooth surface pitting caused by particles fall off, the particles due to low speed stuck in the two friction pairs can not be ruled out in a timely manner, so that the friction pair surface wear and tear, And Speed is more obvious when 400r/min.
- (3) When the rotational speed is about 800r/min, the friction coefficient and the wear rate are relatively small, it is proved that the friction pair is the best.

Acknowledgment

This work was financially supported by the National Natural Science Foundation of China (51665035) and Doctoral Fund of Longdong University(XYBY1605).

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