Effect of Various Sliding Speeds on Friction and Wear of Silver

Mubarak W. Al-Grafi

Mechanical Engineering Department, College of Engineering,Taibah University, P.O. Box. 344 Al Madina Al Munawara, Zip Code: 42353, KSA
dr.algrafi@gmail.com

Abstract: Silver has wide industrial applications in the area of electrical contacts and dental restorative materials. This paper evaluates the effect of speed on wear and friction coefficient of silver using block-on-ring machine with five different speeds (500, 600, 700, 800 and 900 rpm) at dry friction conditions. Other parameters (e.g., load, time etc.) that might affect the results were all kept constant. Experiments showed that the change in speed affected the wear rate significantly. Increasing the speed resulted in decreasing the wear rate and friction.
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1. Introduction

Tribology is a science of friction, wear and lubrication and deals with the study of interacting surfaces in motion. Tribology gives an insight into how a material will perform when subjected to sliding action with other materials. Silver is an important metal with usage ranging from dental restorative material to coatings in electrical contacts. Many researchers have performed studies to understand the response of silver under wear conditions.

In (Wibberley and Eyre 1969) demonstrated that recrystallization occurred in tough-pitch copper but not silver-bearing copper during dry sliding wear experiments. A pin on disc machine was used for all experiments carried out at constant sliding speed of 185 cm/sec. Silver reduced the mild-severed transition load and increased the wear rate in the severe region. The presence of silver decreased the load at which the mild-severe wear transition occurred.

In (Mueller, et al. 1985) cyclic wear tests with human enamel pins on rotating amalgam discs at 9.8 MPa contacting stress were conducted with Sybraloy, Cupralloy, Aristalloy C.R., and Minimax amalgams. Surface profile tracings were made across the wear tracks. Results indicated that Minimax exhibited the greatest wear depth for all amalgams but Sybraloy showed the greatest wear for the higher copper-containing amalgams. A hardened stainless steel pin, which did not wear, generated amalgam wear tracks of a similar appearance to that generated from enamel.

The use of a pin-on-disc configuration for investigating the wear mechanism or behaviour of solid materials was examined in (So 1996). The results between the arrangements of the rotating pin and stationary pin under the same load and speed were different. The bulk temperatures of the rubbing specimens increased with the duration of testing, which eventually arrived at a steady state. However, before the wear condition reached the steady state, it varied continuously. The friction coefficient increased with sliding speed when the applied load on the rubbing specimens was over certain levels. All these contradictions were explained with the accurate prediction of bulk and flash temperatures at the contact area. The work provided a more reasonable method for the calculation of temperatures and the real and apparent contact areas.

The feasibility of a new moving pin technique for pin-on-disc wear testing which is more efficient and able to fully utilize the disc surface area in the wear testing process was evaluated in (Yang 1999). The experiments were carried out on a CNC lathe with a G96 constant speed. Sandvik grade S6 tungsten carbide inserts were used as pins and three types of disk materials were employed. The wear rate and the wear coefficient of the inserts were determined. It was found that wear rate and the wear coefficient of tungsten carbide varied from 1.07×10^{-7} to 0.18×10^{-7} mm^3/mm and 1.09×10^{-6} to 0.58×10^{-6} respectively. The wear coefficient was again found to be a better parameter for comparing the wear of tungsten carbide inserts and the results obtained from the new moving pin testing technique were found to be more consistent.

Effect on the adhesive wear on the high speed steel P6M5 and tungsten carbide coating was investigated in the pair with tempered steel 45 in air environment in (Babilius and Ambroza 2003). Sliding speed was changed from 0.3 m/s to 1.5 m/s and the load from 30N to 150N. The wear was also investigated at 20°C, 200°C, 300°C, 400°C, 500°C and 600°C temperatures at a constant 90N load and various sliding speeds. It was concluded that the wear rate of WC-12% Co coating at temperature 20°C increased when sliding speed was decreased. Whereas it was increased when the temperature was evaluated from 20°C to 600°C and sliding speed was decreased. Friction force for the same coating reduced when sliding speed increased from 0.3m/s to 1.5m/s and temperature was elevated from 20°C to 600°C.

Sliding wear behaviour of Ni-based composites, prepared by powder metallurgy route and containing different amounts of silver was investigated under different loads and speed in (Tyagi, et al. 2011) by conducting wear tests against a counterface of AISI 52100 ring using a ring-on-disk setup. One composite containing 12 wt.% silver and 4 wt.% h-Bn was also prepared and tested under same conditions to investigate the synergic action of Ag and h-Bn. The friction coefficient and the wear rates were significantly reduced by addition of solid lubricants whereas the reduction was 3-5 times in the wear rates. The friction coefficients of composites decreased with increasing load and sliding speed whereas the wear rates increased marginally. No noticeable synergy was observed between silver and h-Bn because h-Bn failed to form strongly adherent transfer film on counterface surface.

In (Ameen, et al. 2011), analysis was performed on the wear rate for different materials (Steel, Aluminium and Brass) under the effect of sliding speed, time and different loads, where the apparatus pin-on-disc was used to study the specification of the adhesion wear. The experiments were performed on a group of specimens under different cases of times of 5 to 30 minutes and under different loads 0.5 to 2 kg and different speeds 2.5 to 9 m/sec. A mathematical model was developed for all cases that were studied depending on the methods of least square which helped in foretelling about the wear rate through the knowledge of time limits as a variable with fixing other variables; also building a model with the same method by which foretelling the rate of adhesive wear through knowing the sliding speed as a variable after fixing the other variables. From the results it was clear that the cracks which were vertical to the direction of sliding and were met together with the lines of weariness, and the results showed that the rate of adhesion wear were in direct proportionality with time, sliding speed and load. The low carbon steel had the least wear compared to the other materials.

The effect of load and speed on sliding friction coefficient and performance tribology of aluminium-silicon casting alloys was evaluated using a pin-on-disc with three different loads and three speeds in (Al-Samarai, et al. 2012). Factors and conditions that had significant effect were identified. Experiments showed that the load and speed affect the coefficient of friction and wear rate of the alloy. The results showed that the wear rate increased with increasing load and decreased with increasing the sliding distance, whereas the friction coefficient decreased with increasing sliding speed before a stable state was reached. The friction coefficient also decreased with increasing load.

A possibility of improving the sliding wear behaviour or silver/diamond electroplated dispersion coatings was presented in (Rigou, et al. 2012). A certain amount of diamond microparticles was added as suspension to the plating silver bath in order to improve the poor wear resistance of silver. The sliding wear resistance of the obtained surfaces was determined using a pin-on-disc wear tester. The results demonstrated that the highest wear resistance was achieved by addition of the finest diamond particles into the silver plating bath.

In (Bortoleto, et al. 2013), a computational study based on the linear Archard's wear law and finite element modelling was presented in order to analyse unlubricated sliding wear observed in typical pin-on-disc tests. Finite element software Abaqus® with 3D deformable geometries and elastic-plastic material behaviour for the contact surface was developed. The work presented experimental pin-on-disc tests with AISI 4140 pins on rotating AISI H13 discs with normal loads of 10, 35, 70, and 140 N, which represented mild, transition and severed wear regimes, at sliding speed of 0.1 m/s. Numerical and experimental results were compared in terms of wear rate and friction coefficient. The applied numerical formulation showed to be more appropriate to predict mild wear regime than severe regime, especially due to the shorter running-in period observed in lower loads that characterized that kind of regime.

Experimental Procedure:

TE 53SLIM multi-purpose friction and wear tester by PLINT Tribology Products was used to perform the wear studies (Figure 1). The machine was capable of performing a block-on-ring test in which a test block is loaded in the specimen mounting head against a test ring that rotates at a given speed for a specified number of revolutions (Figure 2). The friction force required to keep the block in place is continuously measured during the test with a load cell. This date can be converted to coefficient of friction values. This is important to mention that the TE 53SLIM friction and wear tester performed test conferring to procedures designated under ASTM G 77 and ISO/DIS 7148-2.

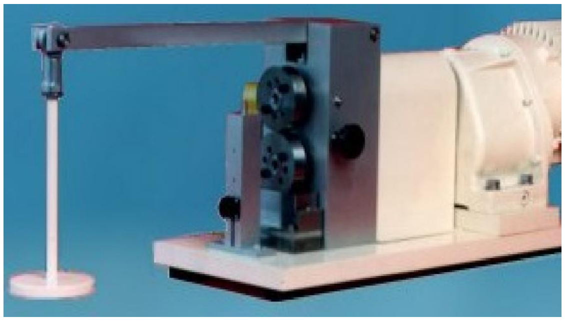

Figure 1: Block-on-ring machine

All the samples for the test were prepared as per the manufacturer guidelines as described in the product manual. Test samples of 12.7mm cube were prepared for each sample. A total of 1.2 kg was applied at the end of lever arm. The tare load due to the lever arm was 42 N, which implied that:

Contact load = 42 N + [5 X (applied load)]

From the above equation, the applied load of 1.2 kg corresponded to a contact load of approx. 101N. The test speed was varied from 500 rpm to a final value of 900 rpm at an increment of 100 rpm and the test was run of 10 minutes for each speed.

Figure 2: Placement of test sample inside the placement block

Results and Discussion:

The variation in wear (µm) with the change in speed is presented in Figure 3. The curves present various speeds. It's apparent from the figure that the wear depth drops with the increase in speed. The results presented is in good agreement with the studies performed in (Al-Samarai, et al. 2012). The reduction in wear is approximately in direct proportionality to the speed. Figure 4 illustrates the effect of sliding speed on the wear depth under a constant load at two different times (250 and 500 sec). It can be seen that the values of wear depth decreases with increasing the sliding speed. This is could be explained as due to the influence of stick-slip effects at the tribo- pair contact surfaces.

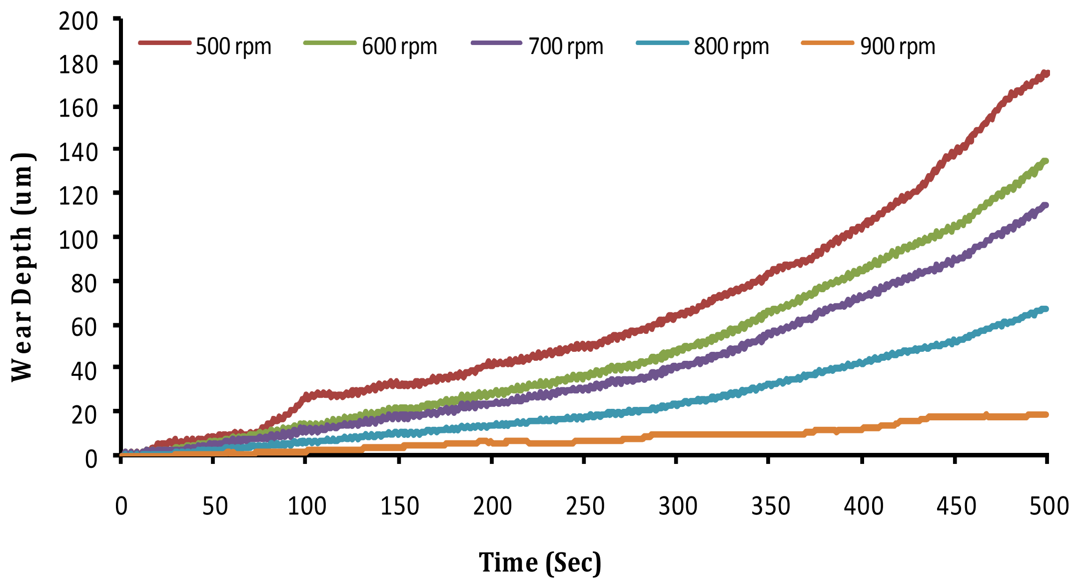

Figure 3: Variation of wear depth - running time at different sliding speeds (constant applied load 101 N)

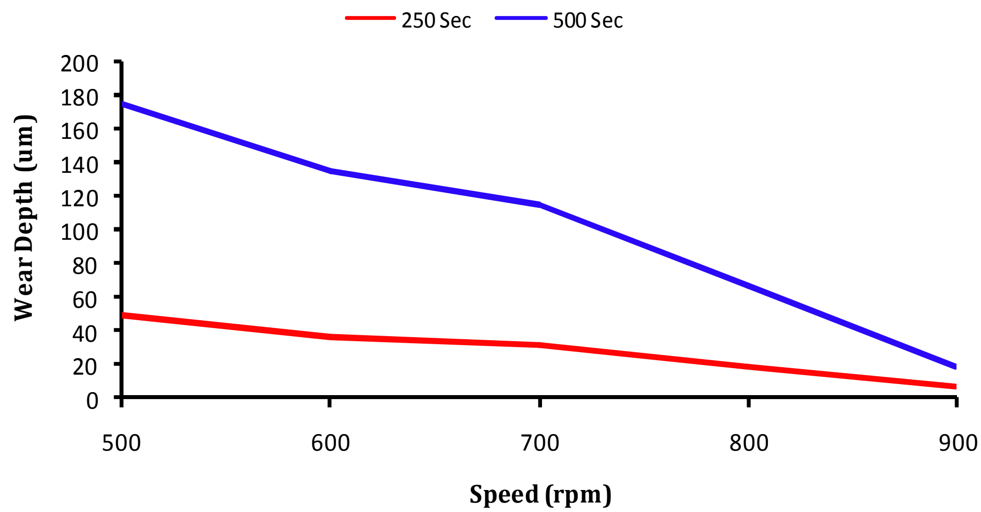

Figure 4 Effect of speed on wear depth (µm) at a constant applied load (101 N)

The effect of increasing speed on the friction force (N) for Silver is presented in Figures 5. Increase in speed had resulted in reducing the friction force. With the increase in speed, temperature and an initial wear resulted in creating a solid thin layer of silver on the rubbing wheel. This acted as a solid lubricant and had thus reduced the friction. The drop in friction is significant when the speed changed from 500 rpm to 600 rpm and to 700 rpm, but the effect is not much prominent when the speed is further increased to 800 rpm and 900 rpm. The temperature rise in case of wear experiments conducted increased to a certain stage, where it became steady and this is the reason that increasing the speed from 700 to 800 and then 900 did not affected the friction much as the temperature was at the top steady limit during these experiments. Friction coefficients against various sliding speed at two instants of time (250 and 500 sec) are extracted and illustrated in Figure 6. This shows that the friction coefficients (µ) decrease as the speed increases maintaining constant values after attaining speed of 650 rpm.

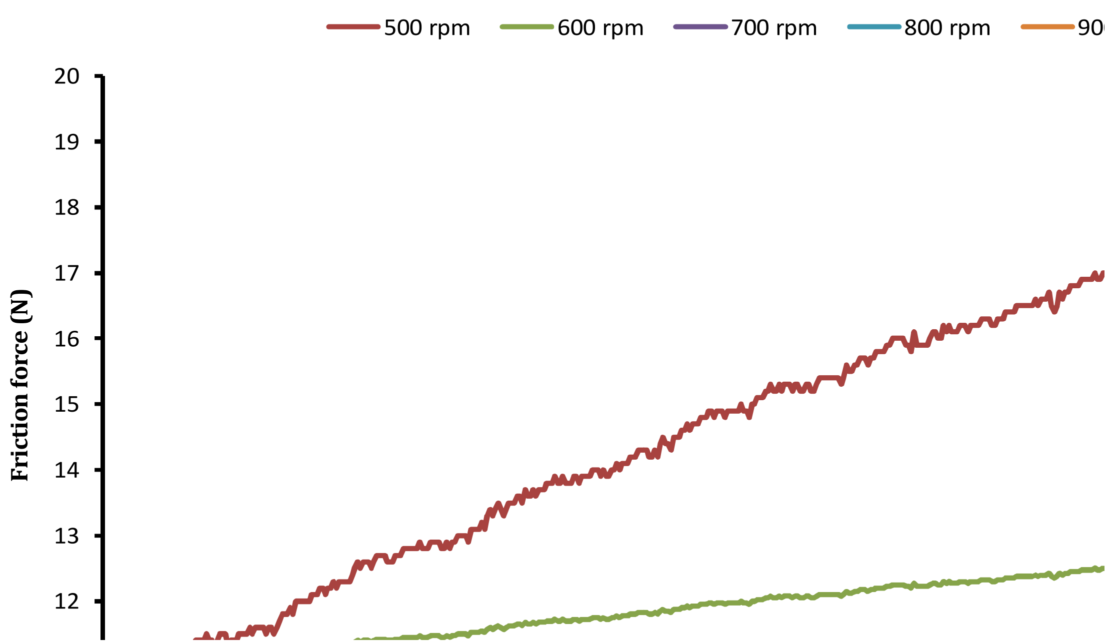

Figure 5: Friction force as a function of running time under a constant applied load of 101N.

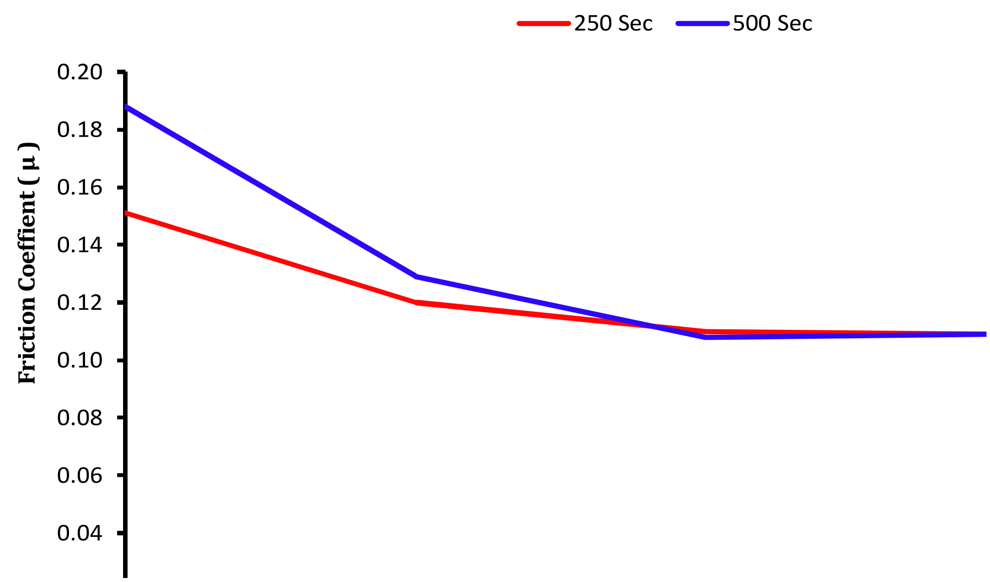

Figure 6: Coefficient of friction against sliding speed at a constant applied load (101 N).

Conclusion:

This paper presented the effect of speed on wear and friction coefficient of silver using pin-on-disc with five different speeds (500, 600, 700, 800 and 900 rpm) at dry conditions. Other parameters (e.g., load, time etc.) that might affect the results were all kept constant.

- Experiments showed that the change in speed affected the wear rate significantly.
- Increasing the speed from 500 rpm to 600 rpm affected the friction significantly but as the speed was further increased, the affect was not prominent.

Corresponding Author:
Mubarak W. Al-Grafi
Mechanical Engineering Department, College of Engineering, Taibah University, P.O. Box. 344 Al Madina Al Munawara, Zip Code: 42353, KSA,
Tel: +966500129029, FAX: +966 143905018. E-mail: dr.algrafi@gmail.com.

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