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Tribological Properties of AlSi17Cu5Mg Alloy Modified with CuP Master Alloy with Various Speeds of Friction

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Abstract

The paper presents the influence of modification with phosphorus (CuP10) on the tribological properties of the alloy AlSi17Cu5Mg coupled abrasively with cast-iron EN GJL-350. Tests of coefficient of friction and wear of mass were conducted on tribological tester T-01. An important aspect in the assessment of the tribological properties is the analysis of initial material microstructure in reference to silumin which underwent modification with phosphorus. It was found that the difference in structure of tested materials, mainly sizes of primary silicon crystals significantly influences the tribological properties whereas the speed change of the friction knot does not have such big influence.

Key words: Friction coefficient, Power of friction, Tribology, Hypereutectic alloy Al-Si

1. Introduction

Traditional methods of producing cast alloys Al-Si are not sufficient particularly in the context of new, higher expectations which are to be met by modern construction materials. Variety of manufacturing techniques applied in foundry engineering allows for controlling the properties of ready products and pushing them in the correct directions and it this way achieving better working properties, mainly the improvement of wear resistance parameters in comparison with materials produced with the use of traditional methods. The wear of the material can be limited, i.e. by application of lubricating agent, modification of chemical composition or the change of speed of friction knot [1÷5]. But in case of materials which work in combustion chamber of combustion engine, additional requirements concentrate on the increase of pressure or working speed of particular elements. Such requirements can be met by new technologies which guarantee the achievement of highly applicable properties with small weight of the casts maintained at the same time [6÷10].

Activities based on the change of physical-mechanical properties (heat conductivity, thermal resistance) of friction materials are being conducted for working knots with intensive friction, after which an intensive heat precipitation occurs in a short time. It happens in case of piston-cylinder friction systems.

2. Aim and scope of tests

The aim of the paper is to assess the tribological properties of alloy AlSi17Cu5Mg which underwent modification with phosphorus (mandrel) in contact with cast-iron EN GJL-350 (engine disk) at different speeds of knot in conditions of dry friction. In order to meet the assumed aim, the scope of the paper includes, inter alia:

- methodological assumptions of tribological research with the use of tester T-01,
- analysis of the friction coefficient for various speeds of knot of tested alloy coupled with cast-iron EN GJL-350.

3. Material and test methodology

The tested material was AlSi17Cu5Mg silumin, similar to series A3XX.X type A390.0 for casting in sand moulds and casting dies meant for casting of pistons for combustion engines, compressor blocks and bodies, pumps and brakes.

Chosen silumin was prepared with foundry AlCu50 alloy, EN AM-AlSi20 alloy (according to PN-EN 575) and pure aluminum (according to PN-EN 576) in the form of ingots. Alloy was melted in melting pot made of SiC with capacity of 200 cm3 in induction vacuum furnace VSG 02/631 by Balzers company.

Modification with phosphorus in the amount of 0.05% mass was conducted with the use of key metal Cu-P (~9.95%P). Refining was conducted with the use of „Rafglin-3" preparation in the amount of 0.3% mass. Detailed technology of hypereutectic silumin preparation with addition of Cu, Ni and Mg was presented in paper [11]. Metallographic tests were conducted on light microscope MeF-2 Reichert. Metallographic microsections were conducted according to a standard procedure.

Tribological tests were conducted with the use of tester T-01 coupled in the pair of mandrel-plate. Tested coupling consists of static mandrel held down with force P to the rotating plate with given n speed. Device T-01 (fig.1) enables determination of friction coefficient and resistance to wear of tested materials. Driving motor of the device is automatically stopped after given time elapses or after given friction path and due to that fact the precise steering of the measurement process is possible.

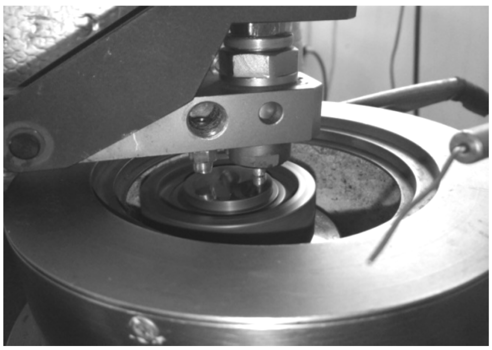

Fig. 1. Tribological tester T-01

Tests were conducted in accordance with norm DIN 50324. For test purposes the parameters were chosen in such a way so that they could fully represent the conditions of cooperation of rider ring with cylinder liner for combustion engine with power of about 100kW, because the used alloy is use for construction of pistons of combustion engines. The mandrel prepared from tested alloy had a diameter of 4mm and the diameter of the disc prepared from cast-iron EN-GJL-350 was 42 mm. The down-force was 0.8 MPa, and the set velocity was regulated 0.1;0.55 and 1.0m/s. Each test was conducted 10 times. During the tests the measurements and registration of the friction force Ft was conducted and then automatically calculated by the measurement system into the friction coefficient μ. Friction path was 1800m.

4. Test results and their analysis

Achieved results of friction coefficient by various knot speeds are presented in table 1. Partial course of the friction coefficient for test material after running at various speeds presents in Fig. 2.

Table 1.
Results of tests of associations AlSi17Cu5Mg alloy/cast iron EN GJL-350

Tested alloy AlSi17Cu5Mg	v, m/s	μ	σ_μ
Primary material	0,1	0,26	0,014
Material after modification	0,1	0,23	0,008
Primary material	0,55	0,27	0,012
Material after modification	0,55	0,25	0,009
Primary material	1,0	0,26	0,014
Material after modification	1,0	0,25	0,007

where:
μ – friction coefficient
σ_μ – standard deviation of friction coefficient

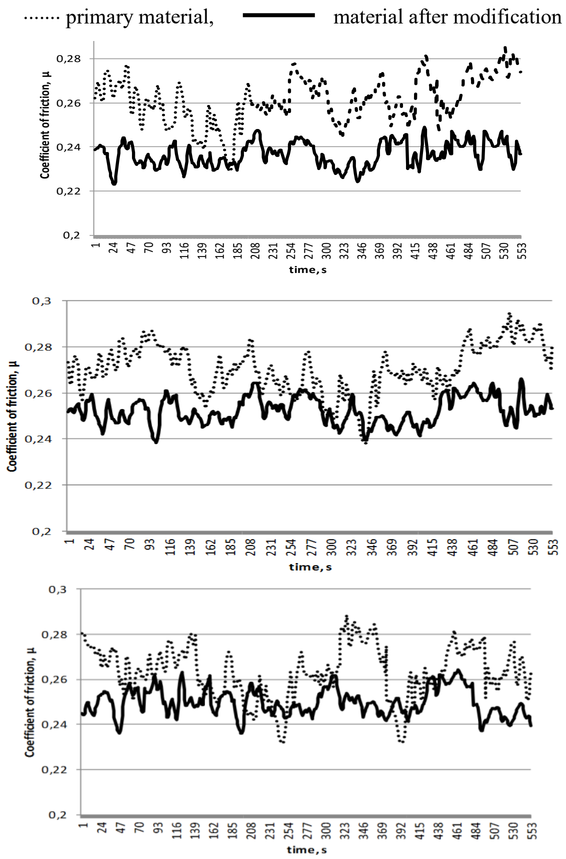

Fig. 2. Partial course of friction coefficient: a) v = 0.1 m/s, b) v = 0.55 m/s, c) v = 1 m/s

Presented tests show that modification of alloy causes the drop in friction coefficient in all tested speeds. The biggest difference was observed for speed 0.1 m/s, which equalled 0.3 and the smallest for speed 1 m/s which equalled 0.1. It should be underlined, however, that standard deviation for friction coefficient in the speed of 1 m/s was two times lower for the modified material than in case of initial (primary) material. Such tendency refers to all tested speeds where tests of modified material shown smaller amplitude of friction force which is directly converted into friction coefficient.

In Figure 3 to 5 the surface of mandrel prepared from alloy AlSi17Cu5Mg after friction, coupled with cast-iron EN GJL-350. On the co-operating surfaces of all mandrels and in all speeds the scratches can be observed which appeared as a result of friction and the direction of which is in accordance with the movement of the plate. Such scratches are smaller for modified material where silicon crystals are disintegrated whereas for initial material the scratches are bigger and correspond with the sizes of non-disintegrated silicon crystals.

a)

b)

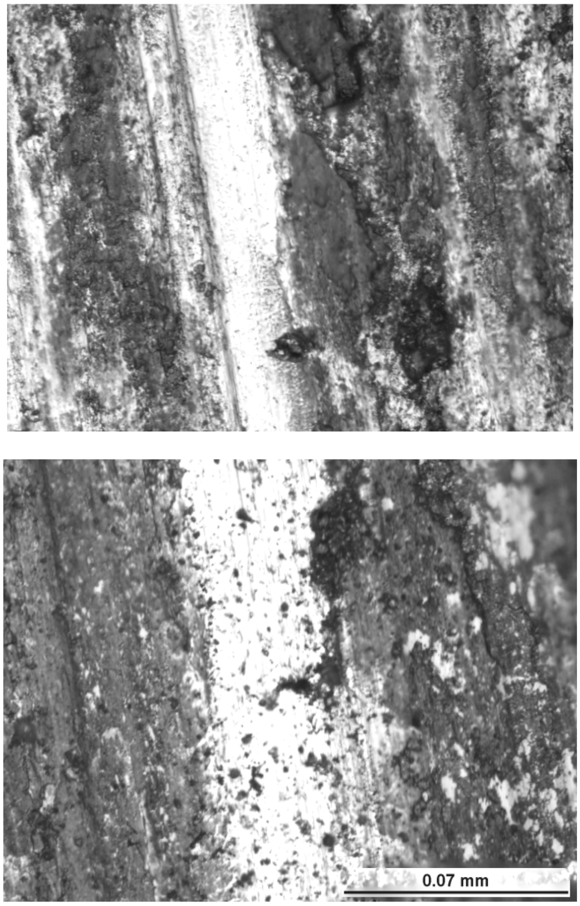

Fig. 3. Surface of AlSi17Cu5Mg alloy: a) no modified, b) modified with CuP - after friction at the speed of 0.1 m/s

On the surface of the initial material there are some broken-out section visible remaining after big silicon crystals (fig. 3a, 5a), whereas in case of modified material the disintegration of silicon crystals is visible but only by very big magnifications (fig. 3b). Such observations were made for all tested speeds and it is also visible in the partial course of friction coefficient (fig. 2), which for initial material is characterised with big variability – standard deviation.

Together with the speed increase the friction coefficient for both materials is similar and it can be confirmed by the characteristics of the surface (Fig. 5). In case of first two tested speeds the differences are visible, but in case of speed of 1 m/s they overwrite.

a)

b)

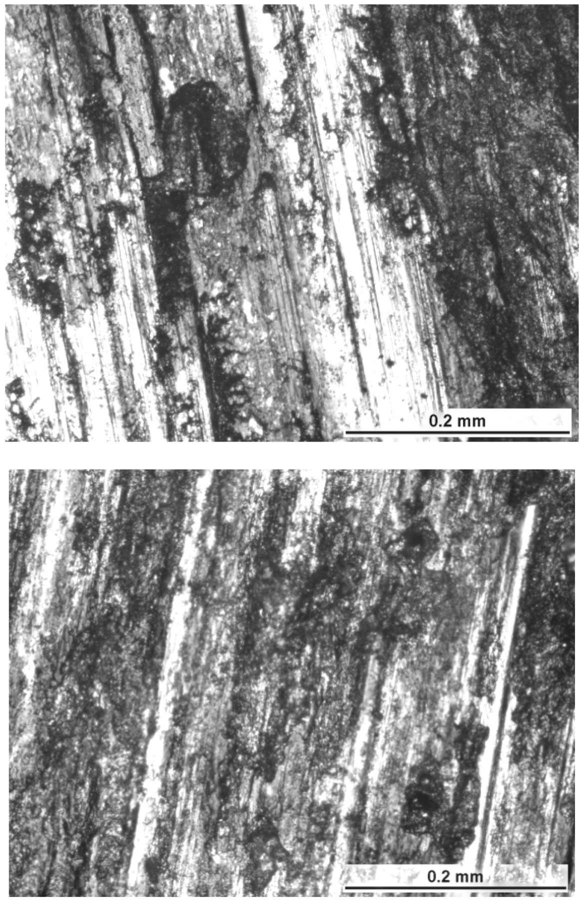

Fig. 4. Surface of AlSi17Cu5Mg alloy: a) no modified, b) modified with CuP – after friction at the speed of 0.55 m/s

5. Summary

Conducted tests with the use of tribological tester T-01 for AlSi17Cu5Mg cast alloy have shown that modification with phosphorus beneficially influences the dry friction conditions for all tested speeds. An equally important aspect is the visible decrease of amplitude of instantaneous power of friction (Fig. 2) which positively influences the whole system of friction coupling. It shows that non-fragmented silicon crystals in initial material every given period of time get removed and the consequence of it is a temporary pitch in the power of friction with following drop in its value. Such situation is definitely not beneficial as it can lead to the cracking of material because of temporary existing forces which can exceed the plasticity limit of the tested material and lead to permanent damage. Additionally, a gradual defragmentation of primary silicon crystals occurs and at the same time they scratch the surface with deep grooves. It influences the increase of wear of both the plate and the mandrel of the tested tribological system.

It is also known that coarse-grained structure has a negative influence on the resistance properties and the ability of the casts to be mechanically processed. Due to that fact the key role in application of Al-Si alloys in industry is grain refining of the structure, particularly decrease of sizes and even distribution of primary Si crystals in the matrix of the solution α(Al). It can be achieved, i.e. by modification, which causes creation of more "plates" for heterogeneous nucleation of such divisions.

a)

b)

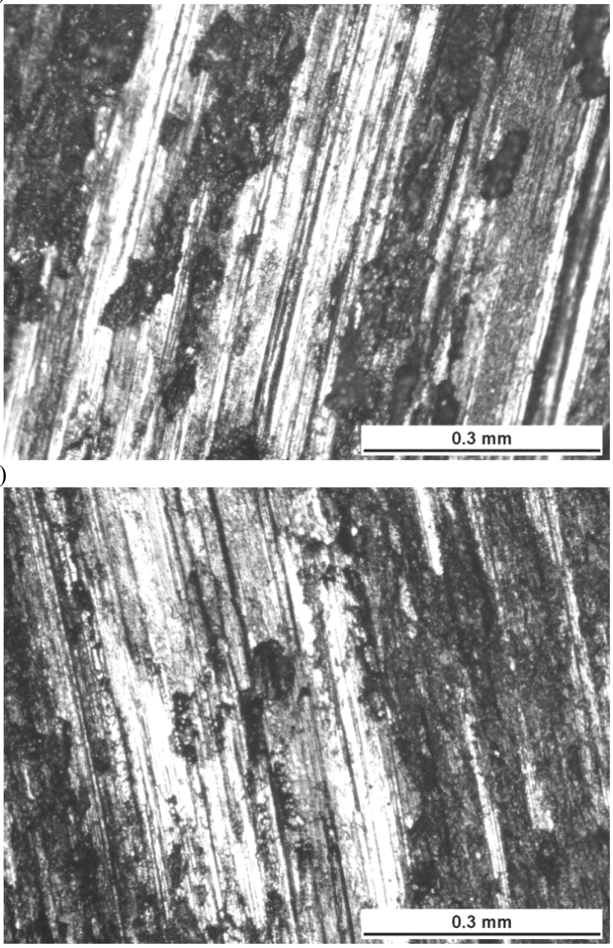

Fig. 5. Surface of AlSi17Cu5Mg alloy: a) no modified, b) modified with CuP – after friction at the speed of 1.0 m/s

Increase in the wear of plate and the mandrel of the tribological system, similarly to the front of initial material, causes additional scratches on the surface and influences the growth of wear but to a smaller extent. To sum up, it can be stated, that:

- modification of alloy AlSi17Cu5Mg with phosphorus leads to decrease of the friction coefficient when coupled with cast-iron EN GJL-350 for all tested speeds,
- despite the fact that modification of alloy AlSi17Cu5Mg with phosphorus leads decrease of the friction coefficient there has been a phenomenon of chipping of chosen silicon crystals observed. That is why it is necessary to conduct further tests on the assessment of the modification process and its influence on friction properties of AlSi17Cu5Mg in contact with cast-iron.

References

[1] Guo, J., Liu, Y., Fan, P. & Qu, H. (2010). Modification of electroless deposited Ni-P master alloy for hypereutectic Al-Si alloy. *Journal of Alloys and Compounds 495*, 3005-3010.

[2] Xu, C.L., Wang, H.Y., Yang, Y.F. & Jiang, Q.C. (2007). Effect of Al-P-Ti-Tic-Nd_2O_3 modifier on the microstructure and mechanical properties of hypereutectic Al-20 wt. %Si alloy. *Materials Science and Engineering A 452-453*, 341-346.

[3] Dercz, G. & Piątkowski, J. (2010). Rietveld quantitative and structural analysis of the Al-W master alloy for silumin modification. *Solid State Phenomena 163*, 161-164.

[4] Leszczyńska-Madej, B. & Madej, M. (2013). Tribological properties of the plastically consolidated aluminum powders. *Tribologia 1*, 91-104.

[5] Dienwiebel, M., Pohlmann, K. & Scherge, M. (2007). Origins of the wear of AlSi cylinder bore surfaces studies by surface analytical tools. *Tribology International 40*, 1597-1602.

[6] Piątkowski, J. (2011). The effect of Al-17wt.%Si alloy melt overheating on solidification process and microstructure evoluation. *Solid State Phenomena 176*, 29-34.

[7] Zuo, M., Liu, X. & Sun, Q. (2009). Effects of processing parameters on the refinement of primary Si in A390 alloys with a new Al-Si-P master alloy. *Journal of Materials Science 44*, issue 8, 1952-1958.

[8] Piątkowski, J. & Gajdzik, B. Testing phase changes in Al-Si cast alloys with application of thermal analysis and differential calorimetric analysis. *Metalurgija 52/4*, 469-472.

[9] Piątkowski, J. (2009). The phosphorus interaction on the process forming of primary structure of hypereutectic silumins. *Archives of Foundry Engineering 9*, 125-129.

[10] Figlus, T. & Stanczyk, M. (2014). Diagnosis of the wear of gears in the gearbox using the wavelet packet transform. *Metalurgija 53, issue 4*, 673-676.

[11] Piątkowski, J. (2013). *Physical and chemical phenomena affecting structure, mechanical properties and technological stability of hypereutectic Al-Si alloys after overheating*. Silesian University of Technology, Gliwice (in Polish).