LUBRICATING BEHAVIOR OF COPPER RHENATE AT ELEVATED TEMPERATURES①

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ABSTRACT The copper rhenate ($Cu(Re_4)_2$) was prepared using chemical method, and its thermal stability was analysed by TGA (Thermogravimetric Analysis). The lubricating behavior of the copper rhenate at elevated temperatures were determined under three rubbing-pairs (Al_2O_3/Glass, Al_2O_3/Stainless steel and Glass/Glass) by means of high-temperature pin-on-disc tester. The results show that the copper rhenate dehydrates at 80~150 ℃, decomposes from 510 to 730 ℃, and has a good lubricating property between room temperature and 700 ℃, especially from 450 to 600 ℃, in which its friction coefficient is about 0.15. Under the rubbing pairs of Al_2O_3/stainless steel, the copper rhenate possesses long-term lubricating role at high-temperatures.

Key words copper rhenate high-temperature lubrication rubbing-pairs

1 INTRODUCTION

With the rapid development of industries and high technology research, there are more and more mechanisms used at high temperatures, such as rubbing-pairs of aviation mechanisms, heat process equipment for nonferrous metals, mechanic device of nuclear reactor and adiabatic motors. The problem of high-temperature lubrication of these equipment is required to be resolved urgently. But most of the single constituent solid lubricants have no all-round antifriction function from room temperature to high temperature (above 800 ℃). Thus, to find and study solid lubricants used in wider temperature range is an important subject. Sliney combined chronium carbide (Cr_3C_2) with silver and barium fluroide/calcium fluoride (BaF_2/CaF_2) to make self-lubricating coating which can work in a wider temperature range[1]. Peterson investigated the lubricating property of several kinds of oxides and mixed oxides[2]. The antifriction roles of oxide films on the surface of high-temperature self-lubricating alloys were also studied[3-5]. The lubricating behavior of the iron rhenate has been investigated by the authors[6], based on which the copper rhenate was compounded, which has better lubricating property than iron rhenate, and may be generated during the wear process of Cu-Re alloys at elevated temperatures. The lubricating behavior of the copper rhenate was evaluated at elevated temperatures.

2 EXPERIMENTAL

2.1 Preparation of samples

First, pure rhenum powder was added into solution of H_2O_2 and stirred. After the rhenum powder had dissolved completely, the excessive H_2O_2 and H_2O were removed away by heating and a solution of $HReO_4$ was obtained. The next, NH_4OH was dripped into a solution of $CuSO_4$ until the precipitation process completed, then pure $Cu(OH)_2$ was obtained by full centrifugal wash. At last, the $Cu(OH)_2$ was added into the solution of $HReO_4$ and stirred. After the complete dissolution of the $Cu(OH)_2$, hydrated

① Supported by the National Natural Science Foundation of China (No. 59571062) and State Key Lab. for P/M
Received Oct. 11, 1996; accepted Feb. 6, 1997

copper rhenate ($Cu(ReO_4)_2 \cdot H_2O$) powder was prepared using the heating evaporation method.

2.2 Apparatus and test procedure

The friction coefficient was determined with a self-made pin-on-disc wear device, which was driven by a stepless motor. A furnace surrounds the pin-on-disc sample, so that the friction test can be run at room temperature up to 800 ℃. The friction force was continuously recorded with an X-Y recorder. The signal of friction comes from a stress sensor pressed by an arm which is connected with the ball sample holder rigidly, as shown in Fig. 1.

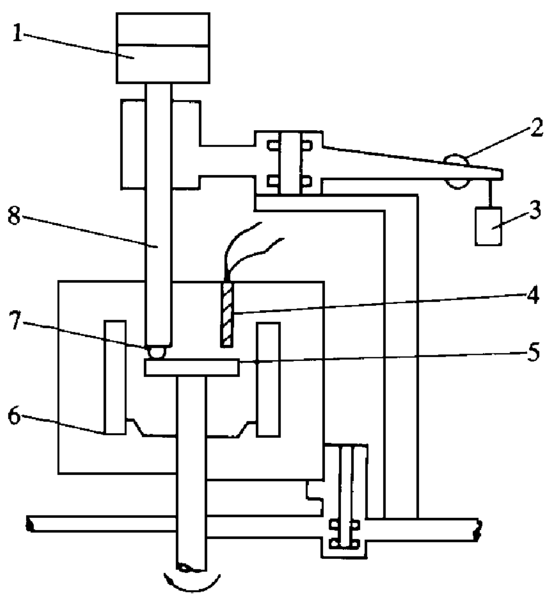

Fig. 1 Schematic diagram of high temperature wear apparatus

1 —Dead weight; 2 —Stress sensor;
3 —Balance; 4 —Thermocouple;
5 —Disc specimen; 6 —Furnace;
7 —Pin specimen; 8 —Pin holder

The disc samples were made of two different kinds matte meterials, glass and stainless steel, whose surface roughness (Ra) is about 3 um. The pin samples were Al_2O_3 ball and glass ball with a diameter of 12.7 mm. The powder of copper rhenate was smeared on frictional orbit of disc. The tests were run under a load of 20 N, and at a speed of 0.12 m/s. At each temperature, the test was run over 10 min. When the testing temperature was changed, the disc sample was replaced, the touching position of the ball sample was also changed and washed with alcohol.

3 RESULTS AND DISCUSSION

3.1 Dependence of friction coefficient on time

The dependence of friction coefficient (μ) on sliding time for the powdered copper rhenate under three kinds of rubbing pairs is shown in Fig. 2. At the initial stage of slide, the dry powdered copper rhenate on disc surface was not compressed and formed film with bearing capacity. Part of the load was exerted on the asperities, therefore the friction coefficient is high. After some time of slide, the tips of the asperities were smashed, then the powderd copper rhenate could act as effective lubricant, as a result the friction decreased. Comparing the three curves in Fig. 2, it can be seen that the friction coefficient is relatively low and stable under the rubbing pair of Al_2O_3/Glass. Under the rubbing pair of Al_2O_3/stainless steel, the value of μ increases slowly with sliding time. This is because that the stainless steel is relatively soft, and under the repeated action of the harder balls, the asperities would be pressed to flat gradually, and the lubricating films would be squeezed to two sides of the friction orbit. The friction form is a mixture of ceramic/metal and oxide/oxide, i.e. partial film lubricating state. Thus the value of μ is relatively higher.

Fig. 3 shows the dependence of friction co-

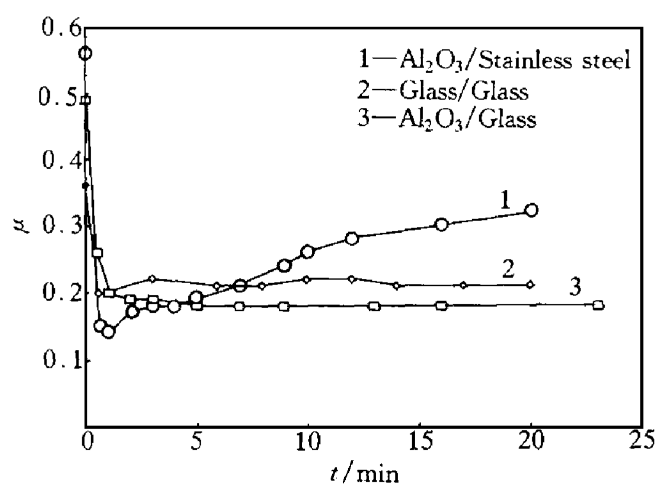

Fig. 2 Dependence of friction coefficient on time at room temperature

efficient on sliding time of the copper rhenate at 500 ℃. Comparing Fig. 1 with Fig. 2, it can be seen that the lubricating behavior of the copper rhenate at 500 ℃ is better than that at room temperature. The lowest friction coefficient is as small as 0. 11. But there are two steep rises of the value of μ under the rubbing pairs of Glass/ Glass and Al_2O_3/ Glass respectively at 2. 8 min and 5. 5 min, which shows that the lubricating films were broken. X-ray diffraction analysis of the debris on wear track collected at those moments demonstrated that besides the glass constituent in the debris, CuO is the main constituent and the copper rhenate is very little.

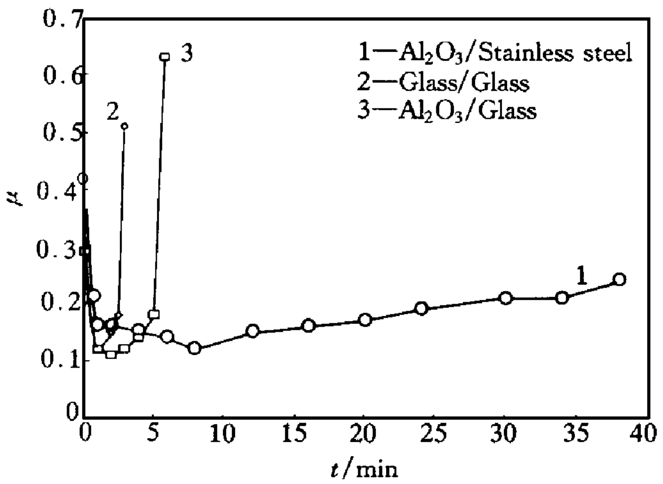

Fig. 3 Dependence of friction coefficient on time at 500 ℃

3. 2 Dependence of friction coefficient on temperature

The dependence of friction coefficient on temperature is shown in Fig. 4. Although the value of μ under different rubbing pairs have some differences, the tendency of variation of lubricating behavior of the copper rhenate *vs* temperature is similar, namely the value of μ is lower (0. 18 ~ 0. 21) from room temperature to 100 ℃; relatively higher (0. 38 ~ 0. 41) from 200 ℃ to 300 ℃; above 300 ℃, the friction decreases, and the value of μ is lowest (0. 13 ~ 0. 15) at 500 ℃, but above 500 ℃, the friction coefficient increases slowly.

In order to fully understand the lubricating behavior of it. TGA was carried out on the copper rhenate. the result in Fig. 5 shows that except a dehydration mass loss at 80 ~ 150 ℃, there exists an obvious mass loss from 510 ℃ to 730 ℃, which corresponds to the decomposition of the copper rhenate as follow:

$$Cu(ReO_4)_2 \longrightarrow Re_2O_7 \uparrow + CuO$$

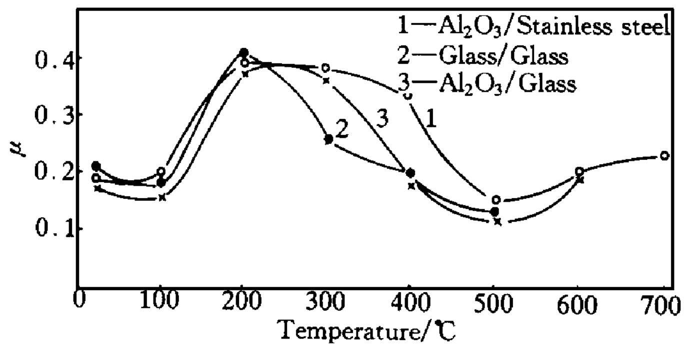

Fig. 4 Dependence of friction coefficient on temperature

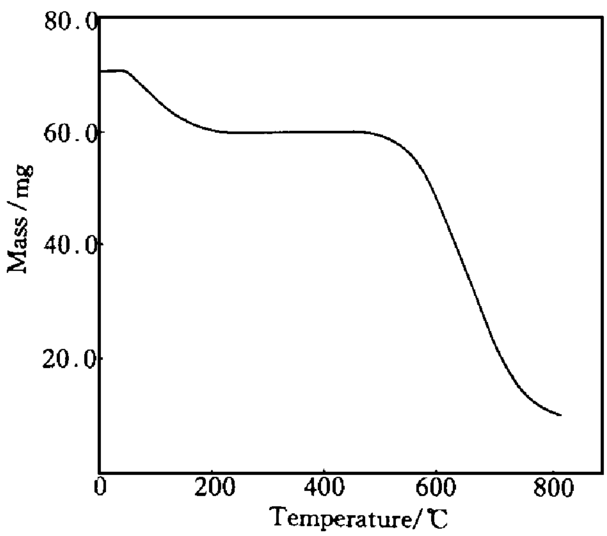

Fig. 5 TGA diagram of copper rhenate

The volatile Re_2O_7 is a soft oxide with good lubricating behavior. Because of the friction heat and the bad thermal conductivity of the glass disc, the real temperature on the wear track is far higher than the tested. Thus, the decomposition of the copper rhenate will be sped up and its lubricating role will disappear, which can be explained by curves 2 and 3 in Fig. 3. Because the surface of the Al_2O_3 ball is smoother than that of the glass ball and relatively thin film can play lubricating role, the service life of the lubricating film corresponding curve 3 is longer than that of curve 2. Curve 1 in Fig. 3 shows that the value of μ is still low under the rubbing pair of Al_2O_3/ stainless steel through a sliding time of 40 min. One reason is that the thermal conductivity of stainless steel is better than that of glass, and the temperature on the wear track of stainless steel is lower than that of glass. Accordingly the decomposition rate of the copper rhenate on stainless steel disc is also lower than that of on glass disc, the other reason is that the hardness of stainless steel is lower than that of glass and so the copper rhenate can embed and diffuse in stainless steel more easily and even has chemical reaction with stainless steel and produce other rhenum - containing with lubricating role.

According to the results of TGA and Fig. 4, it is clear that the copper rhenate has very good lubricating role, when it contains crystal water or is within the range of decomposition temperature. After the dehydration of it at 200 ~ 300 ℃, the value of μ increases a little but the oxide still has lubricating role. Because its melting point (640 ℃) is within its decomposition temperature, the $Cu(ReO_4)_2$ can be thought to have very good lubricating behavior at test temperatures near the melting point. The result agrees with a conclusion in Ref. 2 that oxide will still display good lubricating property when its melting temperature is within 200 ℃ of the test temperature.

4 CONCLUSIONS

(1) The copper rhenate dehydrates at 80~ 150 ℃ and decomposes from 510 ℃ to 730 ℃.

(2) The copper rhenate shows good lubricating property from room temperature to 700 ℃, expecially from 20 ~ 100 ℃ and from 400 ~ 700 ℃, its friction coefficient is about 0.15; under the rubbing pair of ceramic/ metal, it possesses long-term lubricating role at high temperatures.

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(Edited by Zhu Zhongguo)