SELECTED TRIBOLOGICAL CHARACTERISTICS OF A390.0 ALLOY AT ELEVATED TEMPERATURE UNDER DRY FRICTION CONDITIONS

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The article presents the tests determining the coefficient of friction μ and the amount of wear for the A390.0 alloy combined with EN GJL-350 cast iron at elevated temperature of up to 200ºC under dry friction conditions. It also presents the results of research concerning mechanical properties (HB, HV, Rm) and yield properties ($R_{0,2}$, A_5, Z) of the alloy examined. The A390.0 alloy is used for manufacturing pistons for spark-ignition internal combustion engines, therefore the research parameters were selected so as to correspond to the conditions inside a spark-ignition turbocharged internal combustion engine with the power of up to 100 kW. The research was conducted in order to determine whether the alloy analyzed meets excessive wear resistance requirements, which are imposed on piston materials to be used in modern spark-ignition turbocharged internal combustion engines.

The A390.0 alloy belongs to AlSi casting alloys. The properties of these alloys are determined by the state of their structure, i.e. mainly the size, the distribution of intermetallic phases in the metallic matrix, and the morphology of eutectics. As the silicon content approaches hypereutectic composition, the influence of the refinement of grains containing solid solution dendrite families decreases, and the significance of the morphology of primary silicon crystals and their uniform distribution in the matrix increases. The most frequently occurring forms of primary silicon in hypereutectic silumins are: star-shaped, polyhedral, dendritic (at rapid cooling), and ornament. They are precipitations assuming the structures of i.a. radial plates, needles, polyhedrons, long-pointed stars – unfavorable from the perspective of performance and machinability of hypereutectic silumins Such an unfavorable structure may be transformed i.a. as a result of modifications with, for instance, individual or combined phosphorus-, titanium-, and boron-based master alloys.

The objective of such modifications is to increase the density of heterogeneous bases and to hinder nucleation of silicon crystals, and, what it involves, to limit their growth. However, it should be noted that the refinement of silicon crystals alone is insufficient. It is also necessary to obtain the proper shapes of silicon crystals being close to spheroidization. As an example of that may serve modified fine-grained silicon crystals with sharp edges having an adverse effect on e.g. tribological properties. Consequently, it is necessary to develop manufacturing processes enabling multidirectional optimization. The research concerned the A390.0 alloy, whose chemical composition is given in Table 1, modified with phosphorus (0.05% by wt. of the alloy) using the CuP10 master alloy. The alloy was refined using Rafglin-3 preparation (0.3% by wt.)

Alloy	Chemical composition, mass %						
	Si	Fe	Cu	Mn	Mg	Zn	Al.
A390.0	16.8	0.573	4.95	0.189	1.001	0.145	remainder

Table 1. Chemical composition of the A390.0 alloy

The tests were performed in a pin-on-disc system, according to the ASTM G 99 standard. This means that the coefficient of friction may be determined after grinding-in, i.e. when the whole surface of the pin exhibits traces of wear. Otherwise, the test should be repeated. In the tests conducted, the pin was made of the A390.0 alloy, and the disc of the EN GJL-350 cast iron. The tests were carried out for technically dry friction, under a load of 1.3 MPa, a velocity v = 1.2m/s, at variable temperatures of 100ºC, 125ºC, and 150ºC. The path of friction was 1000m. The parameters were selected so as to correspond to the conditions inside a turbocharged spark-ignition internal combustion engine with a power of 150kW and a direct fuel injection. Because of the high load, in all cases the whole surface of the pin showed traces of wear. In total, 12 tests were performed. The mass decrement of the mating pin and disc elements was measured with a Radwag AS 220/C/2 balance whose precision was 0.1mg. The observations of the surface after friction were performed with an Olympus SZX9/8X stereoscopic microscope and a Hitachi S-3400N scanning electron microscope.

Fig.1 presents the surface of the disc and the pin after applying friction at 125ºC. Fig. 2 shows the scale of material wear of the disc and the pin in the tribo-pair analyzed, while Table 2 presents the results of friction coefficient.

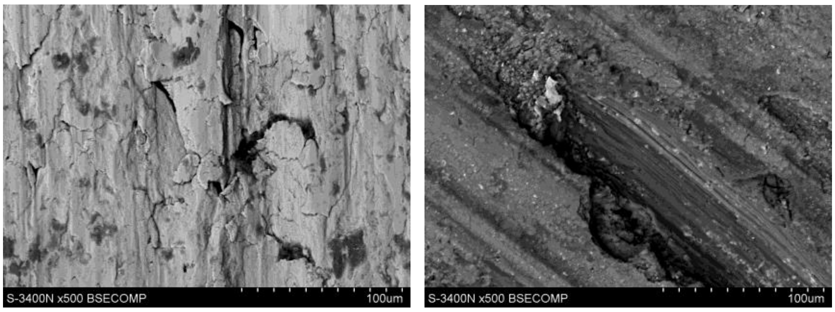

Fig. 1. The surface after friction at 125ºC: a) disc (EN GJL-350), b) pin (A390.0)

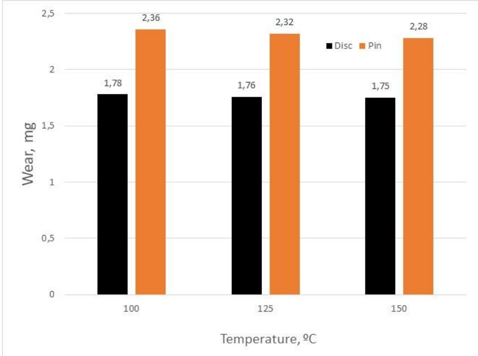

Fig. 3. The scale of material wear in the tribo-pair tested

Alloy examined: A390.0	Temperature, ºC	μ	σ_{μ}
Sample No. 1	100	0.33	0.008
Sample No. 2	125	0.33	0.005
Sample No. 3	150	0.32	0.002

where: μ – friction coefficient, σ_{μ} – standard deviation of friction coefficient

Table 2. The results of the A390.0/EN GJL-350 tribo-pair tests

The highest coefficient of friction μ = 0,33 was obtained for two temperatures examined, 100ºC and 125ºC, whereas the lowest, μ = 0,32, was obtained for the highest temperature, 150ºC. It is worth noting, however, that for 100ºC the standard deviation was 0.008 whereas for 125ºC it was at the 0.005 level. For the temperature of 100°C the wear was 1.78mg for the disc (EN GJL-350) and 2.36mg for the pin (A390.0). For the temperature of 125°C the respective wear was 1.76mg for the disc and 2.32mg for the pin. For the highest temperature, 150ºC, the wear was at the level of 2.28mg for the pin and 1.75mg for the disc.

The application of air supercharging (turbo charger), particularly in spark-ignition engines, and the installation of direct injection systems changed the characteristics of loads present during the operation of a car-engine piston to such extent that it became necessary to test the already-existing materials under new operating conditions. On the basis of the tests performed, it may be concluded that the A390.0 material modified with the CuP master alloy without additional modifications does not fulfill the requirements characterizing operating conditions of modern internal combustion engines. Values of the friction coefficient for all tested loads exceeded the level of 0.33. The research studies were deliberately conducted at elevated temperatures in order to most accurately reproduce the actual conditions of engine operation. The aforementioned studies indicate a necessity to search for new material solutions, and they prove that the materials in use so far have ceased to meet the design requirements of new engine technologies

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