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MICRO SCRATCH TEST CHARACTERISATION OF ZA-27/SiC NANOCOMPOSITES

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Abstract: *In this study tribological properties of obtained nanocomposites were investigated using micro scratch tester. Tested nanocomposites were developed on well-known tribological ZA-27 alloy using compocasting technique. SiC nanoparticles (average size 50nm) in different volume fraction were used as reinforcement. Main scratch test results were coefficient of friction, penetration and residual depth. Obtained results for nanocomposites were compared to the obtained results for base ZA-27 alloy. Scratch test results and SEM revealed existence of structural irregularities such as porosity (trapped gas bubbles in material structure) and agglomerated nanoparticles. Existence of structural irregularities mainly diminishes positive effects that are expected from addition of hard nanoparticles.*

Keywords: *ZA-27, Nanocomposite, Scratch test, Wear, Friction, Penetration depth, Residual depth.*

1. INTRODUCTION

Engineers and researchers from all over the make an effort to obtain the material that is perfect in tribological manner, that has low coefficient of friction and therefore energy efficient and also it is necessary to have a great wear resistant or to be unswerving for a long time. Zink aluminium alloys are well known tribological material and they are widely used in various industrial applications. Zinc and aluminium are the main alloy constituents with low content of copper and magnesium. Content of aluminium can vary and regarding that exists several alloys with different content of aluminium 8% (ZA-8), 12% (ZA-12) and 27% (ZA-27). Casted zinc-aluminium alloys possess a great combination of strength, toughness and rigidity. Due to low copper content these alloys are very economical and energetically efficient replacement for numerous alloys based on non-ferrous metals. Regarding that they possess a good bearing capability, but from the other side they are characterised by lower casting temperature and cost effectiveness [1-4].

ZA alloys are widely used for plain bearings that work under conditions of low sliding speeds and high normal loads [5, 6].It should be mentioned that one of the main disadvantages of these alloys is their inferiority on higher temperatures [3, 7].

Further improvement of mechanical and tribological properties of ZA-27 alloys lead through development of their composites. Addition of hard ceramic particles improves wear resistance in comparison to the wear resistance of the base alloy [8-14], while addition of graphite particles improves frictional properties [15-21]. Addition of graphite can also improve wear properties through generation of specific tribo-layer on both contact surfaces [6]. In order to improve wear and friction properties hard particles were simultaneously with graphite particles that acts like a solid lubricants [16, 18, 21, 22]. Recently researchers make great efforts to improve base alloys properties with addition natural biomaterials such as cassava leaves [23], coconut [24], palm kernel [25] and egg shell [26].

Beside all these scientific and research effort, influence of nanoparticles on the properties of base metals and their alloys is not fully understood and properly defined. Also numerous problems regarding dispersion, reactivity, and wettability are still present in order to obtain optimal distribution of nanoparticles in base material. Due to that the aim of this study is to investigate tribological properties of ZA-27 nanocomposites reinforced with different volume fraction of SiC nanoparticles obtained by compocasting technique.

2. MATERIAL

As is it previously mentioned ZA-27 alloy is reinforced with SiC nanoparticles, with average size around 50nm. Volume fraction of SiC nanoparticles was 1, 3 and 5%. Chemical composition of base ZA-27 alloy is presented in table 1.

Table 1. Chemical composition of the ZA-27 base alloy

Label	Chemical composition (wt. %)			
	Al	Cu	Mg	Zn
ZA27	25-27	2-2,5	0,015-0,02	Balance

Nanocomposites were obtained by the compocating procedure which comprise adding of nanoparticles in molten alloy under intensive mixing in order to achieve uniform distribution of nanoparticles and to avoid formation of agglomerates. Mixing time depends on volume fraction of nanoparticles. After casting obtained nanocomposites were hot pressed with 250 MPa pressure.

Tribological samples were prepared by milling, grinding and polishing, but making sure that the temperature does not exceed 100°C, which would result in degradation of mechanical properties [3, 7].

3. EXPERIMENTAL DETAILS

Tribological properties of obtained nanocomposites were investigated using CSM micro scratch tester (Figure 1). Micro scratch tests were performed using progressive normal load from 0 to 10 N, with loading rate 10 N/min, while sliding distance was 3 mm. Indenter was diamond Rockwell cone with a 100 μm radius on top. Results of these tests were presented through coefficient of friction, penetration and residual depth plots. Experiments on each sample were performed 15 times. Obtained results for nanocomposites were averaged compared to the base ZA-27 alloy.

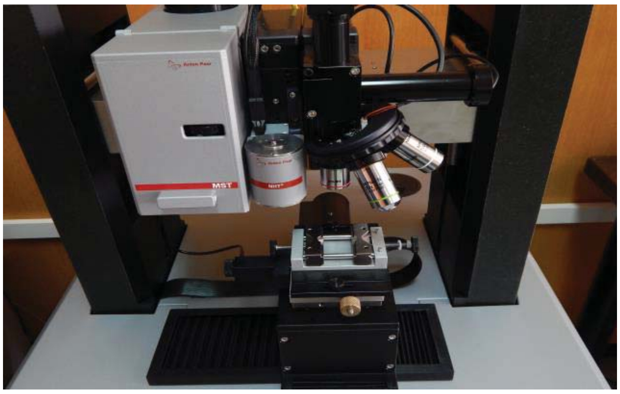


Figure 1. Micro scratch tester

4. RESULTS AND DISCUSSION

Scratch test was repeated on each investigated material 15 times while the distance between tracks were 0.5 mm, and this type of experiment organisation was in order to get a clearer picture of material distribution in surface layer of investigated materials. On figures 2, 3, 4 and 5 presents plots of coefficient of friction, penetration and residual depth for base ZA-27 alloy and for nanocomposites reinforced with 1, 3 and 5 vol. % of SiC nanoparticles. Presented plots are results obtain after one test while averaged values of all 15 tests is presented on figure 6.

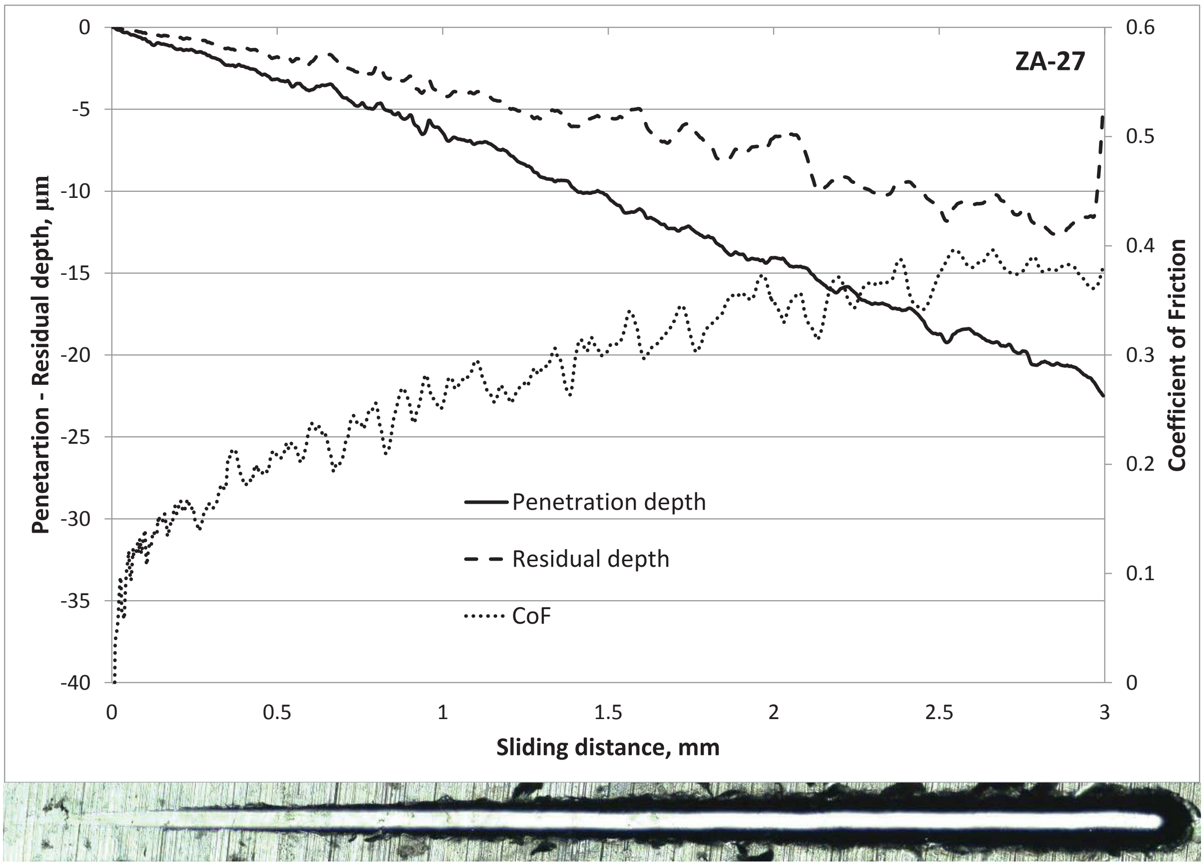


Figure 2. Penetration and residual depth, coeficient of friction and corresponding wear track (below) for ZA-27.

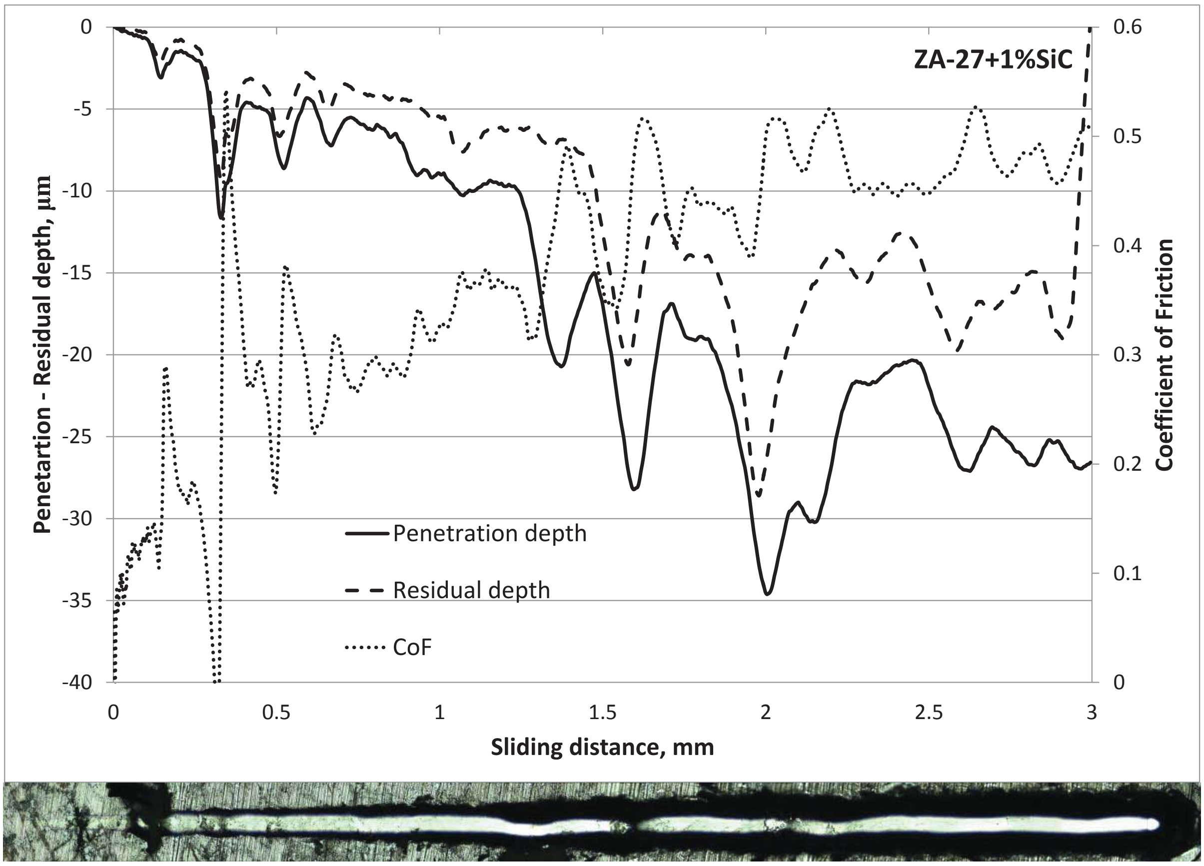


Figure 3. Penetration and residual depth, coeficient of friction and corresponding wear track (below) for ZA-27+1%SiC

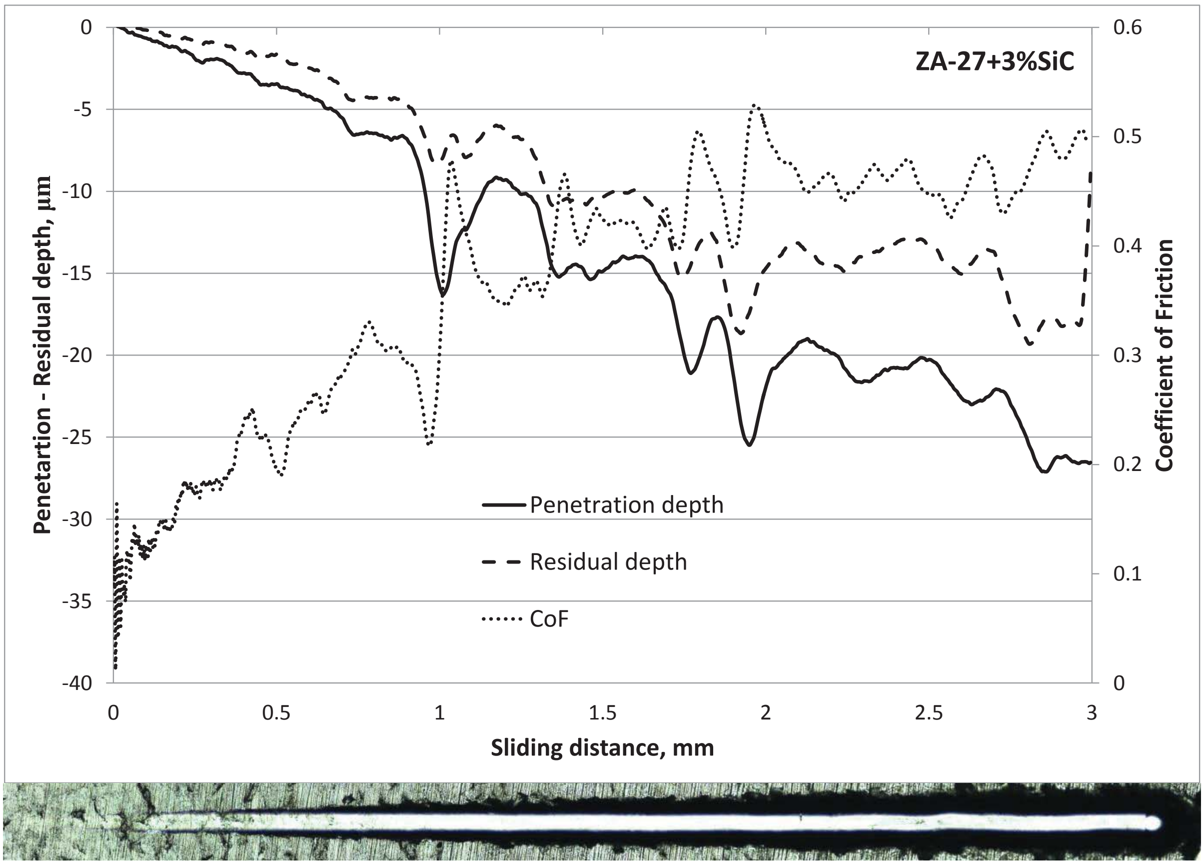


Figure 4. Penetration and residual depth, coeficient of friction and corresponding wear track (below) for ZA-27+3%SiC

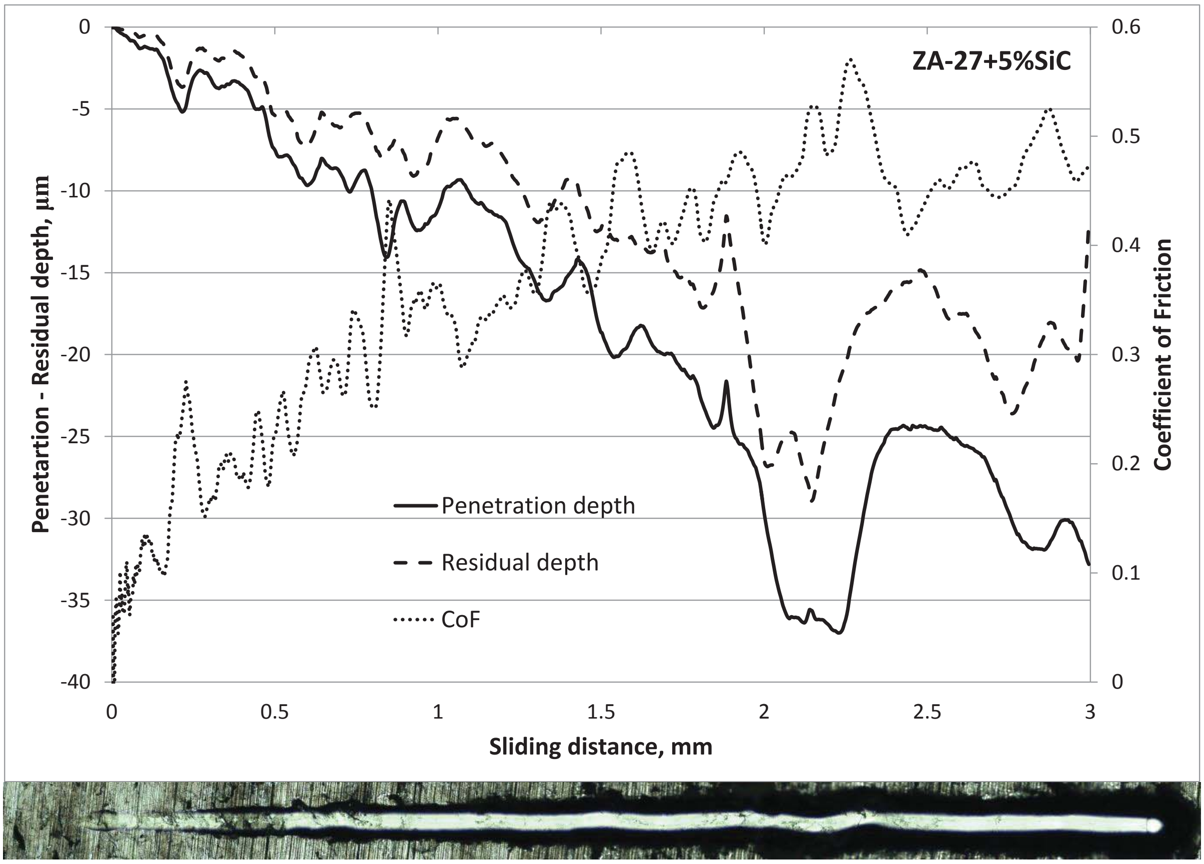


Figure 5. Penetration and residual depth, coeficient of friction and corresponding wear track (below) for ZA-27+5%SiC

Scratch tests results performed on obtained nanocomposites indicated existence of structural irregularities such as air bubbles and agglomerates while it was not the case with scratch test results obtained on base ZA-27 alloy. This conclusion is based on penetration depth curves analysis for nanocomposites where drastic changes are noticeable which refer to decline of indenter during sliding. Increase of penetration depth indicates on surface and subsurface defects. Numerous researchers noticed existence of structural irregularities generated with addition of hard nanoparticles and increase of their content in base material [27-31]. Due to nanoparticles nature gas bubbles generates around them (case when porosity is influenced by individual nanoparticles) or they are generated around agglomerated nanoparticles as a result of aggravated movement of molten metal during casting (case when porosity is influenced by agglomerated nanoparticles) [28]. Gas bubbles could occur due to low wettability between nanoparticles and base material, while generation of agglomerates is a result of increased friction between nanoparticles due to increased surface to volume ratio in comparison to the micro particles [32]. According to the appearance of presented plots for penetration depth of tested nanocomposite it could be concluded that number and size of structure irregularities along scratch track is different and unpredictable.

Change of penetration depth value causes changes of coefficient of friction value and results in higher average value of coefficient of friction in comparison to the coefficient of friction value of ZA-27 base alloy. From these plots it could be concluded that the degree of elastic relaxation is almost equal and constant for all examined materials, which means that is constant despite change of volume fraction of nanoparticles.

Averaged plots of coefficient of friction based on all 15 scratch tests are presented on figure 6. Analysing presented, it is obvious that ZA-27 exhibits lowest value of coefficient of friction during the scratch test sliding. Coefficient of friction as it is previously mentioned highly depend on penetration depth of indenter and regarding that the coefficient of friction of nanocomposites is higher in comparison to the base ZA-27 alloy.

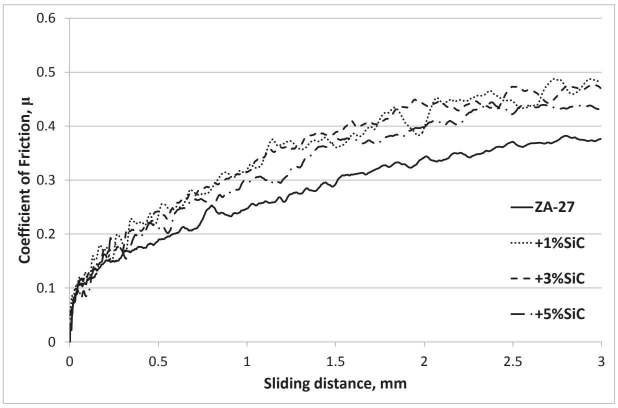


Figure 6. Averaged plots of coefficient of friction for tested materials

Figure 7 present comparative averaged plots of penetration depth for base alloy and obtained nanocomposites. Analysing presented plots it can be concluded that despite existence of trapped gas bubbles in material structure (figure 4) obtained nanocomposite reinforced with 3 vol.% of SiC nanoparticles has the lowest average value of penetration depth. In this case presence of nanoparticles of reinforcement managed to prevent movement of dislocations and on that to improve wear resistance and bearing capability [**Error! Reference source not found.**, **Error! Reference source not found.**]. Also it is noticeable that values of penetration depth for all tested materials are just slightly different in comparison to each other, but the higher differences could be noticed for higher value of normal load.

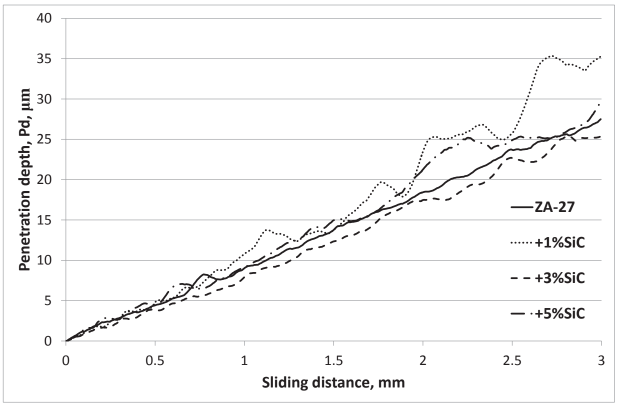


Figure 7. Averaged plots of penetration depth for tested materials.

The lowest average value of residual depth after scratch test exhibits base ZA-27 alloy than nanocomposite reinforced with 3 vol. % of SiC nanoparticles (Figure 8). This phenomenon could be explained by that the existence of trapped gas bubbles and agglomerates of nanoparticles cannot contribute to elastic relaxation of the nanocomposites. Scratch tests on base ZA-27 alloy revealed several smaller structural irregularities in comparison to the obtained nanocomposites.

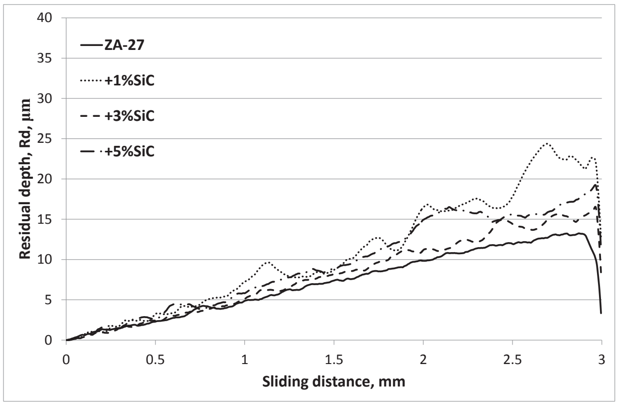
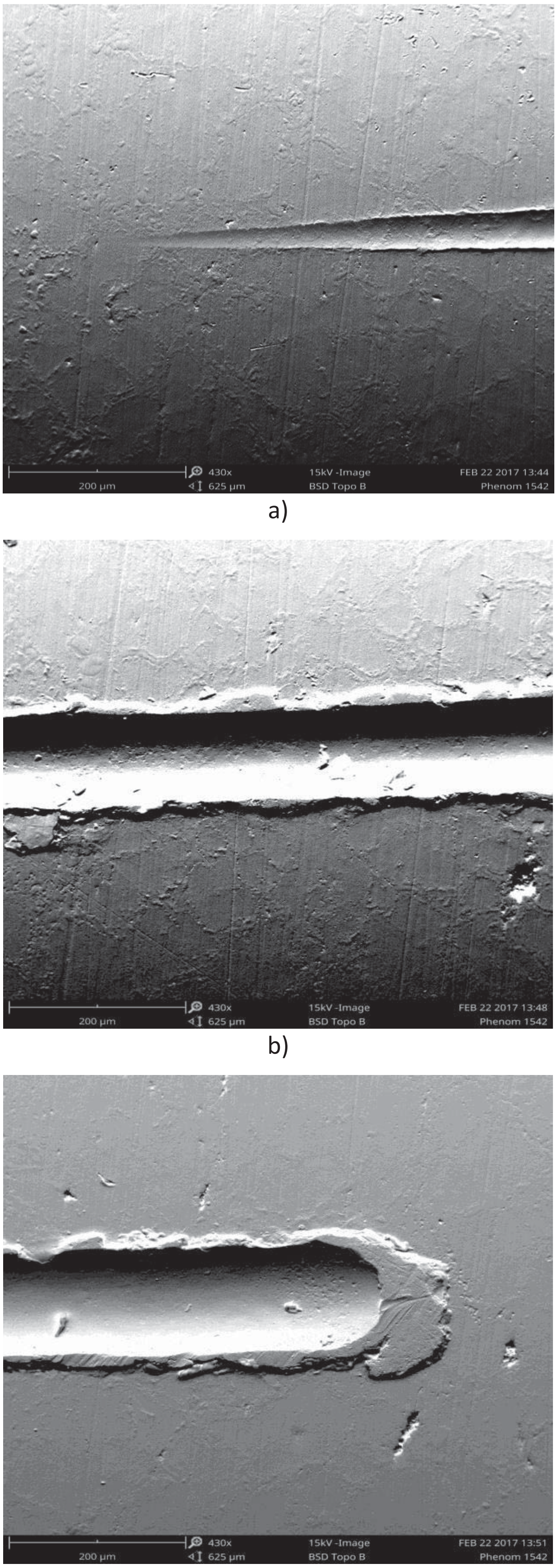


Figure 8. Averaged plots of residual depth for tested materials.

Obtained wear tracks were analysed using optical and scanning electron microscopy (SEM). Micro scratch tester is equipped with optical microscope which allows generating panoramic view of obtained wear track and matching with the corresponding results (coefficient of friction, penetration and residual depth plots). Generated panoramic view of obtained wear allows graphic presentation of noticed changes on plots. SEM equipped with topographic mode was used to analyse plastic deformation generated on the wear track sides (Figure 9).

SEM analysis of wear track shows that inside the wear track large number of small cavities is noticeable. Also analysing surrounding surface shows previously mentioned structural irregularities (Figure 9b and 9c). Pile up material on the sides of the wear track is apparently compact, especially at the end of the track where the material pile up is much bigger in comparison to the pile up on the side.



a)

b)

c)

Figure 9. Scanning electron microscopy of obtained wear track on nanocomposite reinforced with 1 vol. % of SiC: a) at the beginning, b) in the middle and c) at the end.

Regarding that it could be concluded that generated wear debris during the scratch is push in front of indenter, than deformed, compacted and pushed out due to conical geometry of indenter.

5. CONCLUSION

Micro scratch test was used to properly evaluate tribological properties of ZA-27 based nanocomposites reinforced with 1, 3 and 5 vol. % of SiC nanoparticles.

Micro scratch test revealed existence of structural irregularities of obtained nanocomposites. Structure irregularities such as gas bubbles and agglomerates of nanoparticles has a great influence on the penetration depth value.

The lowest averaged value of penetration depth during the scratch test exhibits nanocomposite reinforced with 3 vol. % of SiC nanoparticles.

Base ZA-27 alloy exhibits the lowest value of coefficient of friction during the scratch tests.

The lowest averaged value of residual depth exhibits base ZA-27 alloy.

SEM analysis of generated wear track showed plastic deformation and pile of material along the sides and at the end of the wear track.

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