Experimental Research on the Friction and Wear of the Rifling of the Gun

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Abstract

Based on the discriminance of the radial wear quantity of the rifling, this text carried out the pin-disc friction and wear test by using the pin sample made of PCrNiMo gun steel material and the disc sample made of the 96-brass band material, to simulate the engraving process of driving band into rifling. The effects of sliding speed and contact pressure on friction and wear properties of the pin pattern were systematically investigated. The wear appearance, the element of friction surfaces and the variation curve of microhardness of friction surfaces of pin samples were analyzed by scanning electron microscopy, energy dispersive spectrometer and microhardness tester. The influence of high speed and high temperature conditions on the friction coefficient, wear rate and the friction and wear mechanism of gun steel under high speed and high temperature conditions are discussed, which can provide reference for barrel design and artillery evaluation.

Keywords

Rifling; Sliding speed; Contact pressure; Friction coefficient; Wear rate.

1. Introduction

Rifling radial wear has been a lot of attention of gun ballistics and discussed in focus, according to the study, many problems appear wear ballistic gun and artillery rifle radial wear[1]. Moreover, the rifling radial wear the army is the main basis for determining the static artillery service life of [2], domestic and foreign experts on the gun tube life, will also be the rifling radial wear criterion as the research focus of [3-5]. Therefore, it is necessary to conduct an in-depth analysis on the radial wear of rifling.

For the further study of gun bore rifling friction and wear process, understand the projectile rifle radial wear quantity changes within the bore wear the most serious of the rifling starting in the test as the research object, on the basis of [6], a more comprehensive simulation test, analyze the law of friction and wear, lay a good foundation for further accurate determination of artillery service life.

2. Test equipment and method

2.1 Test equipment

In the process of high speed dry sliding friction and wear, a large amount of friction heat is produced, which causes heat accumulation on the friction surface and increases the friction surface temperature. In order to simulate the working conditions of high temperature and high speed, a new type of MMS-1G high temperature high speed pin plate friction and wear test machine is adopted in this paper. The maximum friction velocity of the test machine is 100m/s, the maximum load is 450N, the maximum friction torque of 20N.m can be measured in the test process, can realize the automatic loading and unloading, stepless speed, temperature and speed of the digital display. The diagram of high temperature and high speed friction and wear test machine is shown in figure 1:

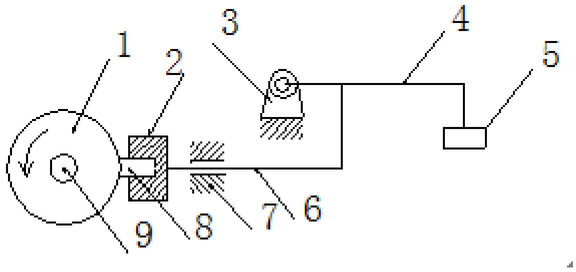

Fig. 1 Sketch of high temperature and high speed friction and wear test machine, 1- millstone, 2- sample rack, 3- hinge, call 4-, loading device, 5- counterweight, 6- transmission lever 7 fixing device 8 sample 9- power shaft

2.2 Test material.

2.2.1 pin test material

The specimen material used in our army is gun barrel material, and its main chemical components are as follows:Table 1.

Table 1. Chemical composition of pin material (wt %)

C	Si	Mn	P	S
0.36	0.28	0.32	0.008	0.002
Cr	Ni	Mo	V	Cu
1.28	3.14	0.38	0.28	0.11

2.2.2 mate material

The auxiliary material is made of our active duty band brass 96 brass material. The main ingredients are as follows:Table 2.

Table 2. Three Scheme comparing

Cu	Fe	Pb	Ni	Zn	total impurities
96.55	0.013	0.019	0.005	allowance	<0.2

2.3 Asd test scheme

The friction plate is made of brass material and made of friction plate and cannon steel. According to the principle of tribology, the simulation test should be as close as possible to the real situation. This experiment is to simulate the friction and wear between the gun barrel and the rocket belt copper, which is closer to the reality from the surface. The result shows that this scheme is feasible. All the tests in this paper are done under this scheme.

The test was carried out on a high speed and high temperature dry sliding friction and wear test machine. It was divided into two parts:

Test (a) contact pressure, sliding velocity, ambient temperature of the change of pin wear rate and friction coefficient, and the sliding speed, ambient temperature and friction coefficient, wear rate diagram.

Test (two) under certain conditions the sliding speed of the contact pressure, the temperature change of the surrounding medium, pin wear rate and friction coefficient, relationship between contact pressure, ambient temperature and friction coefficient, wear rate and draw.

The friction torque is measured by the friction torque sensor on the test machine, and the friction force F is calculated by the friction torque comparison arm. The friction coefficientμis calculated by the following formula.

$$\mu = \frac{F}{N} \tag{1}$$

In style: F is the friction force; N is the normal pressure applied to the pin sample.

The wear loss is obtained by measuring wear weight loss. The samples were washed and dried by alcohol before and after each test. The wear quality loss of pin samples was measured with an electronic analytical balance of 0.1mg, and the wear rate W was calculated according to the following formula:

$$W = \frac{\Delta W}{2\pi R t n \mu N} mg.(N.m)^{-1} \tag{2}$$

Its physical meaning is the amount of wear per unit friction work. In style: Δ W is wear quality loss(mg);R is the average radius of friction, The distance between the friction surface of the specimen and the center of the rotation axis of the disk specimen (m) ;t is the friction time (sec);n is the rotational speed of the disc sample(r/min);N is the normal pressure applied to the pin sample(N);μ is the coefficient of friction.

3 repeated tests were carried out under each working condition, and the average friction coefficient and wear rate were obtained from the 3 tests. Read the friction torque every 20 seconds.

3. test result

3.1 Influence of sliding speed on friction coefficient and wear rate

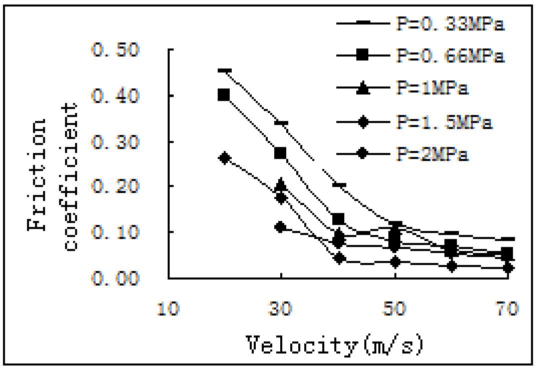

Fig. 2 Influence of sliding speed on friction coefficient

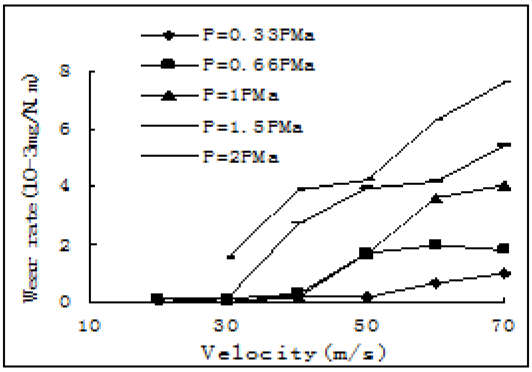

Fig. 3 Effect of sliding speed on wear rate

Fig. 2 is the variation curve of the friction coefficient of the test material with the sliding speed under different contact pressure conditions obtained under the test. It can be seen from the diagram that the friction coefficient decreases with the increase of sliding speed. Moreover, compared with the low load, the friction coefficient under high load are attenuated, but its stability than in the low load condition, the friction coefficient increases and decreases with the increase of contact pressure and its stability.

As can be seen from the test results shown in Fig. 3, when the sliding speed changes in a larger range, the wear rate increases with the increase of sliding speed. When the speed is less than or equal to 40m/s, the wear rate is very small, and the wear rate is not obvious with the increase of speed. When the speed is greater than 40m/s, the wear rate is higher, and the load is bigger, the trend of this increase is intense.

3.2 Influence of contact pressure on friction coefficient and wear rate

It can be seen from Figure 4 that the friction coefficient decreases with the increase of contact pressure in the test speed range. When the sliding speed is low, the increase of contact pressure, the friction coefficient decreased rapidly, the fluctuation range of the friction coefficient, the stability is relatively poor; but at higher sliding speed, increase the contact pressure of the friction coefficient changed from decreasing to relatively flat straight trend, the friction coefficient decreases not obviously, therefore, the fluctuation of the friction coefficient test material at high sliding speed is relatively small, the friction performance than the sliding speed under the condition of low stability, friction coefficient decreases.

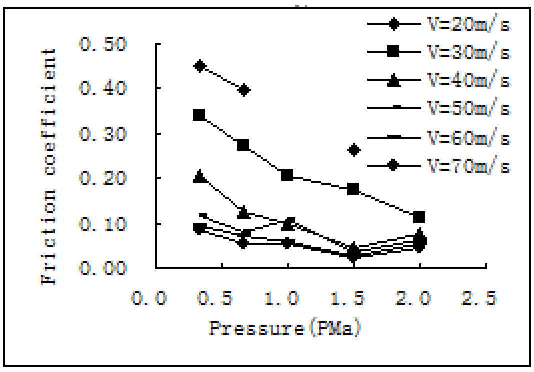

Fig. 4 Effect of pressure on friction coefficient

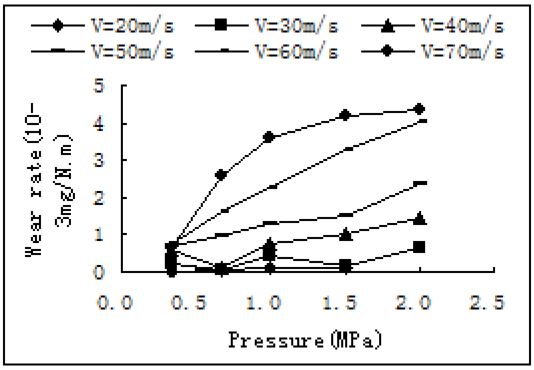

Fig. 5 Effect of pressure on wear rate

As can be seen from Figure 5, the wear rate of cannon steel specimens with the increase of contact pressure is basically a linear trend of increase, performance is very sensitive to the change of contact pressure, material bearing capacity is greatly reduced; with the increase of speed, the wear rate increases, and the increase trend, speed the greater the more significant increase.

4. Analysis and discussion

4.1 Effect of sliding speed

Can be seen from Figure 2, the increase of sliding speed will lead to a decrease in friction coefficient, friction coefficient fluctuation tends to be more stable, there is a definite relation between the macroscopic properties and the change of the friction surface microscopic features.

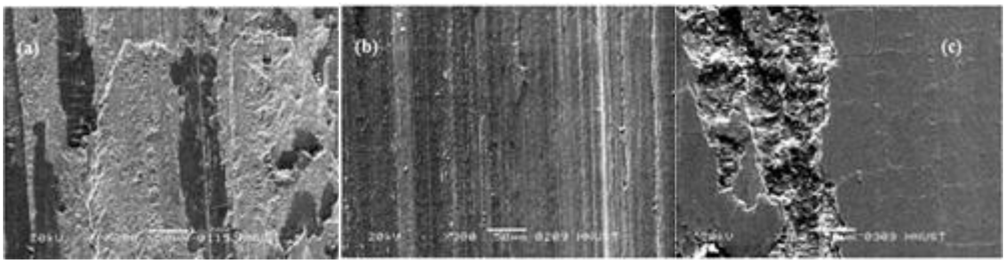

Fig. 6 SEM and EDS analysis of worn surface of pin sample

As shown in Figure 6 (a), when the sliding speed is 20m/s, the contact pressure is 2/3MPa, the metal transfer of friction on the contact surface, the friction surface is rough, which is formed due to the occurrence of adhesive contact at the contact point of plastic deformation. Contact grew up in the direction of movement and is cut off, then the formation of new contacts, new contacts and so on, the cut surface is covered with cut contact and transferring brass with adhesive wear.

As shown in Figure 6 (b), when the sliding speed is 40m/s, the contact pressure is 1MPa, for the same steel copper friction pairs, also found that copper transfer to the surface of steel pin up phenomenon, but there will be others, that is to reduce the amount of transfer and produce smaller debris and wear scar. The increase of velocity means that the friction work increases, the friction heat increases, the strength of the pin sample decreases, and a small amount of plastic deformation occurs on the surface

As shown in Figure 6 (c), with the friction was transformed into a large number of kinetic energy into heat energy, the plastic deformation increased, when the sliding speed to 70m/s, the contact pressure is 1MPa, much larger than kinetic energy into heat energy to low speed, in the process of friction, the friction surface temperature gradually increased. This will cause the plastic deformation of the matrix increases the friction surface to form a thin film, the friction coefficient decreased, while the pin surface hardness decreases, the surface of the spalling, resulting in a further increase in the rate of wear. The friction coefficient and wear rate coincide with the trend of velocity.

4.2 Influence of contact pressure

As shown in Figure 7 (a), we can see that when the load is 0.66MPa, the speed is 70m/s when in high speed condition, the friction of the surface because of repetitive mechanical and thermal stress, resulting in the emergence of pin low cycle thermal fatigue wear, the friction surface of pin specimens appeared above the surface crack crack, but the number is relatively small, and therefore less likely to flake. As shown in Figure 7 (b), with the increase of the contact pressure, the external environment of the friction energy input increases, resulting in friction friction heat generated increases, resulting in increased friction surface temperature, thermal stress intensifies, manifested in the surface of the specimen is increased crack pin number; as shown in Figure 7 (c), according to the theory of tribology, in high speed and high load condition, the friction sliding surface, the dislocation dislocation rarely, mainly concentrated in the surface layer at some distance away. The accumulation of a large number of dislocations will produce micro pores, these pores or because grow up or because the material shear and agglutination, resulting in wear and parallel to the surface of the crack, when the crack reaches the limit length of the material, with thin flap peeling off.

The theoretical analysis shows that: (1) the sliding speed and contact pressure have similar effects on the friction and wear properties of the steel copper pair, and the difference between them is only different. (2) under different speed and contact pressure, the influence of sliding speed and contact pressure on friction and wear properties is different.

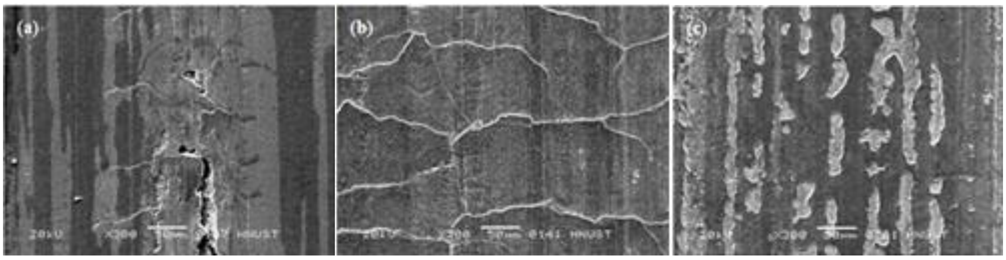

Fig. 7 SEM photos of worn surface of pin sample

5. Conclusion

Considering the engineering application background and a detailed investigation of the basis of high speed and high temperature tribological research status, this paper uses steel copper friction pairs as the research object, in the high-speed pin on disc wear tester for different parameters under the conditions of high speed dry sliding friction and wear test system to study the influences of friction and wear in high speed condition High Temperature Tribological characteristics. The effects of sliding speed and contact pressure on the friction and wear properties are analyzed. And EDX analysis of the pin friction surface using scanning electron microscope, mainly discusses the sliding speed and contact pressure on steel copper friction mechanism of friction and wear properties, friction and wear mechanism under different conditions, some useful conclusions are obtained.

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