

Examining The Effect Of Different Material Surface Morphology On The Development Of Transfer Layers In Lubricated Environments At Inclination Angle Of 1.0 And 1.5 Degrees.

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ABSTRACT :

Metal is cold-and hot-formed to make technical parts in the industrial sector. The condition of the dies used in these manufacturing procedures is one of the factors that establish the surface quality of engineering components. Tribological activities at the die-component contact have a significant impact on the surface finish of engineering components. The surface finish of the products is affected by lubrication, the form of the die, and the hardness of the die surface. This study used a pin-on-plate sliding tester to determine how surface shape, lubrication, and hardness impact the tribological behavior-defining coefficient of friction and transfer layer transfer. The morphology of mild steel (EN8) plate surfaces was altered using three separate surface modification techniques: shot blasting, electric discharge machining, and grinding (silicon carbide wheel polishing). The surface roughness parameters that characterize the morphology of the steel plates were measured using a three-dimensional optical profilometer. We probe the function of hardness by pushing lead, copper, and aluminum (Al6082) pins over steel plates. The studies were conducted using plate inclination angles of 1, 1.5, 2, and 2.5 degrees. Throughout the trials, the standard load was varied between 1 and 150N. The trials were conducted in a lubricated, ambient environment. Surfaces of plates and pins were studied for the formation of transfer layers using a scanning electron microscope. It was shown that the contour of the lubricated harder surface influenced both the friction coefficient and the formation of the transfer layer. The formation of transfer layers on surfaces is seen to grow as the surface roughness rises.

Keywords: Surface Morphology, Transfer Layers, Lubricated Environments, Tribological Behaviour, coefficient of friction.

1. INTRODUCTION

In engineering, a complete understanding of what happens at the contacting surface between two components is necessary due to the high levels of force, heat, and electrical transmission that occur there. In an effort to put the behavior at the interface into a scientific framework, several experiments have been conducted. Their research has shown that, contrary to popular belief, the actual area of touch is less than the perceived area of contact [1-4]. Additionally, they discovered that, on a microscopic scale, the

contacting surface is not smooth but rather has asperities. The real area of contact is less than the apparent area of touch, which causes a great deal of friction. Although the design stresses were greater than the projected engineering stresses based on apparent area of contact [2], the actual stressors were higher than the yield stresses of the material, leading to elastic, plastic deformation, and fracture at the interface. In other cases, asperities on the surfaces make it impossible to create contact. For the purpose of stress estimation at contact interfaces, all research use Hertzian contact theory, which has several potential applications to non-conforming surfaces [3]. The underlying assumptions of Mindlin's sliding contact solution are that shear stress at contact surfaces is proportional to normal stress and that the coefficient of friction between two interacting faces is equal to the proportionality constant. To confirm Amontons' rule while considering surface asperity elastic deformation, Archard [6] made an effort. Although the Amontons' rule defies explanation by a single asperity's elastic deformation, it may be described for confirming surfaces by the combined effects of several asperities. For a greased surface, the results are similar. For situations involving several contacts, Greenwood [7] and colleagues used Hertzian contact theory to assess stresses and deformation at the contact surface. In other words, the inelastic contact phenomena at interfaces remained unexplained by these methods, despite their best efforts. These ideas were applied to electrical contact and frictional difficulties by Bowden and Tabor [8]. Using a caterpillar disc tester, Staph [9] investigated how surface roughness and texture affected scuffing. Additionally, attempts to comprehend the extrudate's surface smoothness and tolerance throughout the extrusion process often amounted to contact issues. After at least three extrusion trials, the finish was found to be enhanced, according to studies on the subject [10]. A better surface finish was achieved by using a lower quantity of choke angle. Periodic variations in the thickness of the transfer layer were determined to be the cause of the observed periodic variations in surface finish. Apparently, nitrating and sintering the surfaces of both polished and parallel ground dye produced the best surface. [11]. Wear under pressures ranging from 50 gm to 10 kg and speeds of 2 to 60 cm/s was investigated by Archard and Hirst [12]. There was an assumption that the wear rate would be directly proportional to the load, but in reality, the surface conditions are load dependent, thus this straightforward connection is not always true. Using a tension bending test, Azushima and Sakuramoto [13] investigated the tribological behavior of the die and work piece in the presence of lubricant. They discovered that, at lower average contact pressures, the asperities flattened with a decrease in coefficient of friction, whereas at higher average contact pressures, surface roughening was predominant. To estimate the adhesion and abrasion friction coefficients, Koura [14] created a theoretical model that included surface roughness. Frictional values are sensitive to surface roughness, as seen by the data. In order to verify Amontons' law, Whitehead [15] tested it on several materials. When testing on electrolytically polished copper surfaces, it was discovered that, at light loads, the sliding did not follow Amontons' law. The creation of an oxide layer was thought to be the cause of the divergence of Amontons' law. Conditional on lubrication, experiments were also carried out. The findings of the tests did not generally support Amontons' rule, but the results of the dry sliding experiment did. In order to grasp the fundamentals of wear, Kerridge and Lancaster [16] performed a severe kind of wear. Conditions produced metallic debris when the system pitted brass against a tougher material component.

Two separate stages of wear were identified. They included the movement of materials and the accumulation of waste in the transfer layer. At first, a model was created by Nellesmann and Bay [17] to account for the effects of normal load, asperities slope, friction factor, and lubricant bulk modulus on friction and absolute area of contact. According to the findings, the only factors that matter are normal pressure and bulk modulus. In order to predict the surface roughness of the product under lubricated circumstances, Theng-Sheng Yang [18] developed a unique model. Our model better predicted the surface in the case of lubricated sheet metal forming. To identify the cause of continuous sliding, Rigney and Hirth [19] developed a model. This idea is based on the plastic deformation at the surface or very close to it. The model successfully anticipated the link between microstructure, surface temperature, sliding distance, friction, and load. A new theory put forward by Suh and Sin [20] sought to account for friction by taking the environment and sliding distance into account. Mechanical properties, such as hardness, are more important than relative solubility in determining the compatibility of a sliding surface, as the theory goes.

2. OPERATING PROCEDURE

Figure 1 illustrates how lead, copper, and aluminum (Al 6082), which are softer than mild steel (EN8), are machined into the form of a pin. Figure 2 displays the dimensions of the machined EN8 steel in plate form. Every measurement is in mm.

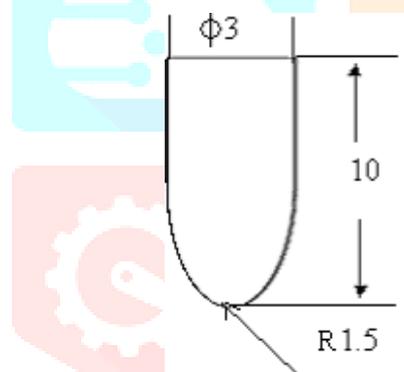


Fig.1. Dimensions of pin

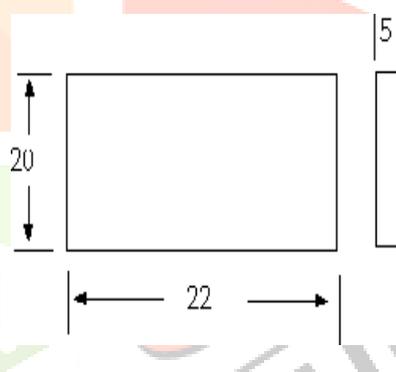


Fig. 2. Dimensions of Mild Steel (EN8) Plate

Electric discharge machining (EDM), sandblasting, and grinding (Silicon Carbide wheel polishing) were the three production procedures that were used to modify the EN8 flat surfaces. A non-contact type three-dimensional optical profilometer was used to examine the surfaces of these altered plates. Every surface had its average surface roughness metric, R_a , recorded.

R_a , the average surface roughness value, was determined to be $0.17 \mu\text{m}$ for ground (Silicon Carbide wheel polished) surfaces, $5.90 \mu\text{m}$ for sand blast surfaces, and $7.84 \mu\text{m}$ for electric discharge machined (EDM) surfaces. R_a of the electric discharge machined surface was largest and R_a of the ground (Silicon Carbide wheel polished) surface was smallest. It was discovered that all three surfaces were dominated by peaks.

To remove any work-hardened coatings that could have developed, the pins were electropolished. A solution of water and soap was used to wash the steel plates and pins before every experiment. The next step was to use an ultrasonic cleaner and acetone to clean the plates and pins.

An inclined Scratch tester, which is also known as a pin-on-plate sliding tester, was used to perform

the trials. It was also used to determine how load affected the friction coefficient. Figure 3 is a schematic depicting the pin and inclined plate.

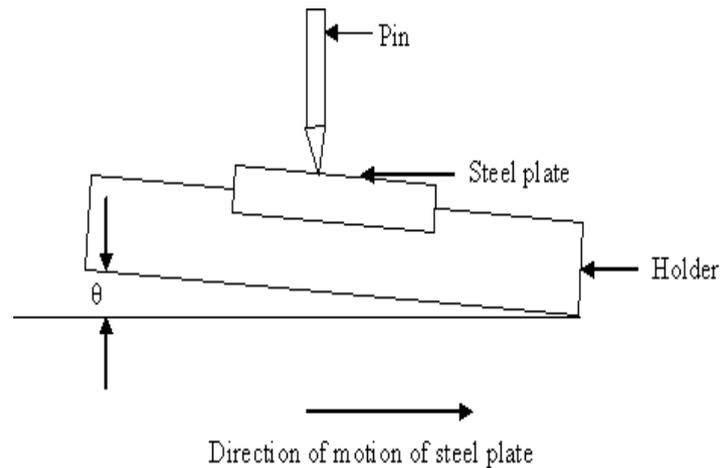


Fig .3: Schematic diagram of Pin on Plate with Inclined steel plate.

The cleaned pins were slid at a velocity across a distance of about 10 mm against the cleaned, lubricated EN8 steel plates from the lower to the top end of the inclined surface. A computerized data collection system was used to continuously monitor shear and normal forces. During the examination, the standard load was modified between 1 and 150N. The coefficient of friction (μ), defined as the ratio of shear force (T) to normal force (N), was calculated using the formula based on the measured forces.

$$\mu = \frac{T}{N} = \frac{F_T \cos\theta - F_N \sin\theta}{F_T \sin\theta + F_N \cos\theta}$$

Experiments were performed for various parameters under lubricated conditions. The metrics included surface roughness (R_a), pin hardness, and plate inclination angle (θ). The pins used were composed of lead, copper, and aluminum. The surface roughness was defined by R_a . The plate inclination angles were 1, 1.5, 2, and 2.5 degrees. Sliding tests were performed under lubricated circumstances for each parameter on each plate in an ambient atmosphere. 0.05 cc of engine oil lubricant (SAE 40, API rating SJ class) was applied to the steel surface, and tests were conducted. The viscosity of the lubricating oil was measured at 40 cSt at 40 degrees Celsius. Tests were done for various surface roughness levels under lubricated conditions at each inclination angle. Experiments were conducted to generate five parallel lubricated wear tracks on the same plate for each angle of inclination. Following the experiment, the pins and EN8 flat surface were analyzed using a scanning electron microscope (SEM) to investigate the origin of the transfer layer and its correlation with the estimated friction coefficient.

3. RESULTS AND DISCUSSION

Lubricated circumstances were taken into consideration when calculating the average coefficient of friction. Figures 4 (a), (b), and (c) exhibit this dependency on the angle of plate inclination when lead, copper, and aluminum pins were slid against shot-blasted and electric discharge machined steel surfaces that were polished with silicon carbide. These pins were used to polish the steel surfaces.

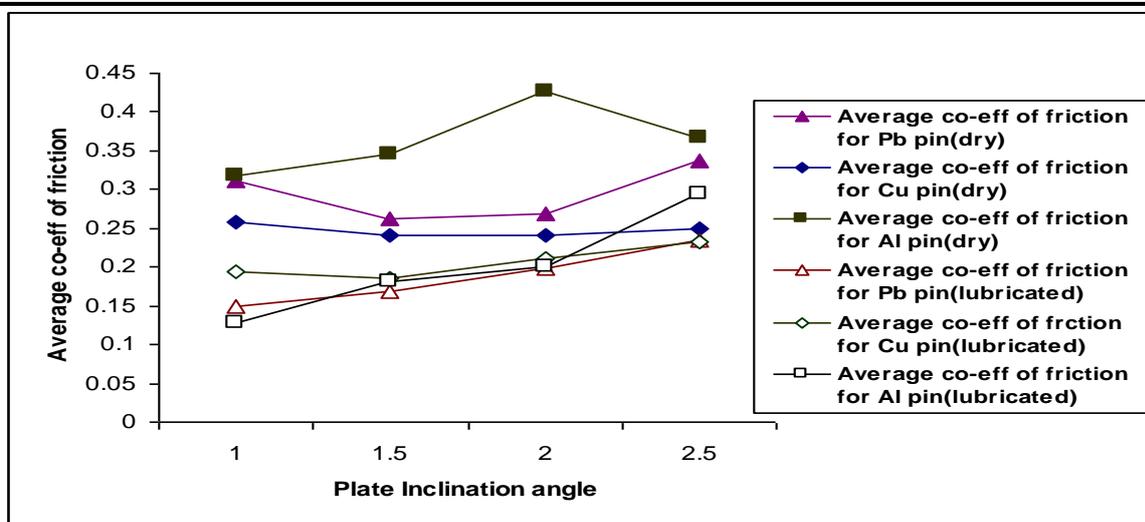


Fig. 4(a): Average co-efficient of friction with plate inclination angle when Pb, Cu and Al pins slid on ground (SiC) steel surfaces.

When slid on ground (SiC) steel surfaces, it was revealed that the average coefficient of friction under dry circumstances did not vary considerably with plate inclination angle, with the exception of aluminum at an angle of 1 degree, for the different pin materials indicated in figure 4(a). This was the case for all of the pin materials. On the other hand, the coefficient of friction of the aluminum pin was found to be greater at an inclination angle of two degrees when compared to other surface inclination angles. For the various pin materials indicated in figure 4(a), it was discovered that the average coefficient of friction under lubricated conditions did not change much with plate inclination angle when the pins were moved on ground (SiC) steel surfaces. The only exception to this was aluminum, which had a coefficient of friction of 1.5 degrees. It was discovered that the coefficient of friction for an aluminum pin at an inclination angle of 1.5 degrees was higher than the coefficient of friction for other surfaces at other inclination angles.

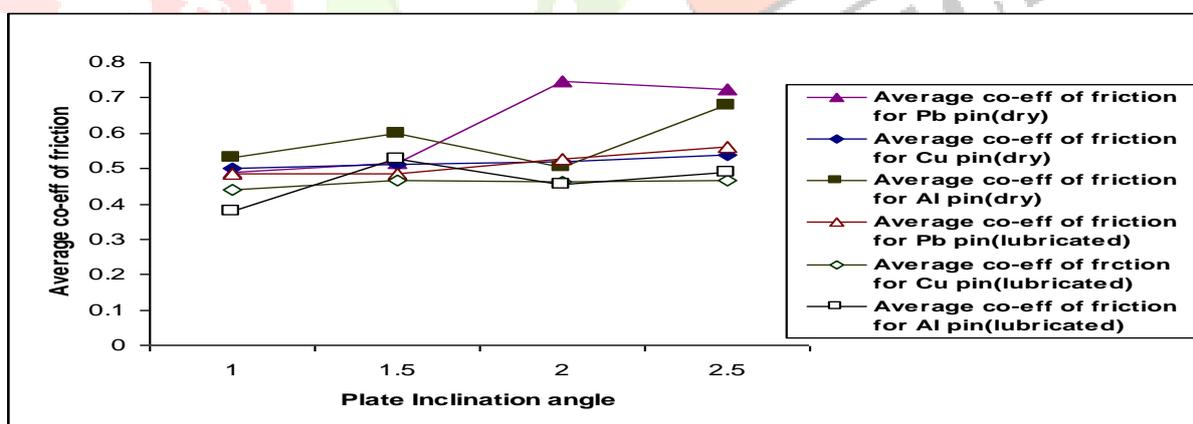


Fig. 4(b): Average co-efficient of friction with plate inclination angle when Pb, Cu and Al pins slid on shot blast steel surfaces

The average coefficient of friction under dry conditions in the case of sand blast surfaces, which is shown in figure 4(b), was also found to not vary much with plate inclination angle, with the exception of a small fluctuation in the average value of the coefficient of friction for lead pin at an inclination angle of 1.0 and 1.5 degrees. This was similar to the findings for ground (SiC) steel surfaces.

The average coefficient of friction under lubricated conditions in the case of sand blast surfaces, which is shown in figure 4(b), was also found to not vary much with plate inclination angle, with the exception of a small fluctuation in the average coefficient of friction value for aluminum pin at an inclination angle of 1.5 degrees. This was similar to the situation with ground (SiC) steel surfaces.

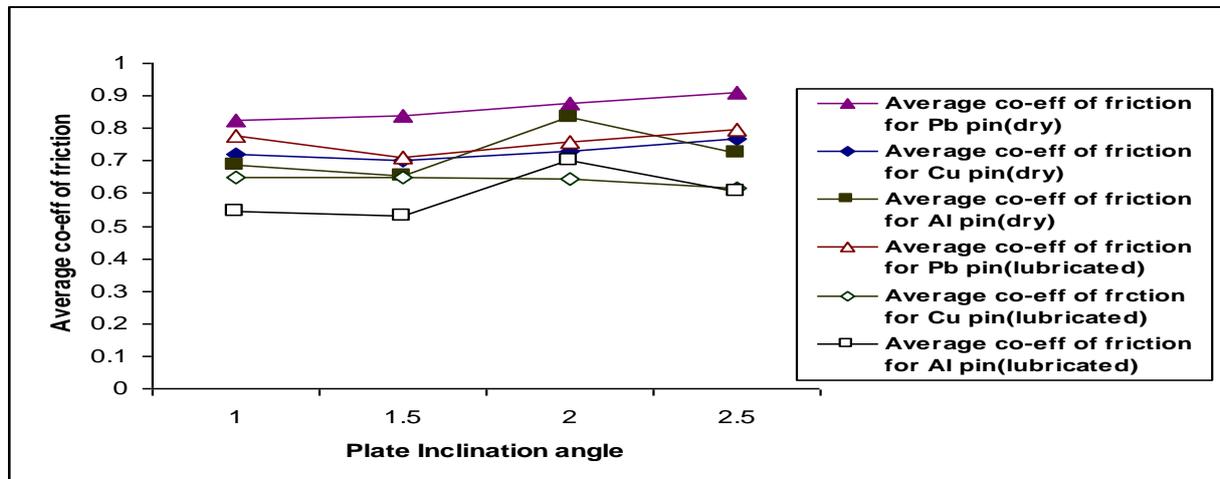


Fig. 4(c): Average co-efficient of friction with plate inclination angle when Pb, Cu and Al pins slid on electric discharge machined steel surfaces.

As is the case with ground (SiC) steel surfaces, it was discovered that the average coefficient of friction under dry conditions in the case of electric discharge machined steel surfaces, which is shown in figure 4(c), does not change much with the angle at which the plate is inclined.

The average coefficient of friction under lubricated conditions in the case of electric discharge machined steel surfaces, which is shown in figure 4(c), is also found to not vary much with plate inclination angle, with the exception of a small fluctuation in the average coefficient of friction value for aluminum pin at an inclination angle of 1 degree. This is similar to the situation with ground (SiC) steel surfaces.

At a number of different plate inclination angles, the average coefficient of friction for lead, copper, and aluminum pins was plotted against the roughness parameter of the surface of the tougher steel. These graphs are shown in figures 5(a) and (b) respectively.

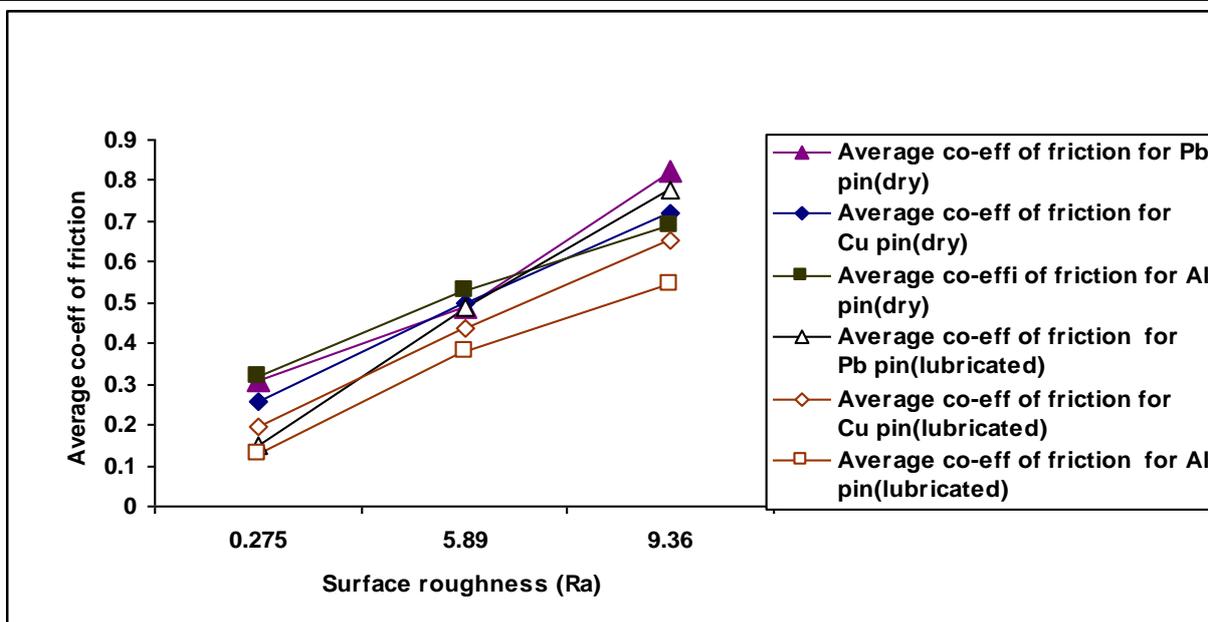


Fig.5 (a): The variation of average co-efficient of friction with surface roughness (Ra) for Pb, Cu and Al pins slid on steel surfaces when $\theta=1$ degree.

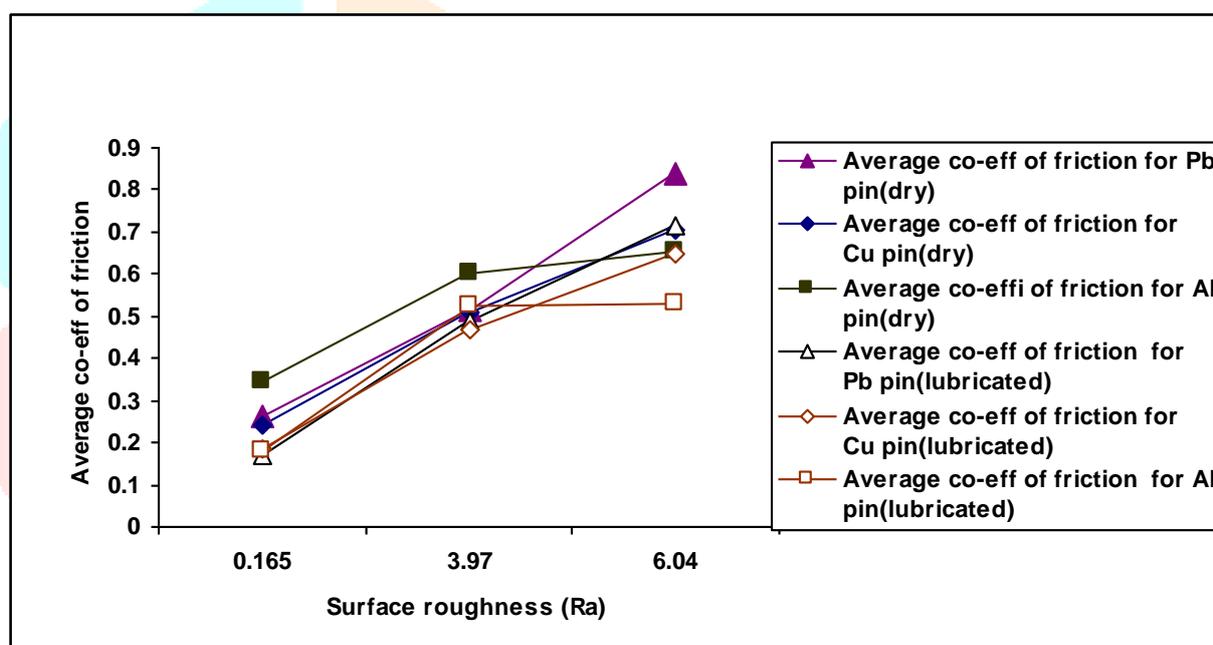


Fig. 5 (b): The variation of average co-efficient of friction with surface roughness (Ra) for Pb, Cu and Al pins slid on steel surfaces when $\theta=1.5$ degree

Both figure 6 and figure 7 depict the scanning electron micrographs (SEM) of the transfer layer on EN8 surfaces while they are in a lubricated state.

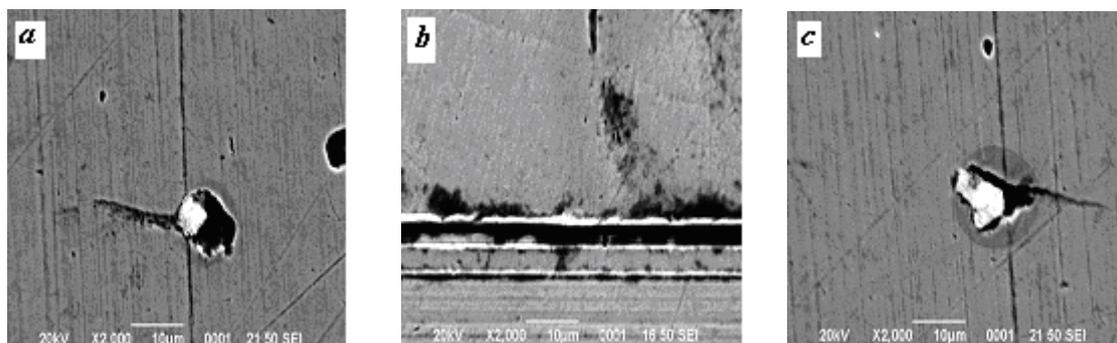


Fig.6 (a) (b) and (c): SEM micrographs showing lead, copper and aluminium transfer layer on ground EN8 steel surface (SiC wheel polished) under lubricated condition

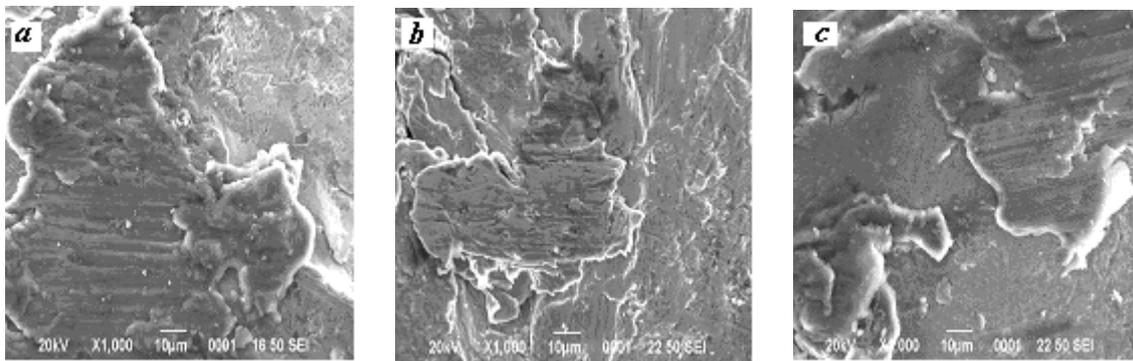


Fig.7 (a) (b) and (c): SEM micrographs showing lead, copper and aluminium transfer layer on shot blast EN8 steel surface under lubricated condition

4. CONCLUSIONS

Using a pin-on-plate sliding tester in a dry and lubricated environment, this study examined the impact of surface morphology and hardness on the coefficient of friction and transfer layer, which define the tribological behavior. The pins used in the experiment were made of lead, copper, and aluminum (Al6082), and they were slid against steel (EN8) plates at different plate inclination angles.

The following are the results of the experiments: The constant sliding was shown by the fact that the coefficient of friction changes with the sliding distance. No significant relationship was seen between the angle of plate inclination and the average coefficient of friction. It was shown that, under lubricated conditions, the surface roughness (R_a) rose as the average coefficient of friction increased. The correlation between the formation of transfer layers and an increase in the coefficient of friction was shown. The average coefficient of friction in dry conditions was determined to be higher than in lubricated conditions by a significant margin.

REFERENCES

1. Y. Tsuya, Microstructure of wear, friction and solid lubrication, Tech. Rep. of Mech. Engg. Lab., 3(81), Tokyo, Japan, 1975.
2. R. Holm, P. Charsley A study of indentation in an AlCu Mg alloy, Materials Science and Engineering: A, Volume 229(1–2), (1997), 10-22
3. K.L.Johnson, Proceedings of institute of Mechanical Engineers, volume 196(1982)363-378.
4. S.Ranganatha, Ph.D. thesis, 2008, Transfer layer formation and friction in extrusion of aluminium; an experimental study using a high temperature vacuum based pin-on-disc machine. Department of Mechanical engineering, IISc, Bangalore, India
5. R.D.Mindlin, Journal of Applied Mechanics, volume 71(1949)259
6. J. F. Archard, Elastic deformation and the laws of friction, Proceedings of Royal. Society of London, Ser. A, 243 (1957), 190-205.
7. J.A.Greenwood and J.B.P.Williamson, Proceedings of Royal. Society of London, Ser. A, 295 (1996) 300-319.
8. F P Bowden, D Tabor, The friction and lubrication of solids, Clarendon press, Oxford, UK, 1954.
9. H E Staph, P.M Ku, H J Carper, Effect of Surface Roughness and Surface Texture on Scuffing Mechanism and Mechine Theory 8(1973) 197-208.

10. S.Abtahi,, Ph.D Thesis 1995 ,Department of Mechanical Design and materials Technology,The Norwegian institute of Technalogy,University of Trondenhim, Trondenhim, Norway,1995.
11. W.W.Theджа, K.B.Muller and D.Ruppin, Proceedings of the 5th international Extrusion Technology seminar, Chicago (1992)467-474.
12. J. F. Archard and W. Hirst, The wear of metals under unlubricated conditions, Proceedings of Royal. Society of London A, 236 (1956) 397-410.
13. Azushima, M. Sakuramoto, Effects of Plastic Strain on Surface Roughness and Coefficient of Friction in Tension-Bending Test, CIRP Annals - Manufacturing Technology, Volume 55(1), (2006), 303-306.
14. M M Koura, The effect of surface texture on friction mechanisms, Wear 63(1980) 1-12.
15. J. R. Whitehead, Surface deformation and friction of metals at light loads, Proc. Royal. Soc., London, A, 201, 1950, 109-124.
16. M. Kerridge and J. K. Lancaster, The Stages in a Process of Severe Metallic Wear Proc. R. Soc. Lond. A , 236(1956) 250-264.
17. T. Nellesmann, N. Bay and T. Wanheim, Real area of contact and friction stress – The role of trapped lubricant, Wear 43(1), 1977, 45-53.
18. Theng-Sheng Yang, Prediction of surface topography in lubricated sheet metal forming, International Journal of Machine Tools and Manufacture, Volume 48 (7–8)(2008), 768-777.
19. D. A. Rigney and J. P. Hirth, Plastic deformation and sliding friction of metals, wear, 53(2), 1979, 345-370.
20. N. P. Suh and H. C. Sin, The genesis of Friction, Wear, 69(1), 1981, 91-114
21. M. Khonsari and E.R. Booser ,“Applied Tribology 2e: Bearing Design and Lubrication” © 2008 John Wiley & Sons, Ltd
22. ASM Handbook Committee (2002); ASM Handbook. Friction, Lubrication and Wear Technology. U.S.A., ASM International. Volume 18
23. John A Williams, (2005). "Wear and wear particles - Some fundamentals"; Tribology International 38(2005): 863-870
24. J. L Meriam; L. G. Kraige (2002). Engineering Mechanics (fifth ed.); John Wiley & Sons. p.328. ISBN 0471602930
25. W. Rasp, C.M. Wichern, Effects of surface-topography directionality and lubrication condition on frictional behavior during plastic deformation, J. Mater. Process. Technol. 125–126 (2002) 379–386.