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Effect of Temperature and Sliding Speed on the Adhesive Wear

A. Babilius*, P. Ambroza

Faculty of Mechanical Engineering, Kaunas University of Technology, Kęstučio 27, LT-3030 Kaunas, Lithuania

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Effect on the adhesive wear of the high speed steel P6M5 (HRC 62) and tungsten carbide coating (WC – 12 % Co) was investigated in the pair with tempered steel 45 (HB 200) in air environment. Sliding speed was changed from 0.3 m/s to 1.5 m/s and the load from 30 N to 150 N. The wear was also investigated at 20 °C, 200 °C, 300 °C, 400 °C, 500 °C and 600 °C temperatures at constant 90 N load and various sliding speeds.

The tungsten carbide coating was deposited by high velocity oxygen fuel gun. It was found out that wear rate of the WC – 12 % Co coating decreases when sliding speed is increasing from 0.3 m/s to 1.5 m/s. Wear rate of P6M5 steel is constant in the range of speeds 0.3 – 0.5 m/s and it changes in a small interval when the sliding speed increases from 1 m/s to 1.5 m/s and the load increases from 60 N to 150 N. Higher temperature and slower sliding speed result higher wear rate of WC – 12 % Co coating. Wear rate of the high speed steel P6M5 by increasing sliding speed and temperature decreases.

Increase of the sliding speed from 0.3 m/s to 1.5 m/s or increase of test temperature from 20 °C to 600 °C results decrease of the friction force.

Keywords: adhesive wear, high velocity oxygen fuel gun, friction force, tungsten carbide coating.

1. INTRODUCTION

There is a growing interest in oil, aircraft, textile, automobile and other industries to improve operating performance of machinery and to reduce the manufacturing costs. In many types of industrial machinery, surface damage, generated by sliding or abrasive contact, by aggressive environments, high temperatures and etc., limits the life of the component and therefore reduces durability and product reliability. This drives the development and implementation of intelligent surface coating that enable to improve the performance of engineering components.

Using of thermal spray processes for deposition these coatings have become an important part of modern industry, offering customized surface properties for a variety of industrial applications ranging from wear resistant coatings to erosion resistant coating for boiler tubes [1].

Thermal spray coatings are formed by the impact and solidification of a stream of molten or semi-molten particles on a surface. The process combines particle acceleration, heating, melting, spreading and solidification in a single operation. The family of thermal spray processes can be divided into individual processes by subdividing them by their energy source. Every thermal spray process uses thermal and kinetic energy to deposit a raw material on the surface of a component. There are five thermal spray processes which are designed to produce radically different amounts of thermal and kinetic energy: flame spray, electric arc, plasma spray, HVOF, and cold spray. The high velocity oxy-fuel process has demonstrated to be one of the most efficient techniques to deposit high performance coatings at moderate cost. A major advantage of this approach is that it can yield cermet based coatings having a lower level of porosity than other thermal spray processes [2, 3].

The main purpose of this study was to investigate WC – 12 % Co coating wear and friction force dependence on sliding speed at room temperature when load increases from 30 N to 150 N, and at temperatures from 20 °C to 600 °C, when the load is constant and equal to 90 N.

2. EXPERIMENTAL

This paper presents both high speed steel P6M5 (HRC 62) specimens and tungsten carbide WC – 12 % Co coating, deposited on the high speed steel P6M5 specimens by high velocity oxygen fuel gun (HVOF), wear and friction force results. Operation principle and spay parameters had been discussed in the previous papers [4, 5]. Thickness of the coating was 300 μm. During the spraying process the specimens were heated up to temperature 150 ºC. Temperature was measured with an appliance "Testo 860 – T2". Control specimens were made of tempered steel 45 (hardness 200 HB).

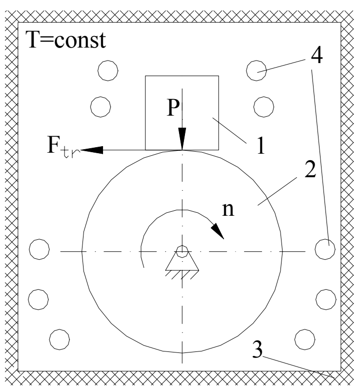


Fig. 1. Principal scheme of the wear machine: 1 – counter face 8 × 8 × 40 mm, 2 – turning specimen Ø15 × 15 mm, 3 – furnace, 4 – heating elements

*Corresponding author. Tel.: + 370-687-48719; fax:+ 370-37-324108.
E-mail address: *a.babilius@technologija.lt* (A. Babilius)

Wear rate and friction force tests were carried out on the wear machine. Principle scheme of the machine is shown in Figure 1 [6].

Before the test all specimens were washed by ethyl alcohol, to obtain clean surface and to ensure uniform test conditions. Wear rate was defined by use of analytical scales BLP – 200 after 2000 m way was made. Friction force was registered by an electronic recorder PDS 021.

Wear tests in this investigation were carried out at various conditions. Dependence of the wear rate and friction force on sliding speed was established at room temperature. Tests were carried out at following speed values: 0.3 m/s, 0.5 m/s, 1 m/s and 1.5 m/s. In any case effect of load on wear rate was investigated. The load had been increased in discrete steps between limit values 30 N and 150 N.

Wear rate was investigated at 20 ºC, 200 ºC, 300 ºC, 400 ºC, 500 ºC and 600 ºC temperatures at constant load 90 N as well.

3. RESULTS AND DISCUSIONS

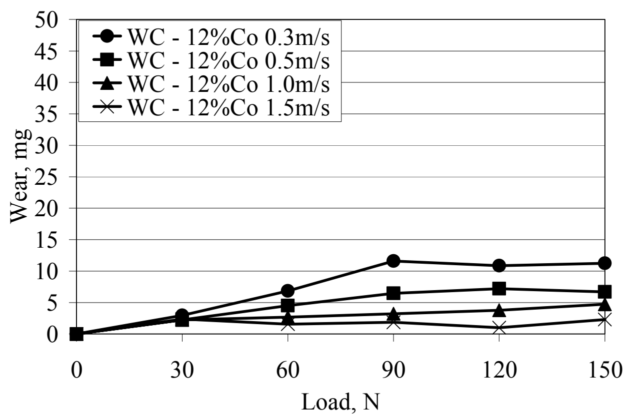
Relationship between wear rate and sliding speed for both WC – 12 % Co coating and high speed steel P6M5 at various loads and temperature 20 ºC is shown in Figure 2. Growth of sliding speed results decrease of the WC – 12 % Co coating wear rate (Fig. 2a). At sliding speed value equal to 1.5 m/s and load value 150 N wear obtained is 4 mg, but at sliding speed 0.3 m/s wear has increased up to 12 mg. Load increase resulted increase of wear as well. This allows us to conclude that wear of WC – 12 % Co coating is proportional to the load and sliding speed. The wear of steel P6M5 (Fig. 2b) is proportional to the load only at speed values 0.3 m/s and 0.5 m/s; at speed values 1 m/s and 1.5 m/s in the loads interval 60 – 150 N the wear changes in a small interval only.

Dependence of wear of both WC – 12 % Co coating and steel P6M5 on temperature is presented in Figure 3a. Here is the obvious trend that wear of WC – 12 % Co coating depends directly on sliding speed and also greater wear corresponds to higher temperatures.

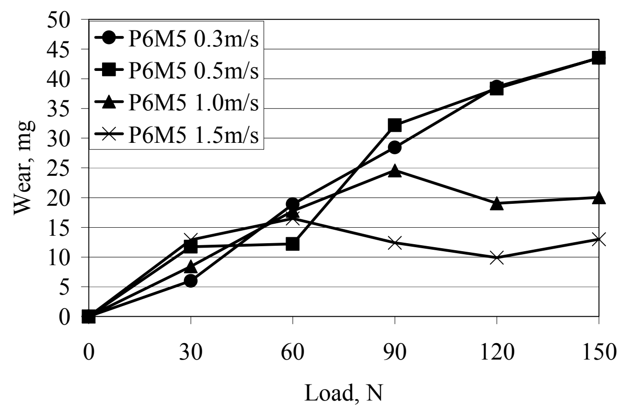
Wear character of steel P6M5 (Fig. 3b) differs from that of coating. When sliding speeds 0.3 m/s and 0.5 m/s increase of temperature results higher wear rate. At temperatures from 300 ºC to 500 ºC wear rate decreases. Further increase of the temperature up to 600 ºC results no noticeable change of wear rate.

At sliding speeds 1 m/s and 1.5 m/s wear character is different. Wear rate decreases in temperature interval 20 – 200 ºC, then at higher temperatures starts to increase and at 400 ºC it reaches the highest value.

Increase of temperature up to 500 ºC results reduction of wear rate; in temperature interval 500 – 600 ºC wear rate obtains constant value. At sliding speed 1.5 m/s and 500 ºC temperature wear of steel P6M5 is negligible. The trend

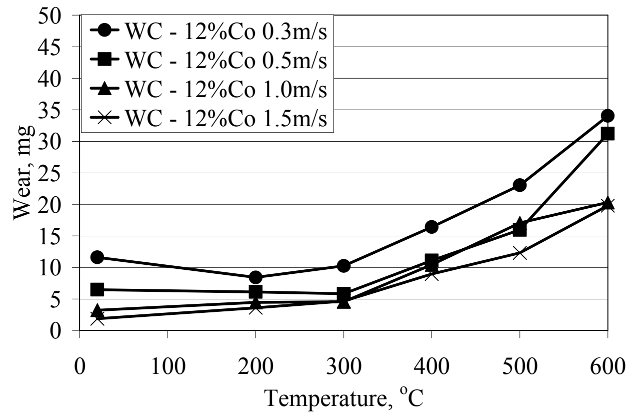


a



b

Fig. 2. Load influence on the wear rate of rotating specimen in pair with couterfase (steel 45) when temperature is 20 ºC and sliding distance was 2000 m. Rotating specimen: a – WC – 12 % Co coating; b – high speed steel P6M5



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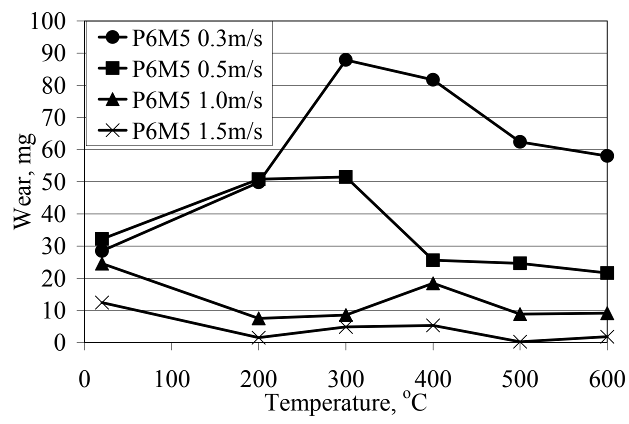

b

Fig. 3. Temperature influence on the wear rate of rotating specimen in pair with couterfase (steel 45) when sliding distance was 2000 m. Rotating specimen: a – WC – 12 % Co coating; b – high speed steel P6M5

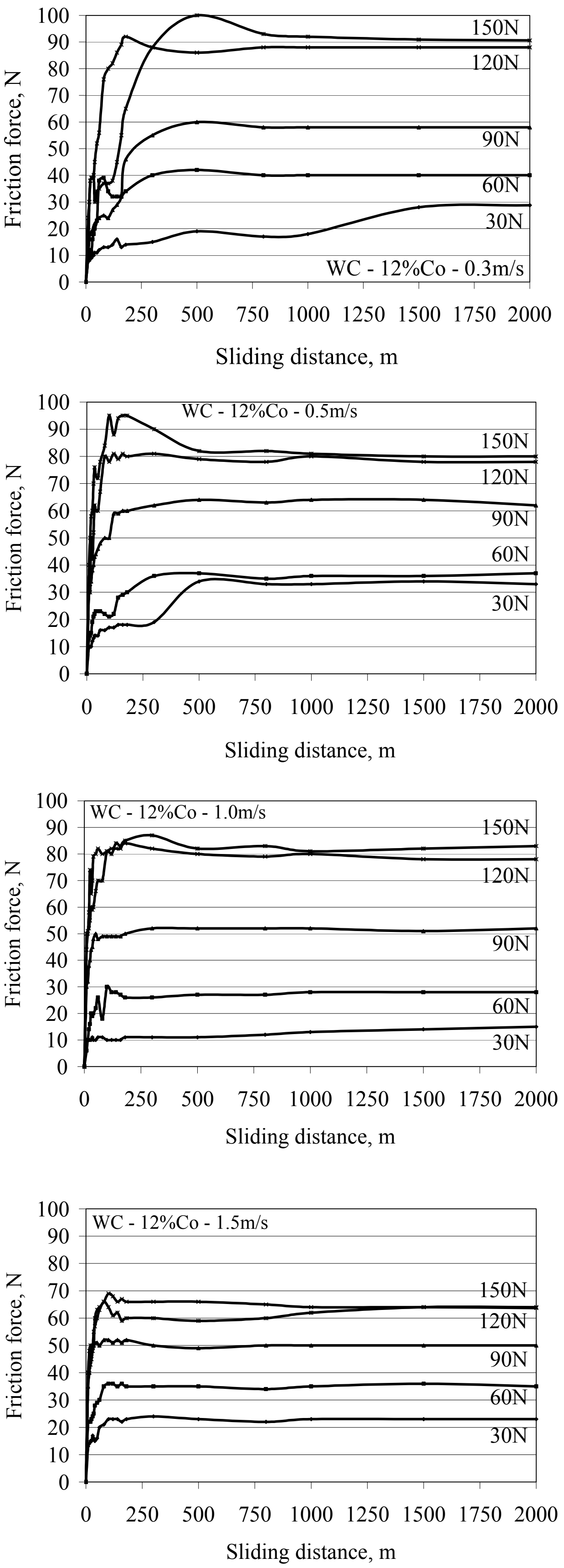

Fig. 4. Influence of load on the friction force of WC – 12 % Co coating in pair with couterfase (steel 45) when sliding speed was different and sliding distance was 2000 m

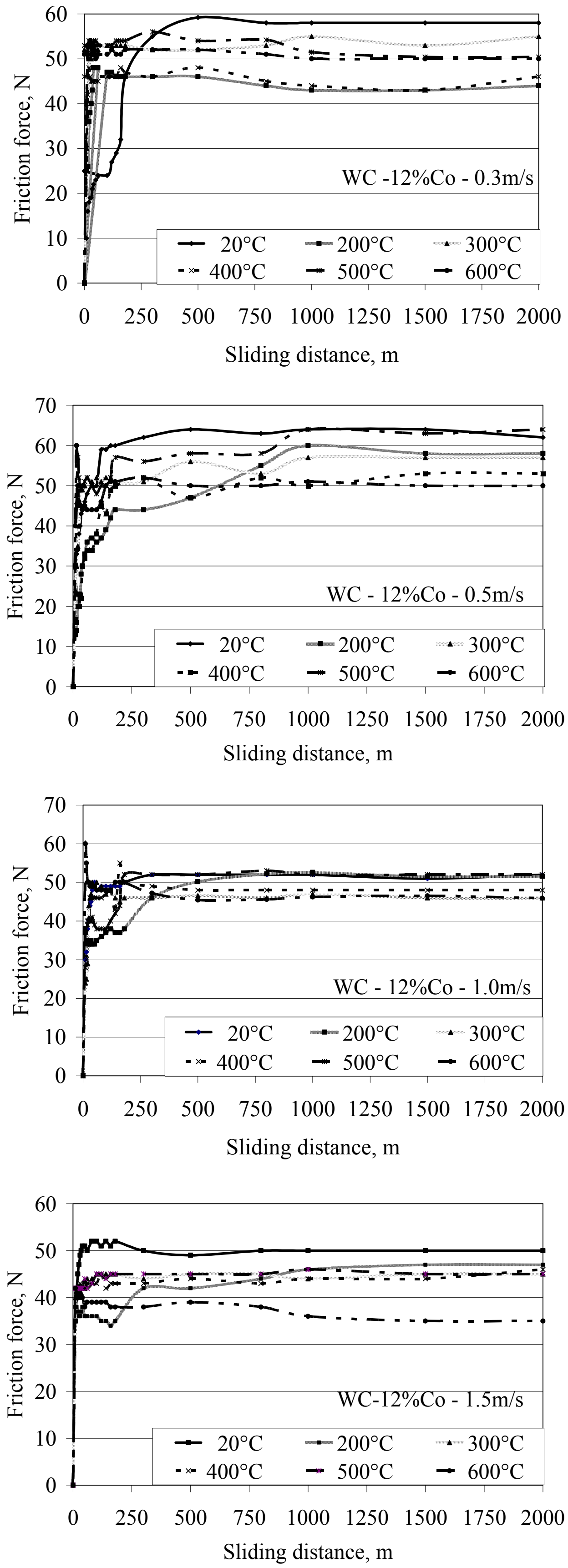

Fig. 5. Friction force dependence of WC – 12 % Co coating in pair with couterfase (steel 45) at different temperatures and sliding speed when load is constant and equal 90 N

that increase of sliding speed results reductions of wear rate is obvious.

Relationship between tungsten carbide coating friction force and both load and sliding speed at room temperature is shown in Figure 4. The graphs show that if sliding speed is increased from 0.3 m/s to 1.5 m/s friction force decreases. Increase of load from 30 N to 150 N results increase of friction force.

Figure 5 presents tungsten carbide coating friction force dependence on temperature at different sliding speeds. Friction force decreases when both temperature and sliding speed increase.

It is known that adhesive metal wear rate at elevated temperatures decreases due to the layer of oxides formed on the surface. This phenomenon is known an oxidative wear. According to the model proposed by Jiang [7] wear resistant oxides layer is formed in the following way: concentrated large particles of wear products fracture into small particles, oxidize, sinter and cover the wear surface. It may be concluded therefore that wear rate of high speed steel P6M5 decreases at elevated temperatures due to the oxides layer formation which results transfer from adhesive wear to oxidative wear.

4. CONCLUSIONS

Wear rate of WC – 12 % Co coating at temperature 20 ºC increases when sliding speed is decreased.

Wear rate of WC – 12 % Co coating increases when temperature is elevated from 20 ºC to 600 ºC and sliding speed is decreased.

Friction force of WC – 12 % Co coating reduces when sliding speed increased from 0.3 m/s to 1.5 m/s and temperature is elevated from 20 ºC to 600 ºC.

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