Tribological Journal BULTRIB Vol. 6, 2016
Papers from the International Conference **BULTRIB '16**
27-29 October 2016, Sofia, Bulgaria
Society of Bulgarian Tribologists
FIT – Technical University of Sofia

TRIBOLOGICAL BEHAVIOR OF ZA-27 ALLOY BASED NANOCOMPOSITE REINFORCED WITH SiC NANOPARTICLES

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Abstract: *Dry sliding friction and wear behaviour of ZA-27 alloy nanocomposite reinforced with SiC nano particles of size 50 nm was evaluated. The content of SiC particles in the alloy was 1, 3 and 5vol. %. The nanocomposites were produced by the compocasting procedure. The SiC nanoparticles as reinforcement were added into the semi-solid ZA-27 alloy under intensive mixing. Mechanical characteristics of obtained nanocomposites were evaluated through hardness tests. A block-on-disc tribometer was used to evaluate the wear volume and friction coefficient, while 30CrNiMo8 steel disc was used as the counterface, under dry sliding conditions at different specific loads and sliding speeds. Wear tracks were examined using optical microscopy. Results indicated that hardness and wear resistance decreases with increasing the content of reinforcement in ZA-27 alloy.*
Keywords: *Wear, Friction, ZA-27, Nanocomposite*

1. INTRODUCTION

Zinc-Aluminium (ZA) alloys are widely used in numerous tribological applications and due to that this family of alloys is very attractive for researchers. Neither one other alloy does not provide such combination of strength, toughness and stiffness as casted zinc-aluminium alloys. In the beginning, content of aluminium was varied, starting from 8% [1, 2], than 12% [3] and finally 27% was proved to be the best balance of zinc and aluminium for tribological applications. Zinc-Aluminium alloys were developed to replace heavy conventional bearing bronze [2-7] and expensive aluminium alloys. These alloys contain a very small amount of copper which is the main reason why these alloys can be very economic and efficient replace for a large number of non-ferrous metals, while they possess higher strength, better wear resistance and lower casting temperature [8]. Main restriction for these alloys is working temperature. On elevated temperatures over 100°C mechanical properties of ZA alloys deteriorates [8, 9].

ZA-27 alloy is the most attractive for many researchers because of their great strength. Great mechanical and tribological properties makes them very applicable for journal bearings, thin walled castings, electrical components, automotive, industrial and agriculture machines and devices, valves etc. [10]. There are a numerous research investigation in order to improve mechanical and tribological properties of ZA-27 alloy, primary trough obtaining composite materials based on ZA-27 alloy. In order to improve frictional properties graphite as hard lubricant was added [11-13], while hard particles were added in order to improve wear resistance [14-19]. In order to combine benefits from hard particles and graphite as a hard lubricant, hybrid composite materials were developed [20]. ZA-27 alloy and their hard particle reinforced composites shown a good corrosion resistance [21-23].

This paper presents tribological investigation of nanocomposites based on ZA-27 alloy obtained by compocasting procedure. Composites are reinforced with SiC nanoparticles. Average nanoparticles size was 50 nm, while the content in the base alloy was 1, 3 and 5 vol. %. Among the various nanocomposites production procedures stirring casting is generally accepted as most cost-effective procedure and also due to mass production applicability compocasting was selected as nanocomposites obtaining procedure.

2. EXPERIMENT

2.1. Materials and method of fabrication

ZA-27 based nanocomposites reinforced with SiC nanoparticles with average size 50 nm were obtained using compocasting procedure. Chemical composition of the base ZA-27 alloy is presented in table 1. Compocasting procedure is carried out in two phases. The first phase is the preparation of semi-solid melt, then infiltration of reinforcement SiC nanoparticles (average size 50 nm) during intensive mixing of the melt. After infiltration of reinforcement nanoparticles the resulting mixture was stirred for 15 min at 1000 r/min and then it is poured in preheated mold. After cooling obtained nanocomposites are cut and then hot pressed on temperature 250°C and pressure of 350 MPa. After hot pressing, nanocomposites are cut into blocks for tribological test.

Table 1. Chemical composition of ZA-27 alloy

Alloy	Chemical composition (weight %)			
	Al	Cu	Mg	Zn
ZA-27	25-27	2 do 2,5	0,015-0,02	Balance

Before tribological tests hardness test and density measurement using Archimedes' principle were done, on base alloy and obtained nanocomposites. Hardness test was realised using diamond Vickers pyramid with normal load of 50 N. Obtained results are presented in table 2.

Table 2. Hardness and density values for tested materials

	Material	**Hardness, HV_5**	**Density, g/cm3**
1	ZA-27	122	4.845
2	ZA-27 + 1 vol% SiC	113	4.664
3	ZA-27 + 3 vol% SiC	112	4.650
4	ZA-27 + 5 vol% SiC	95,5	4.323

2.2. Tribological tests

Tribological tests were carried out in a computer aided block-on-disk sliding testing machine (developed at the Faculty of Engineering ex. Faculty of Mechanical Engineering) with the contact pair geometry in accordance with ASTM G 77–05. A schematic configuration of the test machine is shown in figure 1. More detailed description of the tribometer is available elsewhere [24].

The test blocks (6.35x15.75x10.16 mm) were prepared from obtained nanocomposite materials. The counter face (disc of 35 mm diameter and 6.35 mm thickness) was made of EN: 30CrNiMo8 steel of 62HRC hardness. The surface roughness of the counter face steel disk was Ra=0.192 μm, while the surface roughness of nanocomposites was around 0.09 μm.

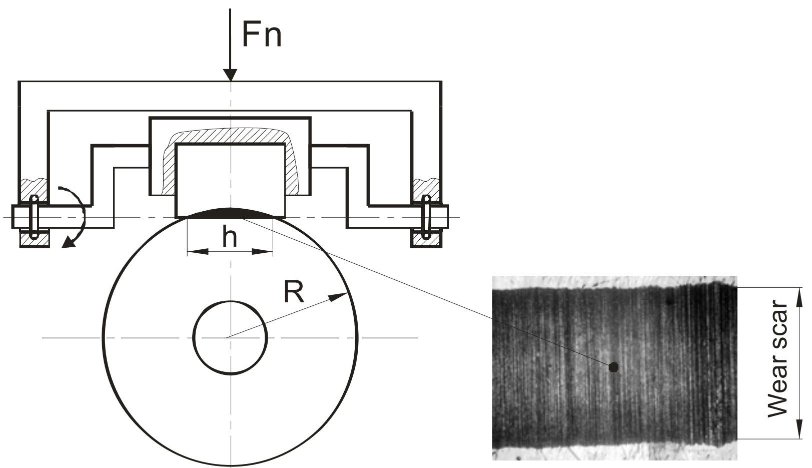

Figure 1. The scheme of contact pair geometry [24].

The tests were performed under dry sliding conditions at different sliding speeds (0.25 m/s, 0.5 m/s, 1 m/s) and applied loads (10 N, 20 N, 30 N). Sliding distance was 300 m and each experiment was repeated five times. The tests were performed at room temperature. The wear behaviour of the block was monitored in terms of the wear track (scar) width (figure 1). Using the wear track width and geometry of the contact pair, the wear volume (expressed in mm3) was calculated.

3. RESULTS

3.1. Wear

Values of calculated wear volume as function of normal load and sliding speed are shown on figure 2a-c and 2d-f, respectively. It should be noted that in the beginning contact is realised through line contact between block and steel disc, while it exceeds in area contact with development of wear. The increase of the normal load produced increase of wear volume (figures 2a-c), especially pronounced under the lowest sliding speed on this test, 0.25 m/s. The increase of sliding speed produced decrease of wear volume and based on that it can be clearly concluded that the lowest value of wear volume can be achieved under the lowest value of normal load and the highest value of sliding speed. figure 2d confirms previous statement. Mentioned trends are noticeable for all tested materials, both base ZA-27 alloy and nanocomposites reinforced with SiC nanoparticles.

It is noticeable from figure 2 that there is no clear distinction in wear volume values between tested materials. Under the lowest value of sliding speed the lowest value of wear volume exerts base ZA-27 alloy, while in all other cases the lowest value of wear volume exerts nanocomposite with 5 vol.% of SiC nanoparticles.

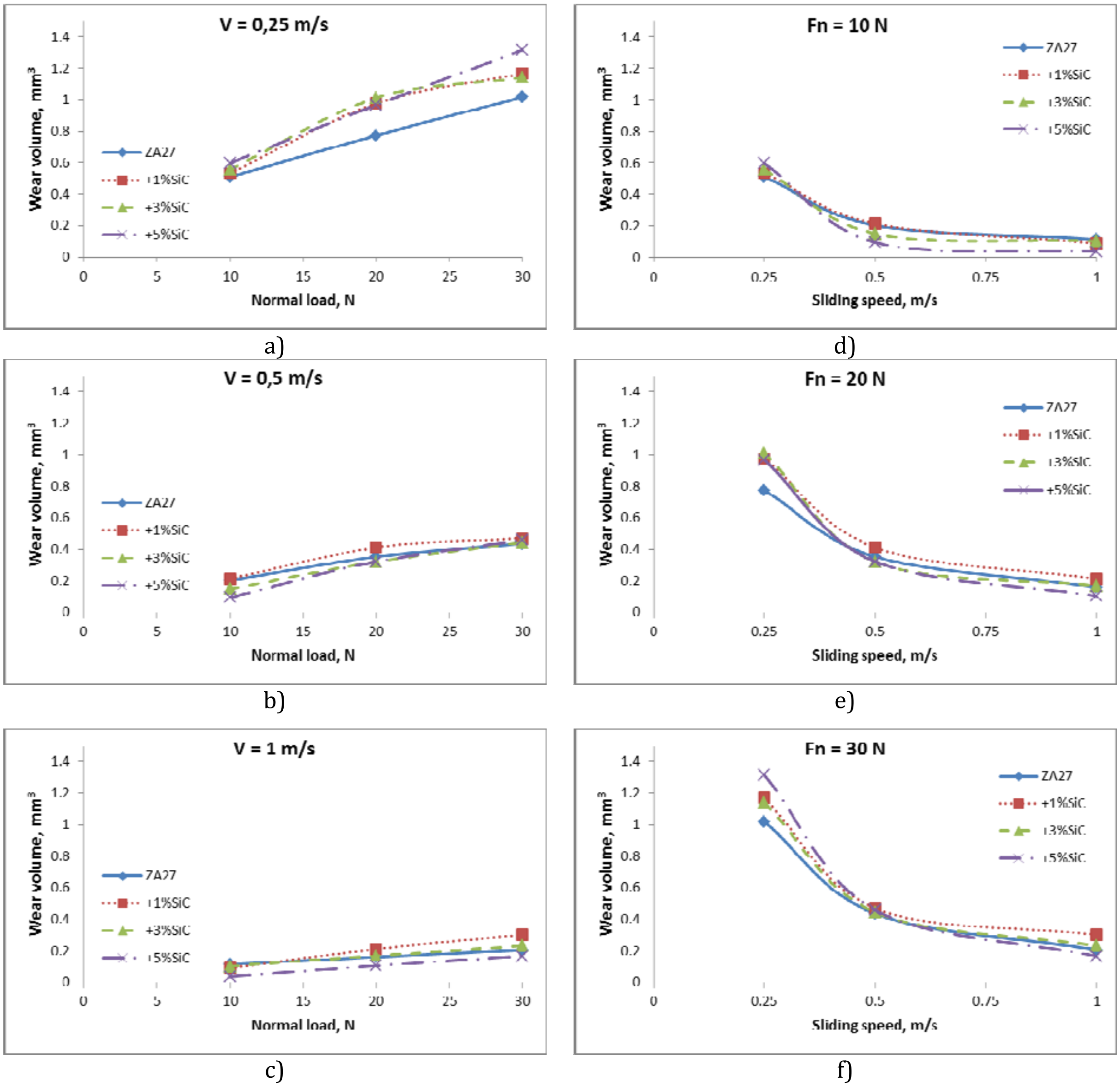

Figure 2. Dependence of wear volume on normal load (a-c) and sliding speed (d-f).

3.2. Friction

Obtained value of coefficient of friction as function of normal load and sliding speed is shown on figure 3a-c and 3d-f, respectively. The increase of the normal load and sliding speed produced increase of coefficient of friction, for all tested materials. The obtained values of coefficient of friction for all tested materials are very close and oscillate in the range from 0.38 to 0.49. Due to that it is impossible to conclude which of the tested materials possess the best frictional properties. Values of coefficient of friction presented in figures 3a-f are steady state values. Also, from presented plots on figure 3 it can be concluded that increase of reinforcement content in base za-27 alloy has no influence on coefficient of friction.

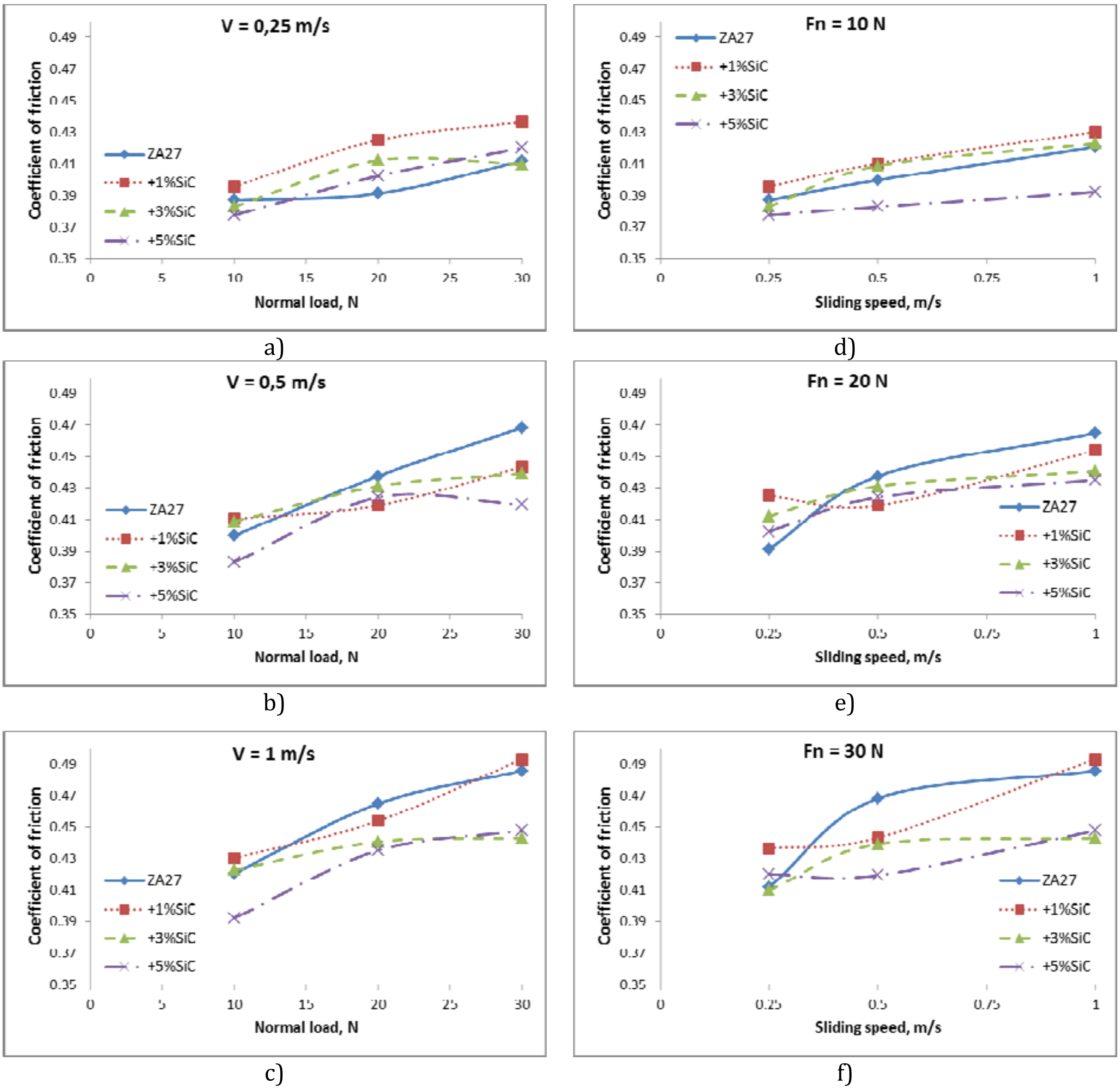

Figure 3. Dependence of coefficient of friction on normal load (a-c) and sliding speed (d-f).

4. DISCUSSION

From presented results it can be clearly noticed that there is no major differences in obtained values of coefficient of friction and wear volume between all tested materials. Based on obtained hardness and density values of tested materials, increase of reinforcement content in base alloy result in decrease of hardness and density of nanocomposites. Decrease of those values indicates on structural irregularities of obtained nanocomposites, such as porosity [25-27] and uneven distribution of nanoparticles in base alloy and formation of an agglomerate of nanoparticles [28-30].

Since the tribological tests were performed without lubrication increase in sliding speed results in increase of contact temperature and based on that oxidation process is pronounced. Decrease of wear volume value with increase of sliding speed indicates that on contact surfaces some kind of tribological layer was generated. Generated oxide layer on contact surfaces protects them and decrease intensity of wear processes.

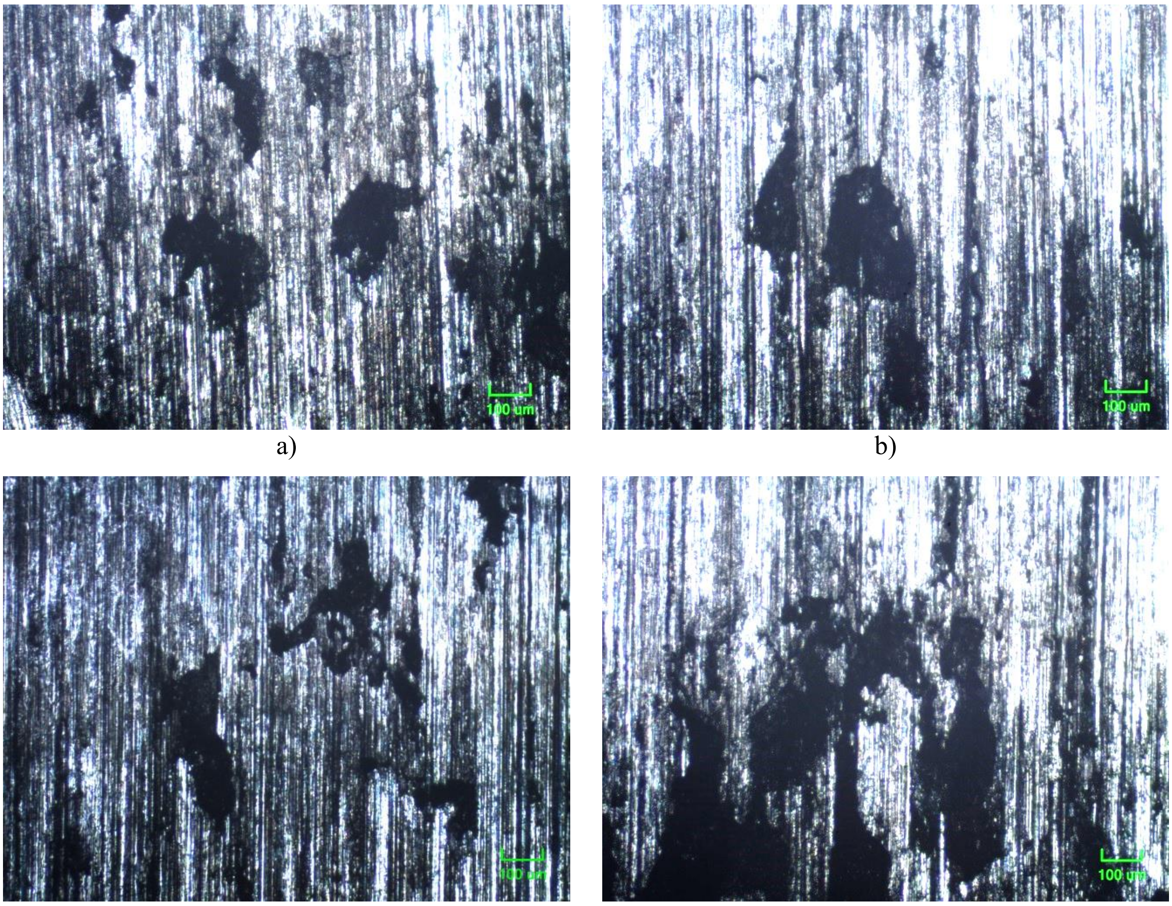

Figure 4. Wear tracks at 20N and 0.5m/s: a) base ZA-27 alloy, b) 1 vol.% of SiC, c) 3 vol.% of SiC and d) 5 vol.% of SiC.

Analysing optical microscopy images of generated wear tracks on tested materials, both base ZA-27 alloy (figure 4a) and obtained nanocomposites (figure 4b-c) the existence of pits within wear track that are surrounded with parallel grooves can be noticed. Parallel grooves within the wear track indicate that abrasive wear is the dominant wear mechanism while noticed pits are result of fragmentation from generated tribological contact layers. Fragmentation can be result of agglomerated nanoparticles in sub surface layer or a result of fatigue of the contact layer [31]. During fatigue process initial crack is generated in places where agglomerates and pores are present. Due to shear force crack develops until reaching the surface or merging with another crack which results in fragmentation of surface layer.

5. CONCLUSION

Paper presents tribological investigation of nanocomposites based on ZA-27 alloy, reinforced with SiC nanoparticles, with average size of 50 nm. It should be noted that nanocomposites were obtained using compocasting procedure, while the content of SiC particles in the alloy was 1, 3 and 5 vol.%. Conclusions drawn from this experimental work are as follows:

- Increase in volume content of reinforcement results in decrease of density and hardness due to existence of structural irregularities such as porosity and uneven distribution of nanoparticles and their agglomeration.

- Present structural irregularities diminishes positive effects of nanoparticles reinforcement and due to that increase volume content of reinforcement has no influence on wear and frictional properties.
- Wear resistance of all tested materials increases with sliding speed increase as a result of tribological layer generation.
- Dominant wear mechanism was abrasive wear combined with fragmentation of generated tribological surface layer.

ACKNOWLEDGMENTS

Research presented in this paper was supported by Ministry of Education, Science and Technology Development of Republic of Serbia, Grant TR-35021.

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