Society of Production Engineering

SPMS 2023

39. Savetovanje proizvodnog mašinstva Srbije

ICPES 2023

39th International Conference on Production Engineering of Serbia

Faculty of Technical Sciences
University of Novi Sad

Novi Sad, Serbia, 26. – 27. October 2023

INFLUENCE OF SURFACE ROUGHNESS ON MATERIAL TRANSFER OCCURRING IN ALUMINIUM DRY SLIDING APPLICATION

Dragan DzUNIC[1, *], Vladimir KOCOVIC[1], Suzana PETROVIC SAVIC[1], Aleksandar DjORDjEVIC[1], Aleksandra KOKIC ARSIC[2], Slobodan MITROVIC[1]

[1]Faculty of Engineering, University of Kragujevac, Kragujevac, Serbia

[2]Kosovo and Metohija Academy of Applied Studies, Leposavic, Serbia

*Corresponding author: dzuna@kg.ac.rs

Abstract: *Aluminium and its alloys are highly represented in industrial application. Despite of good mechanical and conductive properties, both thermal and electric, in tribological manner material transfer that may occur during the dry sliding conditions has great influence on friction and wear of the contact elements. This study represents an attempt one in a row to define the parameters that leads to the material transfer occurring, and in this paper influence of surface roughness was investigated. Tribological test were performed in dry sliding conditions using CSM nanotribometer with ball-on-plate contact configuration and linear reciprocating motion with 0,5mm amplitude and sliding speeds of 1, 5 and 10 mm/s under constant load of 200mN. Obtained results indicated presents of material transfer for all three investigated surfaces prepared using sand paper with different grit sizes 240 and 1000 and polished sample. Appearance of transferred layer, on the steel counter body, and penetration depth value plots refers to cyclic nature of material transfer. Material transfer during the dry sliding contact result in increase of coefficient of friction and wear of tested aluminium samples.*

Keywords: *Aluminium, Friction Coefficient, Wear, Material Transfer, Nanotribometer.*

1. INTRODUCTION

Aluminium and his alloys as a material has a wide industrial application since it is recognized as lightweight metal in comparison to other market available metals and due to its good, mechanical and structural properties and electric and thermal conductivity. Also numerous improvement are possible using aluminium as a matrix material for wide range of composites, reinforced with various types of materials, shapes and sizes [1-3]. In tribological manner, it is possible to improve physical appearance of the contact surface, by lowering the surface roughness and in the same way improving the mechanical properties, using nonconventional techniques such as ball and roller burnishing [4-5].

Despite mentioned improving the problem of material transfer still, exist in dry sliding conditions, which can occur as a result of construction of tribo-mechanical system itself or inadequate lubrication, lubrication medium or due to breakage of lubrication or protection film. Tribological investigations of different aluminium alloy indicated to presence of material transfer to the counter body surface [6-8]. Material transfer were noticed in all dry sliding tests of automotive cylinder aluminium alloy [8], and in some cases of zinc aluminium alloy (ZA-27, 27% of aluminium) nano composite [6]. In both cases it is very hard to predict and to conclude the moment and the reason for material transfer. It can occur at the early begging of the sliding contact, but also in the same contact condition it can be prolonged much later.

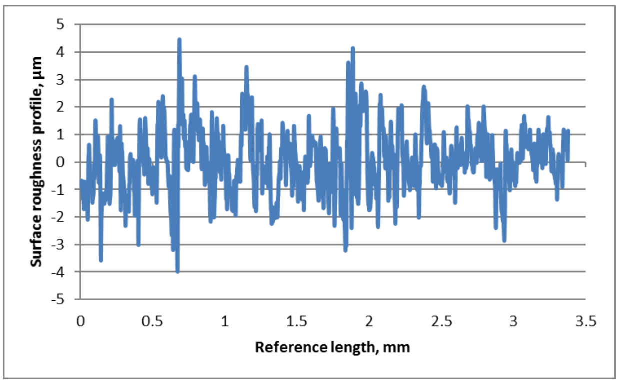
In our previous investigations, we have tried to avoid material transfer by varying material of the counter body (Inox 440c, Ruby, Sapphire, Alumina Al_2O_3 and Silicon Nitride Si_3N_4) [9] or at least define contact parameters without material transfer. In this paper, we investigated influence of surface roughness on mentioned phenomenon of material transfer under dry sliding.

2. EXPERIMENT

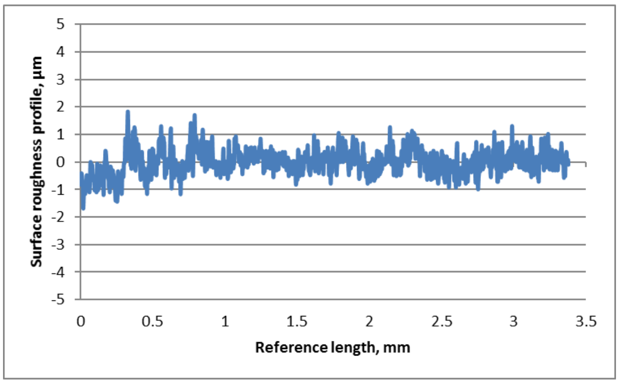
Tribological testing were performed using CSM Nanotribometer with ball-on-plate contact geometry and linear reciprocating motion. 100Cr6 steel was used as a counter body (ball, 1.5 mm in diameter) material. Test samples were prepared from aluminium alloy 6082 (AlMgSi1) T651 grinded with sand paper with different grit size, 240p, 1000p, while the third one is polished. Pilishing was performed using polishing emulsion with 6, then 1 and finish with 0,42µm abrasive particles. Surface roughness were measured using INSIZE C002 profilometer. Friction and wear tests were performed under constant load (200mN), with 0.5 mm amplitude, sliding distance of 1m or 500 cycles and three different sliding speeds (1, 5 and 10 mm/s). Each test were repeated three times. Obtained wear tracks were measured and analysed using optical microscope.

3. RESULTS AND DISCUSSION

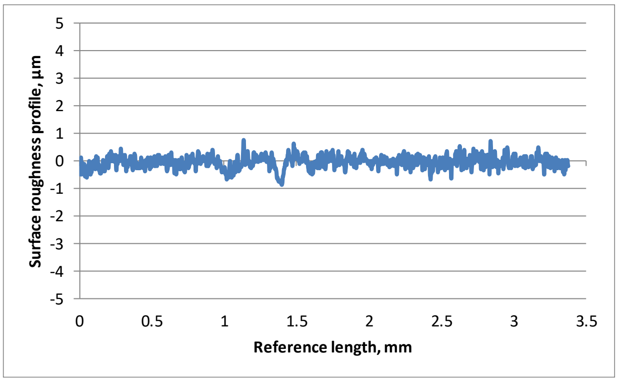
Surface roughness measurement result were presented on figure 1. As it is mentioned before three aluminium samples, with different surface finish (240p, 1000p and polished), were on test.



a)



b)

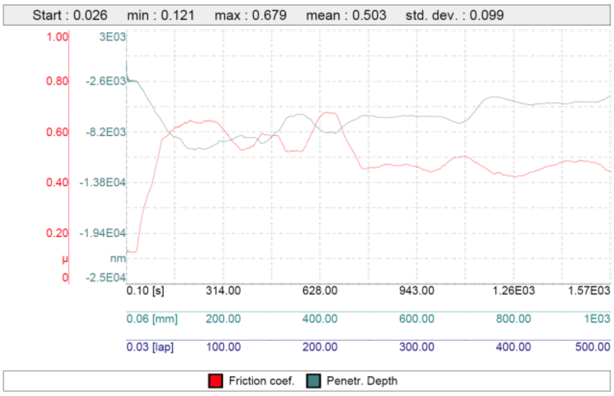


c)

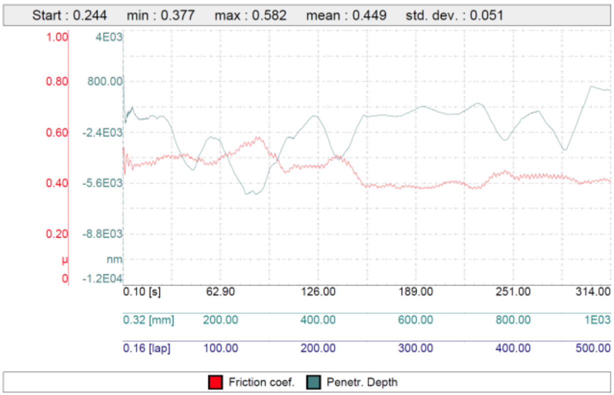
Figure 1. Surface roughness of prepared Aluminium samples with sandpapers with different grit sizes: a) 240p, b) 1000p and polished

Coefficient of friction and penetration depth values are presented on the following plots (Figure 2-4) in comparison to the sliding time, sliding distance and number of cycles. Penetration depth parameter proved to be very useful for analysing the material transfer process. Presented plots represents one tribological test from three that were performed under the same contact conditions.

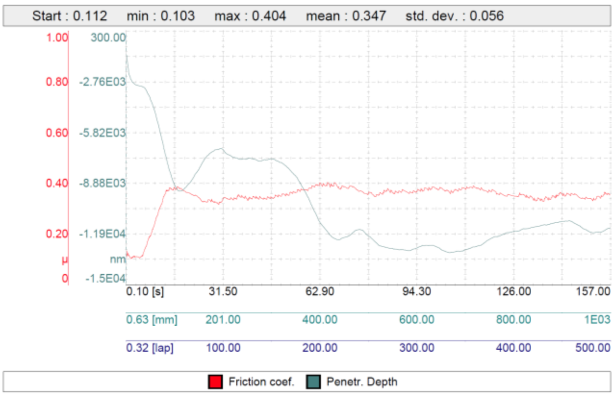
Figure 2 represents COF and PD values for the samples with 240p grit finish under three sliding speeds value. From these plots, it can be concluded that material transfer stars at early beginning of the contact, which followed with the sharp change of both observed parameters.



a)



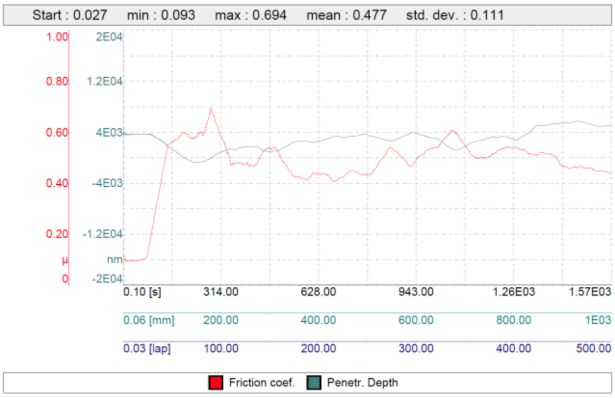
b)



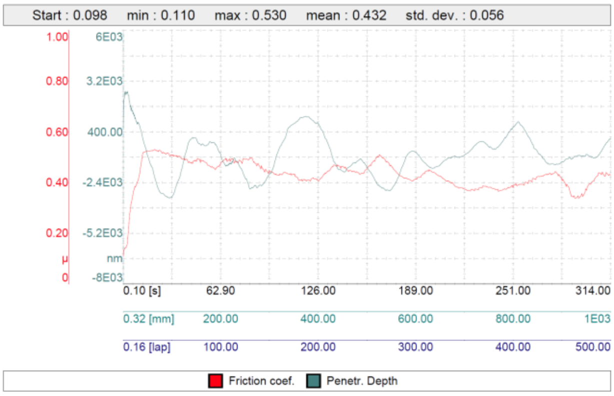
c)

Figure 2. Coefficient of friction and Penetration depth plots for 240p grit size Aluminium sample under three sliding speeds: a) 1mm/s, b) 5mm/s and c) 10mm/s.

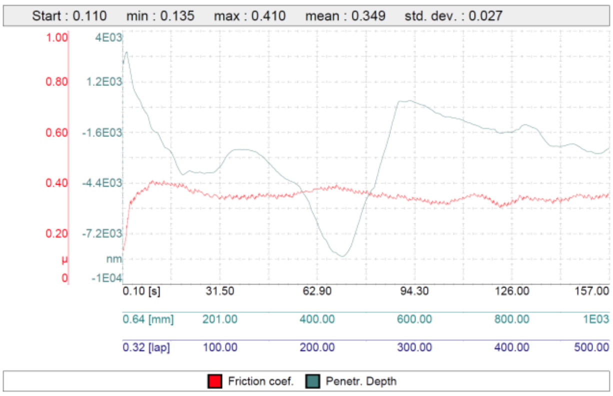
In case of 5mm/s sliding speed material transfer starts almost instantly while for others sliding speeds material transfer occurs in period of 10-20s. Figure 3 represents obtained results for sample prepared with 1000 grit size. Sample prepared with sandpaper with 1000p grit size manifests almost the same trends for COF and PD as previous prepared with 240p grit size.



a)



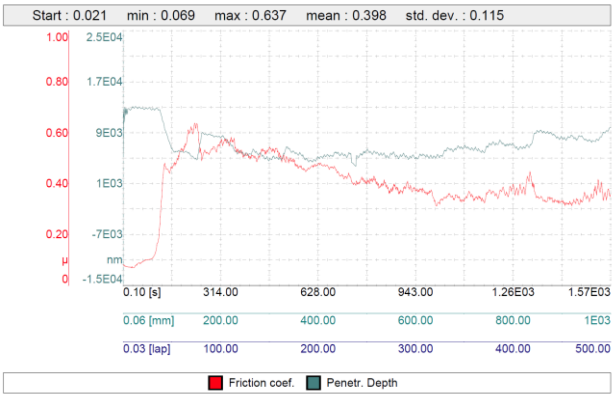
b)



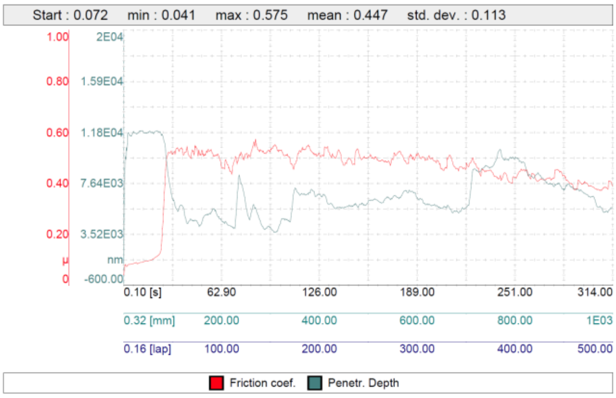
c)

Figure 3. Coefficient of friction and Penetration depth plots for 1000p grit size Aluminium sample under three sliding speeds: a) 1mm/s, b) 5mm/s and c) 10mm/s.

On the figure 4 COF and PD plots are related to the polished sample. As it can be seen from presented plots, material transfer is postponed 10-20s, but in all tests there were no immediate material transfer. Some authors indicated that material transfer is related to the contact temperature, and that with temperature rise material transfer is more frequent and starts much earlier [7], but in the present investigation that's not a case since all tests were performes at the room temperature.



a)



b)

c)

Figure 4. Coefficient of friction and Penetration depth plots for polished Aluminium sample under three sliding speeds: a) 1mm/s, b) 5mm/s and c) 10mm/s.

From all presented plots it is obvious that penetration depth has numerous sharp changes during the sliding period that indicated on unstable and variable thickness of transferred layer on the counter body surface. Transferred layer thickness increases until the critical value that is not able to withstand the tangential force. In that moment part of the transferred layer is detached and become wear debris. That process repeats numerous times during the sliding contact and the change in PD value is more pronounced for rougher surfaces.

Wear tracks were measured and analysed using optical microscope. Measurement were done by measuring the appeared area of the wear track and then analytically wear volume was calculated. Wear volume and standard deviation of measured wear tracks is presented on figure 5. Polished samples exhibits better wear resistance in comparison to the rougher surfaces accept in case of 10mm/s sliding speed.

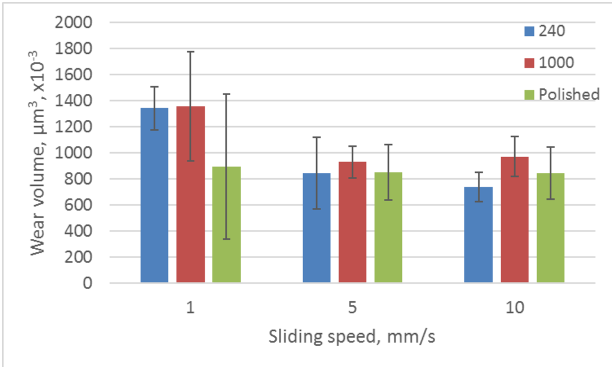
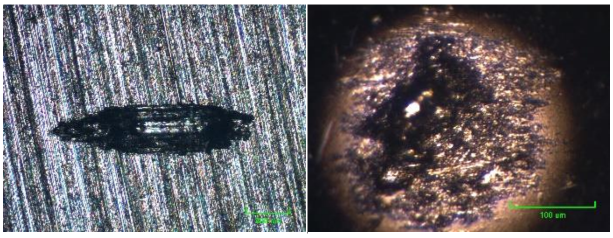
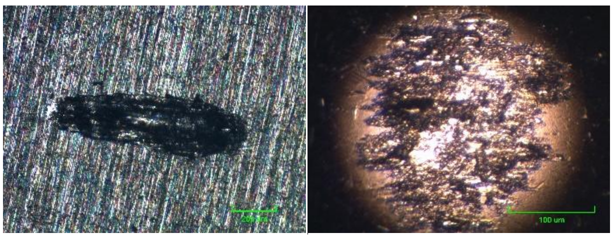


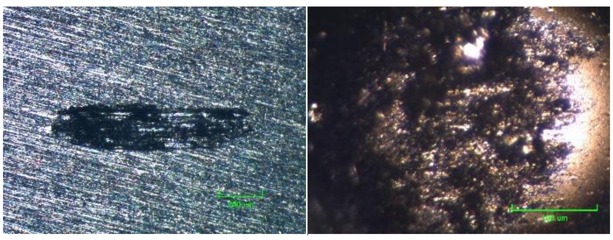
Figure 5. Wear volume of all tested samples



a)



b)



c)

Figure 6. Wear tracks and transferred layer appearance obtained under 5mm/s sliding speed: a) 240p, b) 1000p and c) polished sample.

As a representative example of wear track and transferred layer appearance, those obtained under 5mm/s sliding speed was chosen. Uneven distribution of transferred material on the counter body surface indicates uneven height, which is in corresponding to the presented PD plots. This kind of distribution of transferred material and its unpredictable behaviour are the reason for high deviations in measured wear tracks volume values.

4. CONCLUSION

Influence of surface roughness on material transfer occurring, from aluminium samples to the steel counter body, during the dry sliding contact was presented. It can be concluded that surface roughness has no greater influence material transfer occurring but polished samples has lower wear volume and also PD change is less pronounced in comparison to the samples with rougher surfaces.

Material transfer process is not progressive by its nature, but more cyclic, which correspondents to the presented PD plots.

Material transfer occurring is followed by sharp change in COF and PD value. COF is increased more than four times in comparison to the starting values.

ACKNOWLEDGEMENT

This research was funded by the Ministry of Science, Technological Development and Innovation of Republic of Serbia.

REFERENCES

[1] T. Ma, H. Yamaura, D. Koss, R. Voigt: Dry sliding wear behavior of cast SiC-reinforced Al MMCs, Materials Science and Engineering: A, vol. 360, no. 1-2, pp. 116-125, 2003.

[2] M, R.P., Saravanan, R. and Nagaral, M.: Fabrication and wear behavior of particulate reinforced Metal Matrix Composites-an overview, IOSR Journal of Mechanical and Civil Engineering, 14(01), pp. 10–20. Available at: https://doi.org/10.9790/1684-1401041020.

[3] Y. Sahin: Wear behaviour of aluminium alloy and its composites reinforced by SiC particles using statistical analysis', Materials & Design, vol. 24, no. 2, pp. 95-103, 2003.

[4] Đ. Vukelić, B. Tadic, D. Džunić, Vladimir Kočović, Lj. Brzaković, M. Zivković, G. Simunović: Analysis of ball-burnishing impact on barrier properties of wood workpieces, International Journal of Advanced Manufacturing Technology, Vol.92, No.1-4, pp. 129–138, ISSN 0268-3768, Doi 10.1007/s00170-017-0134-3, 2017.

[5] M.H. El-Axir, O.M. Othman, A.M. Abodiena: Study on the inner surface finishing of aluminum alloy 2014 by ball burnishing process, Journal of Materials Processing Technology, Volume 202, Issues 1–3, Pages 435-442, 2008.

[6] M. Babic, B. Stojanovic, D. Dzunic, M. Pantic: Micro/nanoscale structural, mechanical and tribological characterization of ZA-27/SiC nanocomposites, Journal of Composite Materials, Vol. 54, Iss. 16, pp. 2113-2129, 2019.

[7] Tarasov SYu, Filippov AV, Kolubaev EA, et al. Adhesion transfer in sliding a steel ball against an aluminium alloy, Tribol Int, Vol. 115, pp. 191–198, 2017.

[8] S. Milojević, D. Džunić, D. Marić, T. Skrúcaný, S. Mitrović, R. Pešić, Tribological Assessment of Aluminum Cylinder Material for Piston Compressors in Trucks and Buses Brake Systems, Tehnički vjesnik/Technical Gazette, Vol.28, No.4, pp. 1268-1276, 2020

[9] D. Džunić, S. Petrović Savić, V. Kočović, S. Kostić, A. Đorđević, A. Kokić Arsić, S. Mitrović: Influence Of Counter Body Material On Material Transfer During Ball On Plate Dry Sliding, 18th International Conference On Tribology, Kragujevac, Serbia, 17 – 19 May, pp. 242-247, 2023.