Serbian Tribology Society

SERBIATRIB '23

18th International Conference on Tribology

Faculty of Engineering University of Kragujevac

Kragujevac, Serbia, 17 – 19 May 2023

INFLUENCE OF COUNTER BODY MATERIAL ON MATERIAL TRANSFER DURING BALL ON PLATE DRY SLIDING

Dragan DžUNIĆ[1], Suzana PETROVIĆ SAVIĆ[1,*], Vladimir KOČOVIĆ[1], Sonja KOSTIĆ[2], Aleksandar ĐORĐEVIĆ[1], Aleksandra KOKIĆ ARSIĆ[3], Slobodan MITROVIĆ[1]

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

[2]Academy of Professional Studies Šumadija, Department in Kragujevac, Kragujevac, Serbia

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

*Corresponding author: petrovic.suzana@gmail.com

Abstract: *Aluminium is widely used in various sliding applications. Most of them are in lubricant sliding conditions, but in some cases dry sliding conditions can be projected or can occur due to insufficient lubricant or breaking the lubricant layer. In aluminium dry sliding conditions intensive material transfer occurs. Transferred material are aluminium particles that are firmly bonded to the counter body surface. Due to material transfer friction and wear properties are significantly changed, both are increased several times. Related to that aim of this study is to examine influence of counter body material on material transfer. Moment of material transfer occurring is one of the mysteries, for the same contact pair and same contact conditions it can occur at the begging of sliding contact, but also it can happen much later. Five different counter body material were used for presented tests: Inox 440C, Ruby, Saphire, SiN, and Al2O3.*

Keywords: *Dry sliding, Wear, Friction, Material transfer, Aluminium.*

1. INTRODUCTION

Various aluminium alloys are widely used in many tribological applications, with or without lubrication. Some previous investigation of their properties pointed out that in dry sliding applications material transfer occurs in different phases of contact. Aluminium structural, mechanical and tribological properties can be improved using various techniques. One of them is infiltration of hard ceramic reinforcements in order to improve wear resistance of base material. It can be achieved by different shape and size of reinforcements [1-4]. Properties of the aluminium contact surface can be improved by different mechanical techniques that are based on rolling the ball or cylinder under pressure [5-9].

During researching tribological properties of nanocomposites based on ZA-27 and A356 alloys we have experienced material transfer prom teste nanocomposite to alumina counter body ball surface. In case of ZA-27 nanocomposite material transfer occurred occasionally [10], but in case of A356 aluminium alloy it was a matter of time or number of cycles when material transfer will occur. Since ZA-27 nanocomposites were produced with different volume % of reinforcement (1, 3 and 5) it was noticed that material transfer occurring decreases with increase of amount of reinforcement.

Similar study of material transfer during dry sliding over aluminium alloys where presented by S. Tarasov [11], but on ambient and elevated temperatures. Transferred layer thickness increases with increase of testing temperatures. Material transfer was observed in investigation of steel cast inserts in cylinder liner [12]. Transfer was observed in dry sliding tests that were performed on base material of the cylinder that was made from aluminium, while no material transfer was on steel cast inserts.

What is the reason for material transfer while dry sliding? Does it depends on contact geometry, counter body material, surface roughness of both sample and counter body surface, type of motion, normal load, sliding speed, temperature? Those are just basic questions that wait for answer. Main goal of this study was to provide an answer on one of those questions and to investigate influence of different counter body materials on tribological material transfer from tested Al sample on counter body surface.

2. EXPERIMENT

Experiment were conducted in CSM Nanotribometer in dry sliding conditions, at ambient temperature. Contact geometry was ball (1.5 mm in diameter) on flat in linear reciprocating motion. Normal load (200 mN) and sliding speed (5 mm/s) were maintained constant during these tests, while sliding distance was 1000 mm or 500 cycles. For these test 5 different counter body materials were selected: Silicon Nitride (Si_3N_4), Inox 440c, Sapphire, Ruby and Alumina. Aluminium alloy used as material for test samples were EN AW-6082 (AlMgSi1) T651 and it was grounded, polished and cleaned with isopropyl alcohol. Each test with selected counter body material was repeated five times.

CSM Nanotribometer is equipped with Penetration depth sensor, which can shows us change of transferred layer thickness during the linear reciprocating motion.

Unworn surface of counter body ball made from Inox 440c was presented of figure 1 obtained by optical microscope. This picture is only an example of the counter body surface before dry sliding test and it is given for comparison with counter body surface with transferred material.

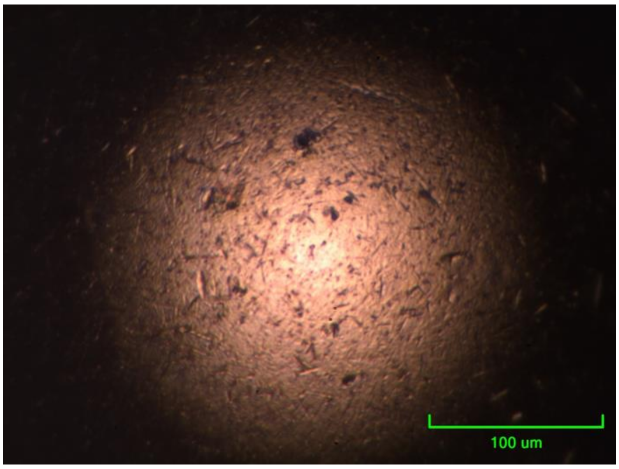


Figure 1. Unworn surface of the Inox 440c ball

3. RESULTS AND DISCUSSION

Friction force, normal load, coefficient of friction and penetration depth was presented on diagram on figure 2 in comparison to the number of cycles or sliding distance. It can be easily observed that material transfer occurred early at the beginning of the sliding contact and that was followed by increase of coefficient of friction value. On a similar way material transfer occurs for all tested counter body materials and for each repeated test, with small difference in the number of cycles when it occurs.

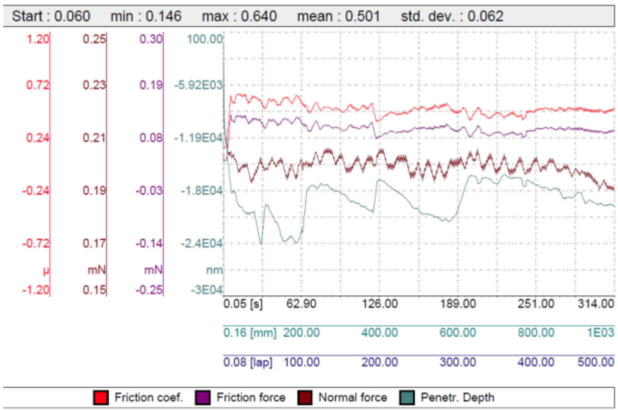
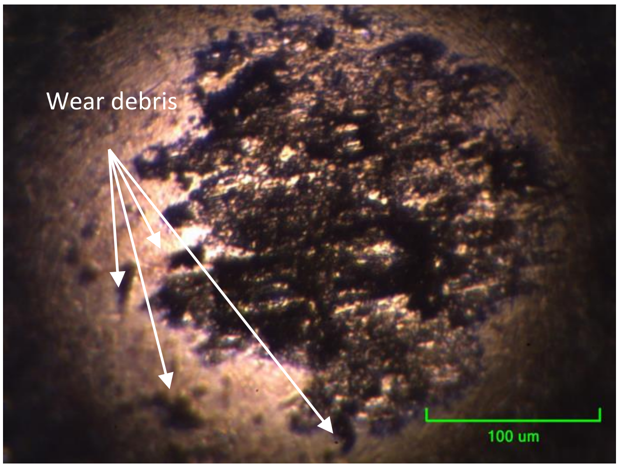
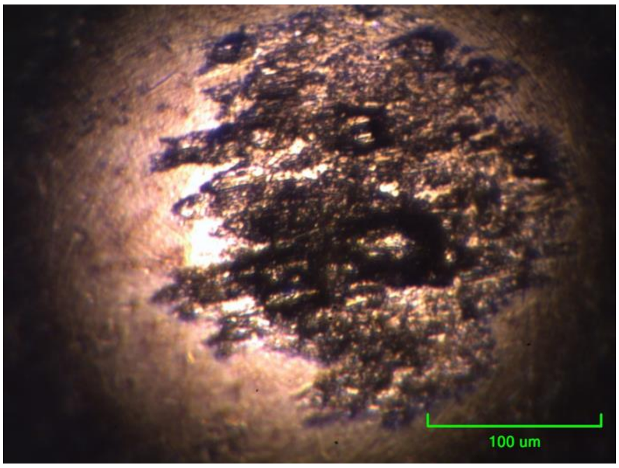


Figure 2. Coefficient of friction and penetration depth in comparison to the number of cycles or sliding distance

Material transfer is followed by increase in coefficient of friction value from 0.1 at the beginning of the sliding contact to 0.5, with small oscillation. From the moment when material transfer occurs contact were established between tested aluminium sample and aluminium transferred on the counter body surface which is the reason for increase of coefficient of friction value. Also from that moment counter body material has no influence of friction and wear.



a)

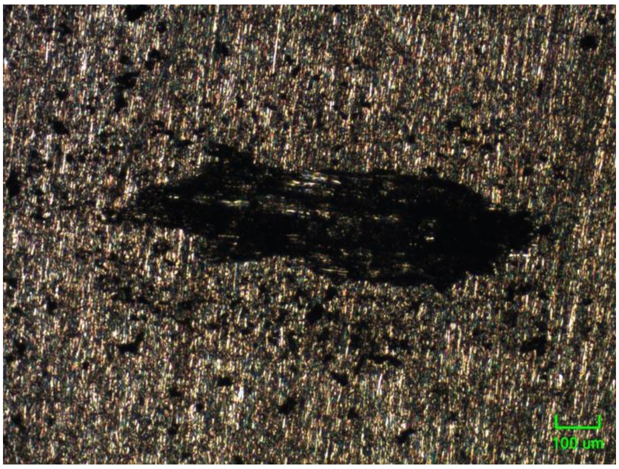


b)

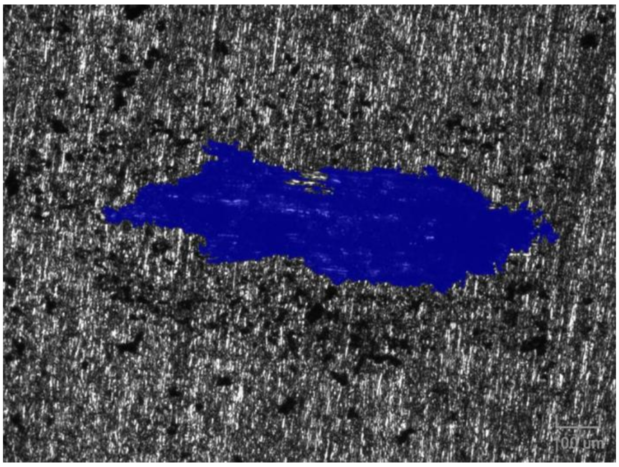
Figure 3. Optical microscopy of transferred layer, a) with wear debris, b) without wear debris

Oscillation in penetration depth indicates on cyclic nature of material transfer proces that is related to the change of tranfered material layer thickness. It is clearly noticeable that tranfered layer thickness increases until the critical value that is not able to withstand the tangential forces. In that moment part of trasfered material breaks off and became loose particle or wear debris. Change of tranfered layer thickness is folloved by slight change of coefficient of friction, due to changed contact surface. From that moment process repeats and tranfered layer thickness increses.

Figure 3 presents an optical microscopy analysis of transferred material on counter body (ball) surface. Figure 3a presents transferred material with loose particles or wear debris slightly attached to the counter body surface, while they were cleaned off with minimal effort using cotton wool stick.



a)



b)

Figure 4. Optical microscopy (4a) of obtained wear track on aluminium sample and analysed with developed algorithm (4b)

Wear tracks on aluminium sample were also analysed using optical microscope in order to measure wear track area. Due to irregular shape of wear track, which is result of irregular shape of transferred layer on counter body surface, authors were compelled to measure wear track area. For precise measuring of wear track area an algorithm was developed which saves time and makes the measurement more reliable since it is independent of the human factor. Wear track and wear track analysed with mentioned algorithm is presented on figure 4a and 4b, respectively.

Obtained results wear track area results were presented on histogram on figure 5, with error bars which represents standard deviation for five measurement obtained from five repeated dry sliding tests with each counter body material.

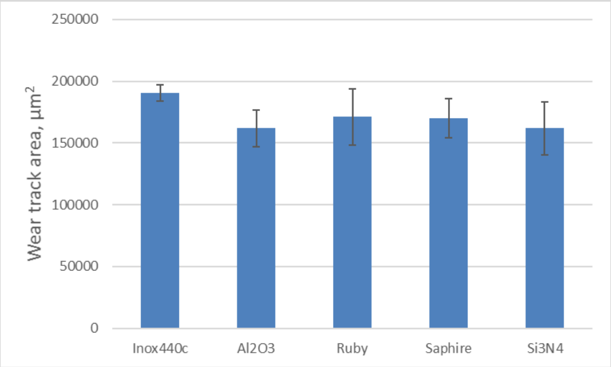


Figure 5. Wear track area for tested counter body materials

Difference in measured wear track area values could not be used for comparing the influence of counter body materials since all tests material transfer occurs at the beginning of sliding and the sliding contact is independent from counter body material. From the moment when transferred layer is established on the counter body surface friction and wear depends on unpredictable nature of the layer itself, since it has irregular shape which directly influences on both, friction and wear track area. Also change in transferred layer thickness depends on the nature of layer itself.

4. CONCLUSION

Material transfer occurred during dry sliding over aluminium has significance influence on friction and wear behaviour of tribological system. In this paper five different counter body materials were used in order to investigate influence of counter body material on material transfer occurrence.

In all five cases material transfer occurs at the beginning of the dry sliding which could be confirmed with coefficient of friction and penetration depth change.

Change of penetration depth value during the dry sliding indicates on cyclic nature of the material transfer process. When transferred layer thickness reaches critical value in which is not able to withstand tangential forces, part of it breaks off and became wear debris.

Main conclusion of the presented investigation is that the counter body material has no significance influence on material transfer, which is probably influenced by contact geometry, dry sliding conditions and the nature of aluminium as a material itself.

Future investigations could be related to influence of surface roughness, sliding speed and normal force influence on material transfer.

ACKNOWLEDGEMENT

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

REFERENCES

[1] M, R.P., Saravanan, R. and Nagaral, M. (2017) “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.

[2] 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.

[3] 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.

[4] A. Abdollahi, A. Alizadeh, H. Baharvandi, 'Dry sliding tribological behavior and mechanical properties of Al2024–5wt.%B4C nanocomposite produced by mechanical milling and hot extrusion', Materials & Design, vol. 55, pp. 471-481, 2014.

[5] E. Becerra-Becerra , C.O. Aguilera Ojeda, A. Saldaña-Robles, J.F. Reveles-Arredondo, J. Barco-Burgos, A. Vidal-Lesso, A review of numerical simulation of ball burnishing process, Finite Elements in Analysis and Design Volume 218, 2023.

[6] Suleyman Cinar Cagan, Catalin Iulian Pruncu, Berat Baris Buldum, An investigation into ball burnishing process of magnesium alloy on CNC lathe using different environments, Journal of Magnesium and Alloys, Volume 8, Issue 4, Pages 1061-1070 . 2020.
[7] 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.
[8] Đ. Vukelić, D. Miljanić, S. Ranđelović, I. Budak, D. Džunić, Milan Eric, Marko Pantic, A Burnishing Process Based On The Optimal Depth Of Workpiece Penetration, Materials and technology, Vol.47, No.1, pp. 43–51, ISSN 1580-2949, 2013.
[9] 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.
[10] Miroslav Babic, Blaza Stojanovic, Dragan Dzunic, Marko Pantic, Micro/nanoscale structural, mechanical and tribological characterization of ZA-27/SiC nanocomposites, Journal of Composite Materials, Vol.0, No.0, pp. 1-17, 2019.
[11] 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.