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WEAR PROPERTIES OF A356/10SiC/1Gr HYBRID COMPOSITES IN LUBRICATED SLIDING CONDITIONS

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Abstract: *This paper presents basic tribological properties of A356/10SiC/1Gr hybrid composites in conditions with lubrication. Hybrid composite specimen is obtained by compocasting procedure. A356 aluminium alloy is used as a base matrix alloy, reinforced with 10wt% of SiC and 1wt% of graphite. Tribological tests are done on advanced and computer supported tribometer with block-on-disc contact pair. By the experimental plan, test is conducted under three different values of sliding speed, three different values of normal load, different sliding distances, and also different lubricants. SEM and EDS are used for wear analysis. The analysis has shown the presence of MML, which means that there was transfer of material from steel disc to composite block.*

Keywords: *Hybrid composites, aluminium, SiC, graphite, wear, lubrication, MML.*

1. INTRODUCTION

Aluminium is the most attractive material in automotive, airplane, space and precise devices industry. Improvement of mechanical and tribological properties of aluminium can be achieved through aluminium reinforcement with the proper material and through creating composite material. The most effective improvement of these properties is achieved through creating hybrid composites with two or more types of reinforcements. By adding the ceramic reinforcement, mechanical properties of the matrix are changed, but in that case problem of machinability occurs. To improve machinability, the graphite is added to composite materials that are already reinforced with ceramic material. Presence of graphite reduces mechanical properties (hardness decreases), but tribological properties are improved [1-5].

Basavarajappa et al [6-8] have studied the tribological behaviour of hybrid composites with aluminum base Al2219 reinforced by SiC and graphite. They studied the tribological properties of hybrid composites with 5, 10 and 15% SiC and 3% Gr obtained with process of liquid metallurgy. The tribological tests show that wear decreases with increasing SiC content in the hybrid composite. With increasing sliding speed and normal load, wear rate of composites is growing. Mahdavi and Akhlaghi [9,10] have studied the tribological properties of Al / SiC / Gr hybrid composites obtained by In situ Powder Metallurgy process. Aluminum alloy Al 6061 is used as a base, reinforced with graphite 9% and 0 ÷ 40% SiC. The tribological tests are done on tribometer with pin on disc contact, and the composite with 20% SiC has the best properties. Further increase of SiC leads to increased wear of hybrid composites.

Suresh and Sridhara [11-14] have studied the effect of SiC content and graphite on the tribological behaviour of hybrid Al / SiC / Gr composites with aluminum base LM25 (Al-Si7Mg0.5) obtained by stircasting process.

Ames and Alpas have [15] studied the tribological testing of hybrid composites with a base of aluminum alloy A356 reinforced with 20% SiC and 3 ÷ 10% Gr. The tribological tests are done on tribometer with block on ring contact. The wear rate of hybrid composites is significantly lower than the wear rate of the base material without reinforcements, especially at low normal loads.

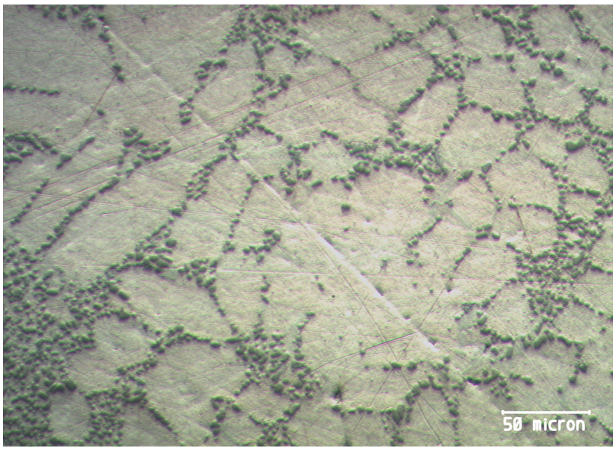
Vencl et al [16,17] have studied the tribological behaviour of hybrid composites with the A356 matrix reinforced with SiC, Al2O3 and graphite. The tribological tests are done on tribometer with pin on disc contact and show that the wear and friction coefficient decreases with addition of graphite.

This paper presents tribological behaviour of hybrid composites with aluminum base of A356 alloy reinforced with SiC and Gr obtained with compocasting procedure. The tests are done on computer aided block-on-disc tribometer under lubricated sliding conditions by varying the contact pairs (sliding speed and normal load).

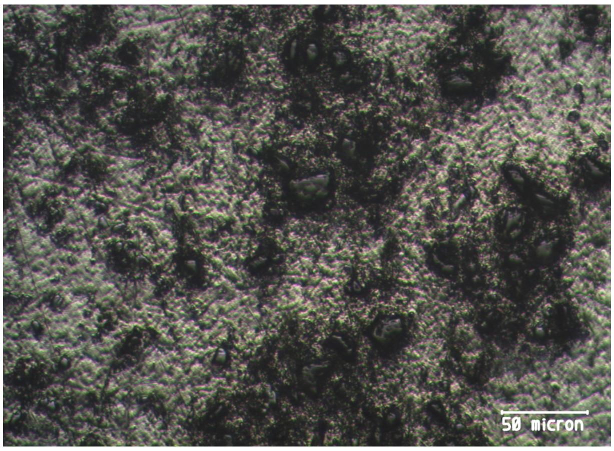
2. EXPERIMENT

2.1 The procedure for obtaining composites

Hybrid Al / SiC / Gr composites are obtained by the modified compo-casting procedure (infiltration of particles in the semi-solidified melt A356 alloy). sub-eutectic Al-Si alloys En AlSiMg0,3 (A356 alloy) is used as a basis. Using compocasting procedure, particle reinforcements are easily infiltrated / trapped. This solves the problem of wettability on the border base and reinforcements. The cost of composite producing with that process is much lower.



a)



b)

Figure 1. The structure of: a) base material A356, and b) hybrid composite Al/10SiC/1Gr.

Figure 1 shows the structure of the base material A356 and the hybrid composite with 10wt%SiC and 1wt%Gr. When mixing composites, particles of graphite have become fragmented with regard to original size of 35 μm. The picture shows the distribution of SiC particulate reinforcements, the size of 39 um.

2.2 Plan of experiment and description of equipment

Tribological tests are done on advanced and computer supported tribometer with block-on-disc contact pair in accordance with ASTM G77 standard. Contact pair consists of rotating disc of diameter Dd = 35 mm and broadness bd = 6.35 mm, and a stationary block of size 6.35x15.75x10.16 mm^3. The discs are made of steel 90MnCrV8 hardness of 62-64 HRC with grinded surfaces.

The tests were performed in lubricated sliding conditions on the samples with the best structural, mechanical and anti-corrosive properties.

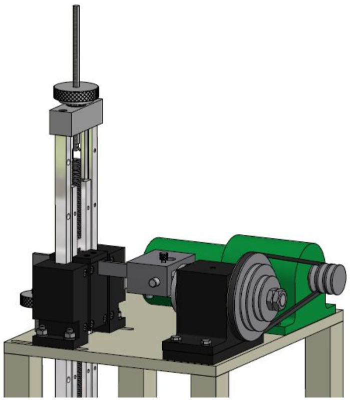


Figure 2. Tribometer.

The values of sliding speed (0.25 m / s, 0.5 m / s and 1 m / s) and the normal loads (40N, 80N and 120 N) are in accordance with the plan of experiment. The tests are performed for sliding distance of 2400 m.

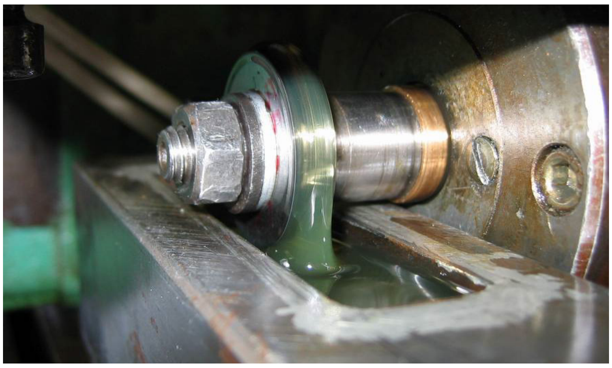


Figure 3. Lubrication of the contact pair.

All tests used the same hydraulic lubricant with improved anti-wear properties, viscosity VG46 (ISO 3848). Lubricant is housed in a small tank, and lubrication is done so that the bottom of the disc is immersed to up to depth of 3 mm into the small tank with lubricant, whose volume is 30 ml. During rotation of the disc, oil is continuously introduced into the zone of the contact and makes boundary lubrication of contact pair (Figure 3).

All experiments were repeated 5 times, and the mean values of obtained values are taken as authoritative.

3. RESULTS OF TRIBOLOGICAL TESTS

Results of tribological tests of hybrid composite Al/10SiC/1Gr and basic material A356 are shown in the following diagrams.

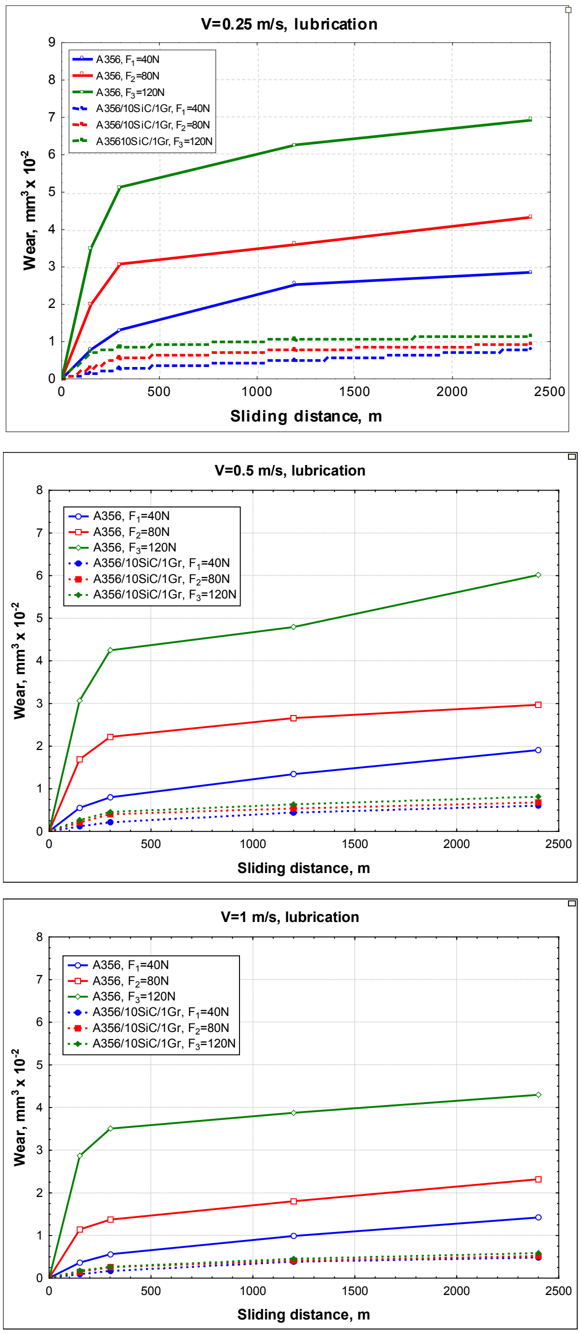


Figure 4. Wear volume for all three values of sliding speed.

Diagrams of wear volume are formed on the basis of wear scar which is obtained by measuring after 150 m, 300 m, 1200 m, 2400 m, and they are given for all three values of sliding speed (Figure 4).

It is obvious that the wear rate of the hybrid composites A356/10SiC/1Gr is several times less than the wear rate of the base material A356. With increase of sliding speed, wear rate of the hybrid composite A356/10SiC/1Gr and the base material are decreases. Wear rate dependence has almost linear dependence for all values of the normal loads (Figure 5).

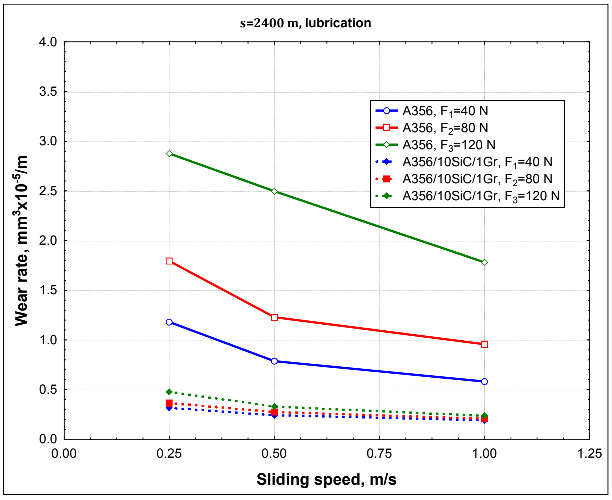


Figure 5. Wear rate dependence on sliding speed.

With increase of normal load, wear rate increases. This increase is particularly pronounced at the base material A356 (Figure 6).

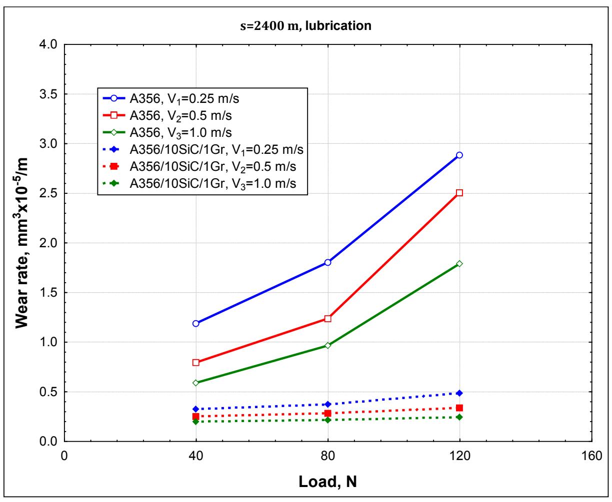


Figure 6. Wear rate dependence on normal load.

Wear rate dependence on normal load and sliding speed for sliding distance of 2400 m, is shown in Figure 7.

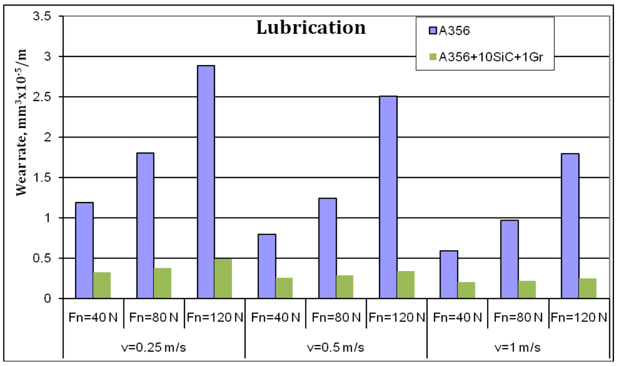
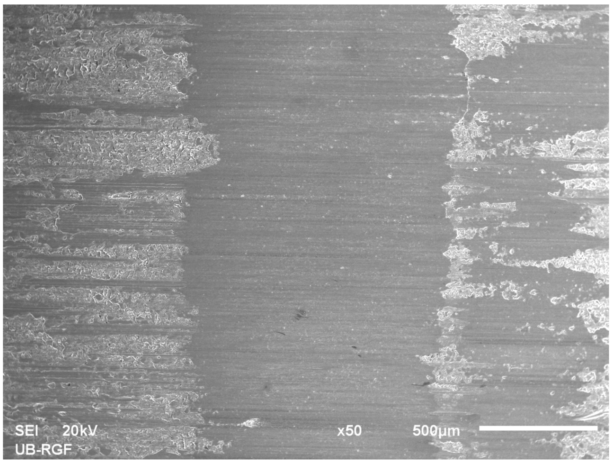
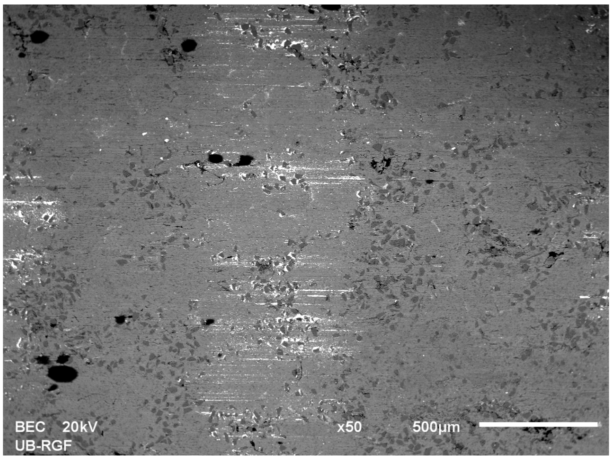


Figure 7. Wear rate dependence on normal load and sliding speed.

After the tribological tests, SEM analysis is performed for wear scar of base material A356 and hybrid A356/10SiC/1Gr composite, whose micro-photos are shown in Figure 8.



a)



b)

Figure 8. SEM micro-photos of wear scar:
a) base material A356,
b) hybrid composite A356/10SiC/1Gr.

4. ANALYSES OF OBTAINED RESULTS

The analyses of the obtained tribological results show that the wear rate or wear volume is much lower in the hybrid composites Al/10SiC/1Gr compared to the base material. Decrease of wear rate occurs due to the effects of SiC from hybrid composite in contact with a steel disc.

Wear rate dependence on normal load and sliding speed are shown in Figures 9 and 10 as the 3D plots. Wear rate is approximated by exponential function with a high correlation coefficient.

Both tested materials show that at least wear occurs at the maximum sliding speed of 1 m / s and the minimum normal load of 40N.

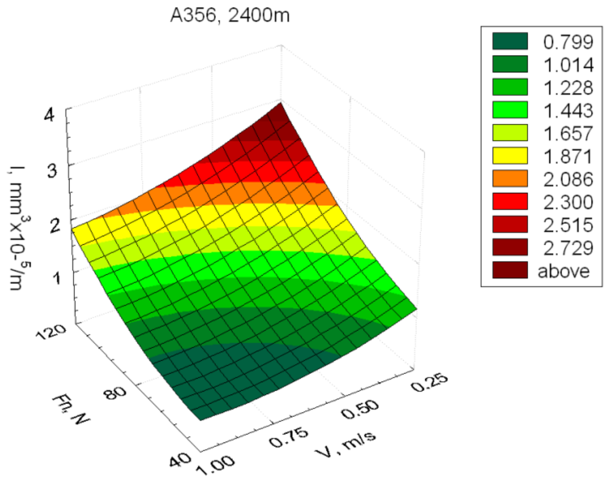


Figure 9. Wear rate dependence on the base material.

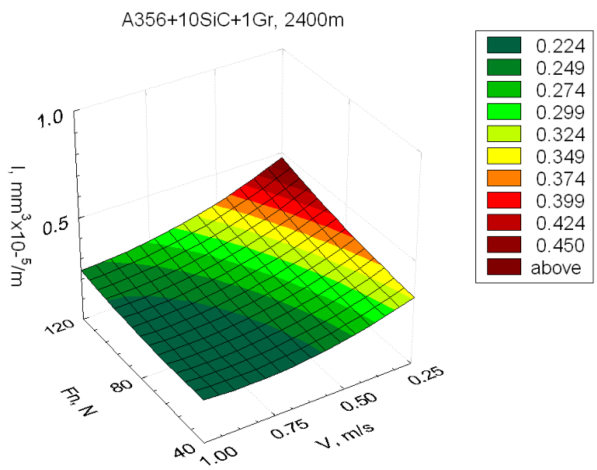


Figure 10. Wear rate dependence on the hybrid composites A356+10SiC+1Gr.

SEM microscopy shows that due to the contact of the SiC composites and Si phases from the basic A356, wear of steel disc occurs. Fe particles enter the surface layer of the composites and lead to the creation of mechanically mixed layer (MML). The formation of MML layer is characteristic of aluminum alloys reinforced with SiC [18-23]. Iron accumulates around the SiC particles taking a position of small particle of graphite. At some parts white lines appear enriched with iron oxides, which are consistent with the sliding direction (Figure 11).

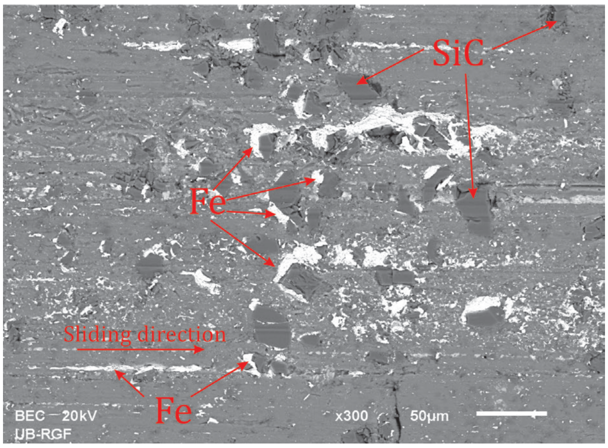


Figure 11. The accumulation of iron in the composite A356/10SiC/1Gr, 120 N, 0.25 m/s.

Figure 12 shows the SEM photograph of part of the hybrid composite A356/10SiC/1Gr. Wear scar is obtained by sliding speed of 0.25m/s and normal load of 120N in conditions of lubrication. At higher loads, the dominant wear mechanism is abrasive wear. SiC particles (darker) and iron particles (bright colours) are clearly visible on the scar. Confirmation of these assumptions is obtained by EDS analysis, as shown in the two spectrums. The first spectrum shows the presence of SiC particles, and the particles of iron and its oxides can be seen on second spectrum .

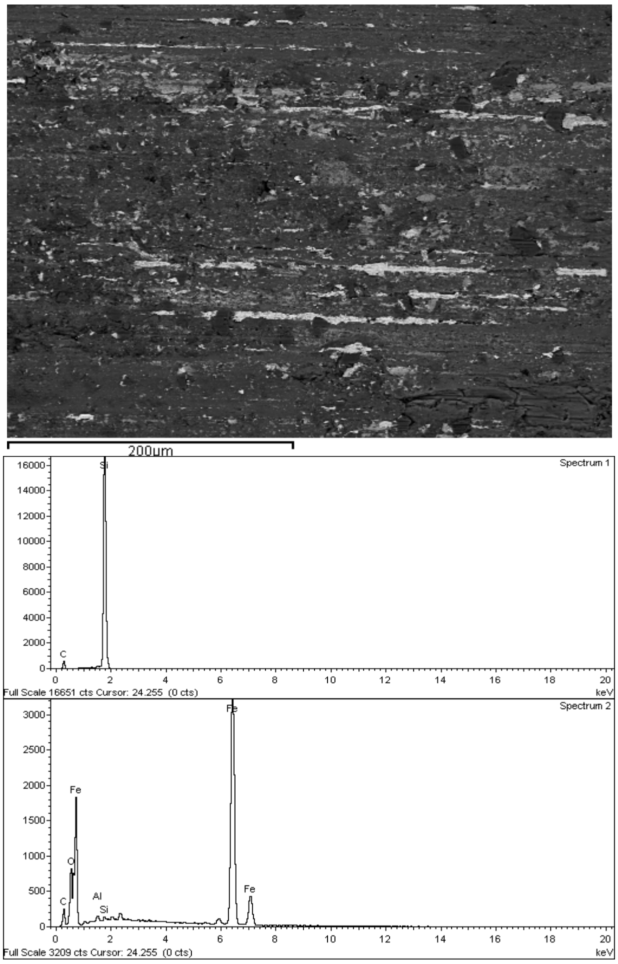


Figure 12. EDS analysis A356/10SiC/1Gr, 120N, 0.25m/s, SEM.

5. CONCLUSION

Wear tests of hybrid composites A356/10SiC/1Gr show their superior performance in relation to the base material A356. Applied compocasting modified procedure, in addition to low prices, confirms the good distribution of reinforcements in the composite.

Wear rate on A356/10SiC/1Gr hybrid composites is 3 ÷ 8 times lesser than the wear rate on the base material A356. It is especially big difference of wear rate at the lowest sliding speed of 0.25 m / s and maximum normal load of 120N. Wear rate decreases with decrease of normal load and increase of sliding speed.

SEM microscopy and EDS analysis confirm a good distribution of SiC reinforcements in the hybrid composite. Also, advent mechanically mixed layer (MML) is obvious, respectively, the appearance of iron and its oxides in the hybrid composite.

ACKNOWLEDGMENTS

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