

Friction and wear properties of artificial joints of CoCrMo alloy

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Abstract. CoCrMo alloy is an excellent material for manufacturing prosthesis. Due to the complex body environment, the prosthesis has a higher requirement for surface abrasion resistance and corrosion resistance. In this paper, the friction and wear properties of CoCrMo alloy artificial prosthesis were studied by a ring block friction-wear testing machine. The results indicate that the friction coefficient of CoCrMo alloy decreases with the increase of the load and rotation speed. The wear mass of the CoCrMo alloy has a good wear resistance and is suitable for manufacturing prosthesis. However, the surface of the CoCrMo alloy partially cracks under heavy load through SEM analysis, which indicates the prosthesis is not suitable for patients who often engage in heavy carrier forces.

1. Introduction

CoCrMo alloy has good mechanical properties, excellent corrosion resistance, friction resistance, and good biocompatibility. Therefore, it widely used to manufacture artificial prostheses in the medical field. Artificial prosthesis implanted in the body has long been in a complex human biological environment, and is not only eroded by body fluids, but also the frictional contact surface is subjected to about 100 to 3 million cycles of weight load and impact each year. Therefore, the friction and wear properties of artificial prostheses are crucial. In recent years, some scholars have conducted some research on the process-ability[1, 2], friction and wear[3-5], and manufacturing prosthesis [6]of CoCrMo alloys.

In this paper, the friction and wear properties of CoCrMo alloy artificial prosthesis were studied by a ring block friction-wear testing machine.

2. Experimental instruments and parameters

2.1. Experimental equipment

Experimental equipment including ring block friction-wear testing machine, CoCrMo alloy ring, block, electronic balance (accurate to 0.01mg) and SEM scanning electron microscope.

The cobalt-chromium-molybdenum alloy friction pair material was cut by a wire cutting machine. The size of a ring was an outer diameter of 40mm, an inner diameter of 20mm, a thickness of 10mm, and a size of 6mm×7mm×31mm cuboids. Figure 1 shows the ring and block used for friction and wear tests, which were polished by a polishing machine. Thoroughly clean was conducted inside the ultrasonic cleaner before each friction test.



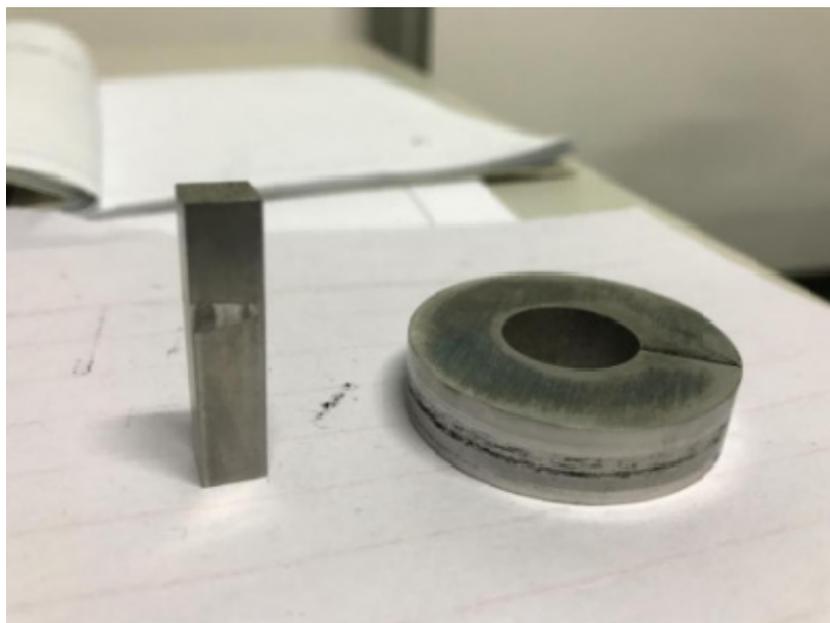


Figure.1 Friction and wear test specimen

2.2. Experimental parameters

Table 1. Experimental parameters of ring block friction and wear testing machine

| | | | | |
|----------------------|----------------------|-----|-----|-----|
| Load kg | 16 | 25 | 45 | 65 |
| Rotation speed r/min | 100 | 200 | 300 | 400 |
| Experimental method | Oil film lubrication | | | |

3. Wear resistance

The friction and wear properties of the CoCrMo alloy were investigated by a ring-block friction and wear testing machine. Meanwhile, loads of 16kg, 25kg, 45kg, and 65kg were used to simulate different loads on the prosthesis. Lubricating oil was used to simulate oil film lubrication in the body and the friction and wear of the body prosthesis was analyzed when the experimenter was in motion.

3.1. Friction coefficient

Assuming the prosthesis is in the hip joint of the lower extremities, the average adult walks about 80 m/min. If it is 0.5 m per step, it should be 160 steps. That is, the frequency of joint motion is 160 beats per min. When strenuous exercise, such as when running, the frequency of activity is recorded as two to three times as much as when walking. That is, the frequency of joint activity is about 320-480 times/ min. At the same time, due to differences in age and sexuality among children, adolescents, adults, etc., there are individual differences. The frequency of joint activity of the experimenter is taken as 100-400 beats/min, namely, the speed of the tester is 100-400 r/min. From the Table 2, it can be seen that the friction coefficient decreases with the increase of the load, decreases with the increase of the rotation speed, which presents a better regularity. The increase in load means that the weight of the experimenter increases, and an increase in the rotational speed means that the experimenter's movement speeds up.

Table 2. The change of friction coefficient with load and speed

| | | | | |
|------------------------|-----|-----|-----|-----|
| rotation speed (r/min) | 100 | 200 | 300 | 400 |
| load (kg) | | | | |

| | | | | |
|----|--------|--------|--------|--------|
| 16 | 0.8434 | 0.7412 | 0.5455 | 0.4783 |
| 25 | 0.5852 | 0.3384 | 0.2558 | 0.3169 |
| 45 | | 0.2872 | 0.2624 | 0.2217 |
| 65 | | 0.2511 | 0.2338 | 0.2134 |

3.2. Wear mass

Figure 2 shows the variation of wear mass of CoCrMo alloy with load and rotation speed. From Figure 2, it can be seen that the wear amount increases as the load increases and the wear amount increases as the rotation speed increases, which is the same as the conventional wear law. In the 30-minute friction test experiment, the minimum wear amount was about 5 mg at a rotational speed of 200 r/min and a load of 250 N, and the wear amount was a maximum of 80 mg at a rotational speed of 400 r/min and a load of 650 N, indicating that the CoCrMo alloy had good wear resistance.

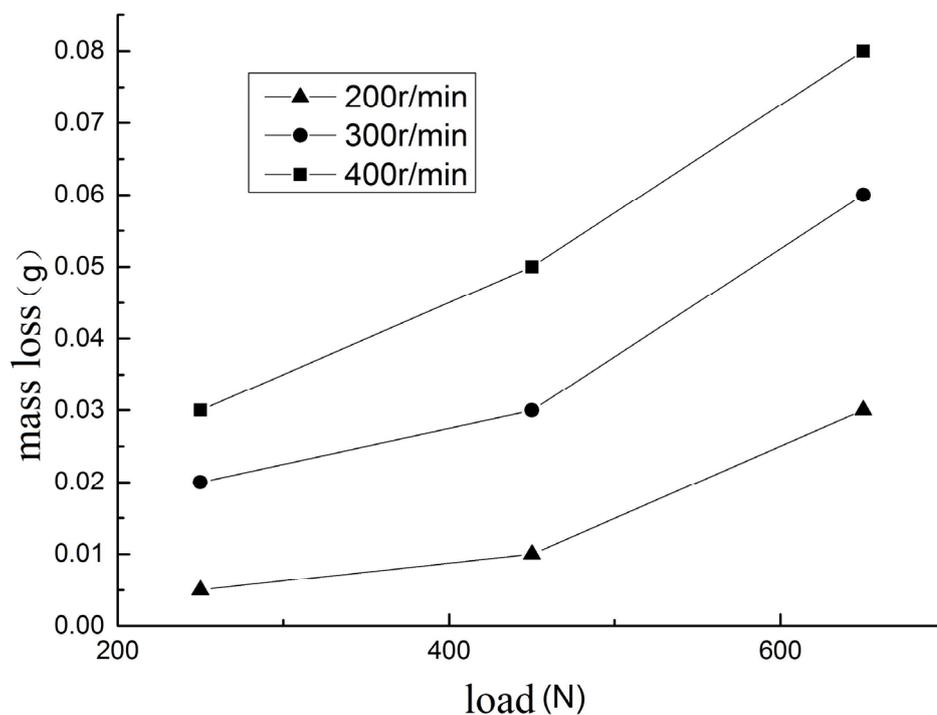
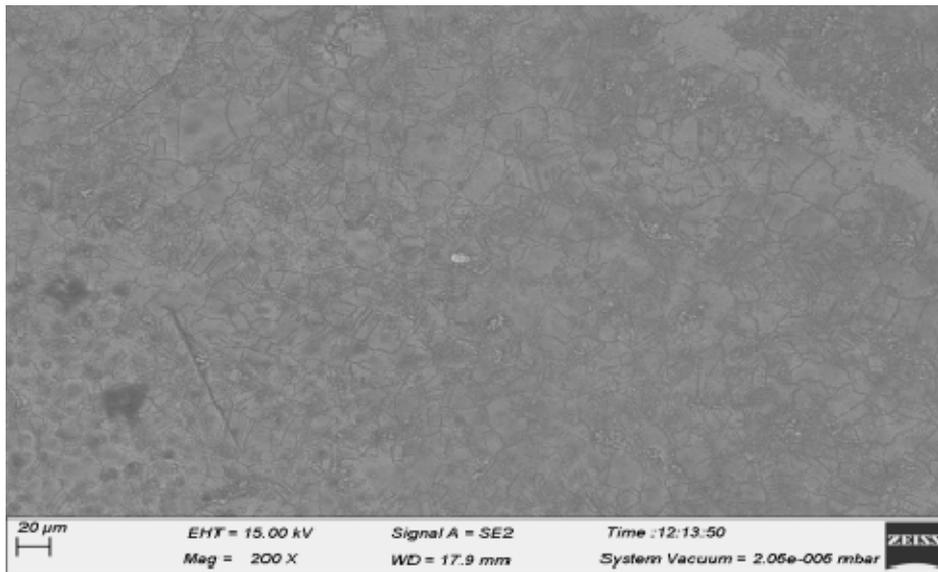


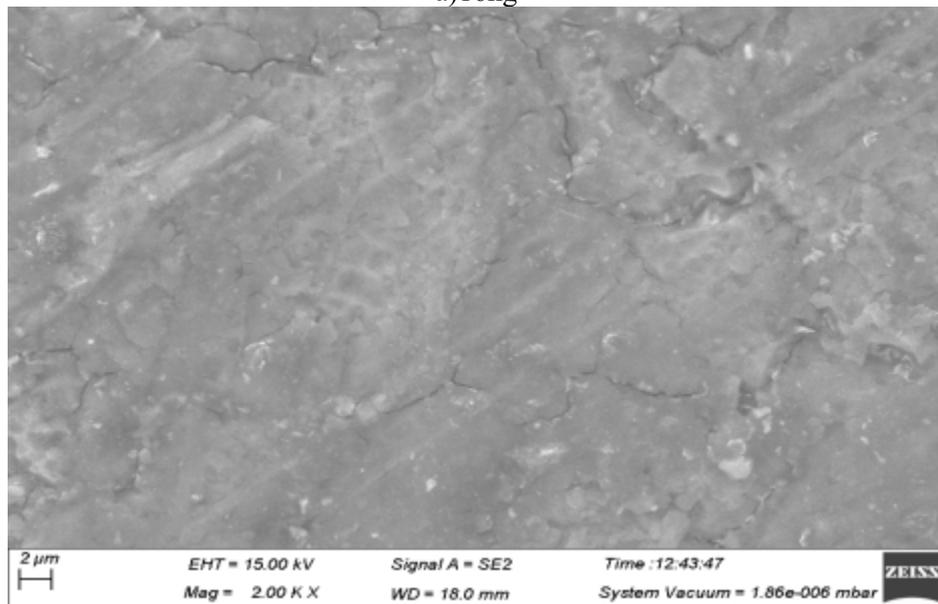
Figure 2. The wear mass of CoCrMo alloy

3.3. The micro-morphology wear surface and wear mechanism

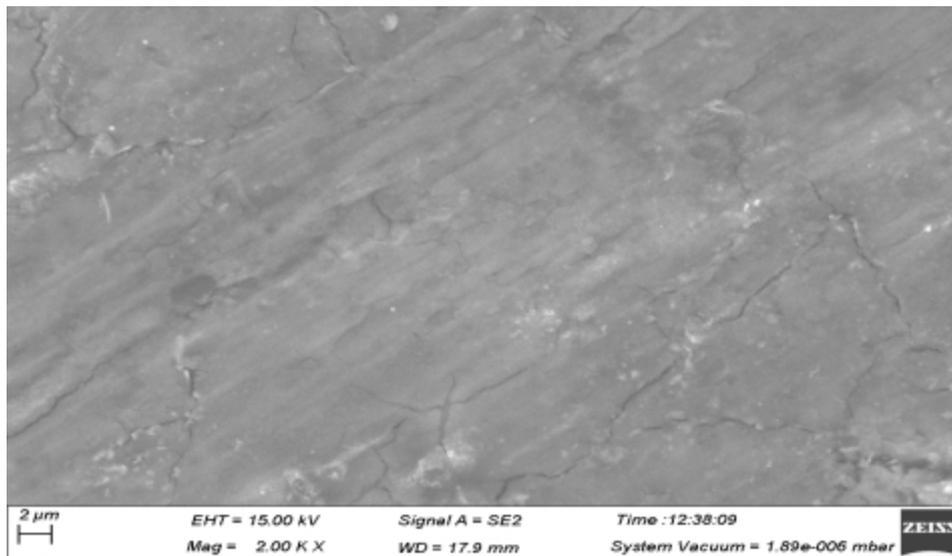
Figure 3 shows that the traces of friction and wear of CoCrMo alloys with loads of 16 kg, 25 kg, 45 kg, and 65 kg respectively. From figure 3, the friction and wear traces are hardly observed when the load is 16kg, and the CoCrMo alloy maintains its original appearance. With the increase of the load, the friction and wear traces at this time are few when the load reached 25kg, and plastic removal tracks appear. When the load is increased to 45kg, the friction and wear traces are clear at this time, strip or band plastic removal traces are observed. When the load is increased to 65kg, the friction and wear tracks are clearly visible and there are some cracks.



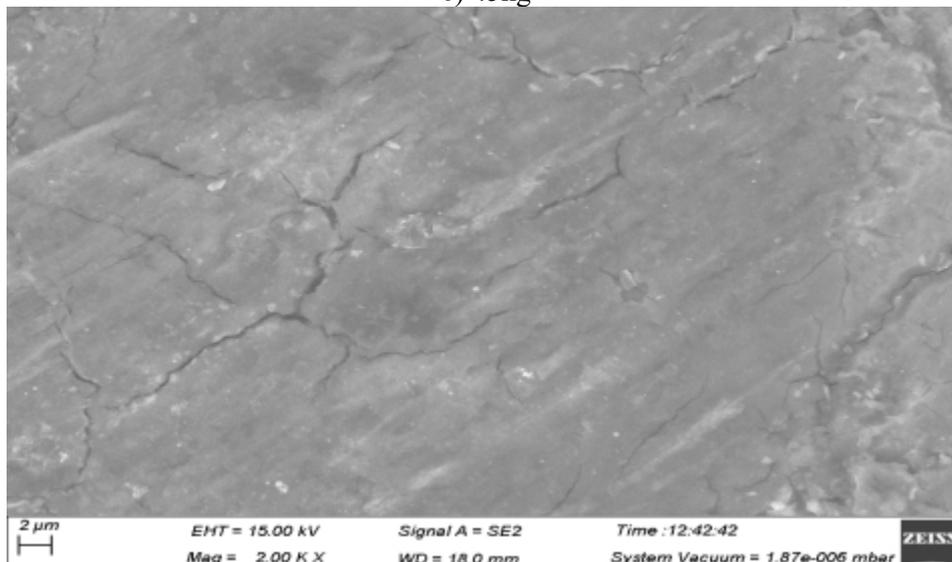
a)16kg



b)25kg



c) 45kg



d) 65kg

Figure 3. The micrograph of the wear traces SEM picture

4. Analysis and Discussion

4.1. Friction coefficient

From Table 2, the friction coefficient shows a decrease with increasing load and rotation speed. When the load is small, only some protruding point contacts of the ring block friction surface, which is equivalent to the bump in the plough another friction test specimen, showing a larger coefficient friction; when the load increases, it means that the bumps are squeezed and undergo elasto-plastic deformation. The original point contact becomes surface contact, which is equivalent to the change of the bump from the plough to friction, showing the friction coefficient decreases. Meanwhile, when the rotation speed increases, the input energy increases, the material contact interface softens and the hardness decreases. Thus, the friction coefficient decreases.

4.2. Wear mass

Figure 2 shows that the wear mass of the prosthesis increases with the increase of the load, indicating that the prosthesis still has a certain consumption in the human body, and it needs regular inspection, such as CT scan, to observe the wear of the prosthesis. Once the wear limit is reached, it needs to be replaced promptly.

4.3. Microscopic appearance of wear tracks

From Figure 3, the wear tracks vary with the load. The wear tracks increase with the increase of load and the wear mass. The main wear patterns are abrasive wear. At same time, there are cracks and shedding in local areas with a certain adhesive wear, which shows that the CoCrMo alloy prosthesis has certain consumption. If the consumption is within the normal range, the function of the prosthesis is not affected. However, in some special cases, such as those engaged in manual labor and other tasks that are often subjected to heavy loads, implants should be carefully implanted.

5. Conclusions

In this paper, using the ring block friction and wear testing machine to study the wear resistance and other properties, we obtain the following beneficial results:

- (1) The friction coefficient of CoCrMo alloy decreases with the increase of load and velocity, so that the friction coefficient exhibits a certain fluctuation.
- (2) The wear mass of CoCrMo alloy is small and wear resistance is good, which indicates its excellent performance for manufacturing prosthesis.
- (3) The friction and wear tracks of CoCrMo alloys change with increasing load. When the load is small, there are almost no wear tracks; when the load is large, plastic wear tracks appear. At the same time, there are cracks in some areas, so it shows that the prosthesis is not suitable for patients with heavy-duty labor, and regular exercise will produce a certain amount of wear, which needs regular inspection and timely replacement.

Acknowledgments

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