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INFLUENCE OF THE METAL-PLATING ADDITIVE "VALENA" ON WEAR OF THE SPHEROIDAL GRAPHITE CAST IRON MICROALLOYED BY Sn

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Abstract: *Wear of moulded spheroidal graphite cast iron alloyed by Sn is studied under conditions of boundary lubrication. The lubricant contains a metal-plating additive "Valena". Five types of moulded spheroidal graphite cast iron specimens are studied with various wt. % Sn: without Sn (0 wt. % Sn), as well as with 0.018, 0.020, 0.032 and 0.051 wt. % Sn. Three types of lubricants are applied: lithium grease NLGI 3, motor oil SAE 15W-40 and transmission oil SAE 80W-90, in cases without and with 0.5 wt. % content of "Valena" metal-plating additive. The study is carried-out under conditions of constant load, sliding distance and velocity, using the pin-on-disk tribometer. Results of the influence of Sn content on the specimens wear are obtained for the various lubricant media.*

Keywords: *wear, additive Valena, tin, spheroidal graphite, cast iron.*

1. INTRODUCTION

The spheroidal graphite cast iron is a high strength construction material with a complex of properties which make it different from the conventional Fe-C alloys, namely high tensile strength, high plasticity and wear resistance, low susceptibility to stress raise, good cutting, casting, as well as welding ability.

The spheroidal graphite cast iron shows wide scope of tribological application in machinery construction, engineering and transport. It is used in the production of reduction gears, plain bearings, guide bars, gear wheels, etc. which operate in various regimes: hydrodynamic, boundary and mixed lubrication, abrasive wear, erosive wear, abrasive wear in aggressive environment, etc. [1-11].

Elements of spheroidal graphite high-strength cast iron, doped mainly with copper, are manufactured in the factory "Osam" in the city of Lovech, Bulgaria. Adding small quantities of tin (Sn) to the melt results in perlitization of the metal base, improved strength, and preserved graphite shape. Further increase of Sn quantity changes the spheroidal shape of graphite. Additional study is needed for the determination of the optimal content of Sn in order to provide perlite structure of the metal matrix preserving the spheroidal graphite form.

Tin price is higher than that of copper; however the used quantity of Sn is 8 to 10 times lower, so use of Sn is advantageous.

Investing in quality of the contact systems is related to optimizing the interconnection of quality with material, surface engineering and tribology. That is an important challenge facing our society, which is reflected thoroughly in the development of the first tribological network under CEEPUS project CIII-BG-0703 "Modern Trends in Education and Research on Mechanical Systems – Bridging Reliability, Quality and Tribology" [4,12-14].

The paper lays emphasis on the ways of quality improvement of contact systems in lubricating conditions in two lines: considering the influence on system's properties of the doping element Sn in the cast iron matrix on the one hand, and, on the other hand, considering the impact between the system, and lubricant with additive, illustrated with the study of the metal-containing oil-soluble additive "Valena" [2,15-17].

In particular, the paper aims solving two problems: Firstly, study of Sn influence, as microalloying element in spheroidal graphite cast iron, on the wear characteristics under conditions of boundary lubrication with various conventional lubricants, and, secondly, study of the influence of Valena additive on the wear of spheroidal graphite cast iron under the same lubrication regimes. The physical, chemical and tribological properties of this additive are not systematically studied, which is one of the reasons for the present study.

2. MATERIALS, DEVICES AND PROCEDURE

Sample specimens of high-strength cast iron were with the following wt. % contents of Sn: 0 (without Sn), 0.018, 0.020, 0.032 and 0.051. The specimens are made from samples casted in "Osam" factory in the city of Lovech (Bulgaria), by using the "Tundish casting process". After the Sn microalloying, the cast iron brands GJS 400-15, GJS 500-2, GJS 600-3 and GJS 700-2 were obtained. Hardness of the tested specimens (with different content of Sn) is shown in Table 1.

Table 1. Hardness of the tested specimens

Sn [wt. %]	0	0.018	0.020	0.032	0.051
Hardness, HB	179	197	203	262	277

Metallographic analysis of the microstructures, by means of optical microscope Neophot 32, is done by using microsections of the studied cast iron samples.

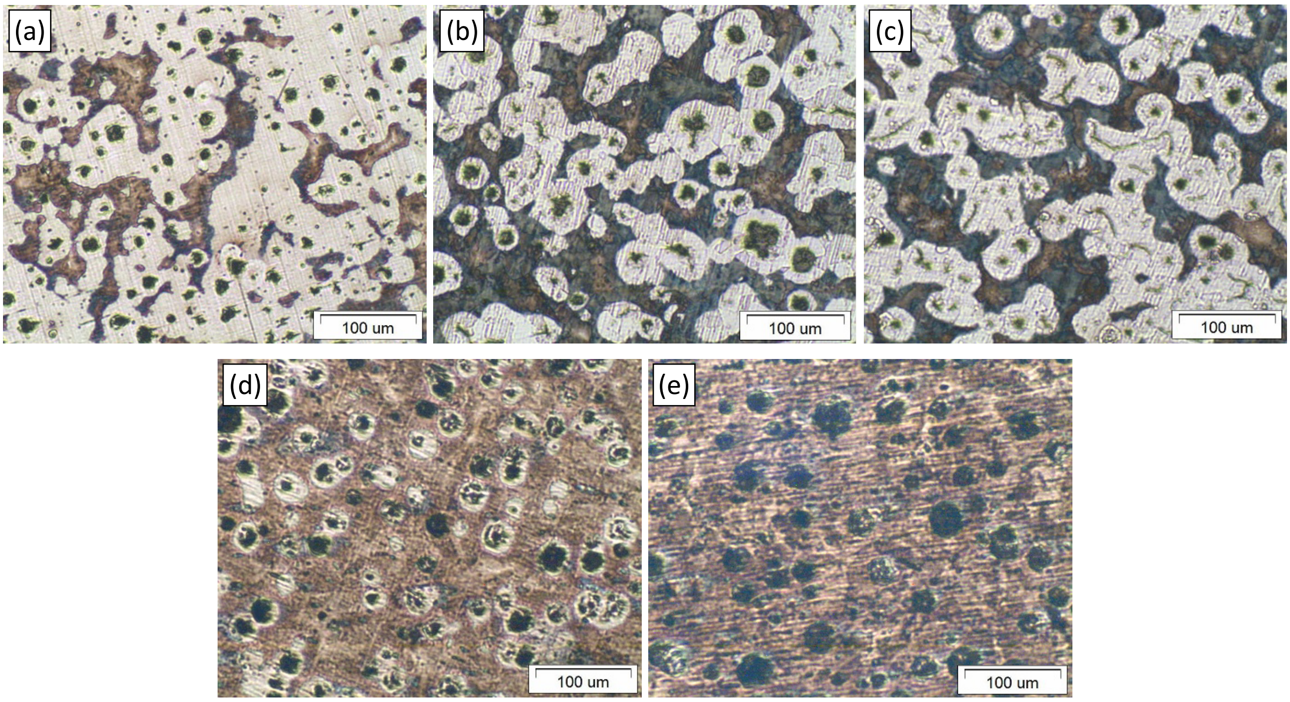

Figure 1. Microstructure of the tested cast iron specimens: (a) 0 wt. % Sn, (b) 0.018 wt. % Sn, (c) 0.020 wt. % Sn, (d) 0.032 wt. % Sn and (e) 0.051 wt. % Sn

Figure 1 shows the microstructures of the tested specimens with different content of Sn.

Three types of lubricant are used for the study of specimens' wear, namely: lithium grease NLGI 3 (commercial name: Litol-24 [18]), motor oil SAE 15W-40 and transmission oil SAE 80W-90, without and with 0.5 wt. % Valena additive. The additive called "Valena" is a metal-containing oil-soluble composition for lubricants, registered as Russian patent in 2005 by Babel et al. [15]. It is a dark-green plastic material designated to improve the tribological properties of lubricants, and in particular to improve the friction, wear and seizure properties, as well as the protection against hydrogen wear.

Wear tests are carried-out on the tribometer shown schematically in Figure 2.

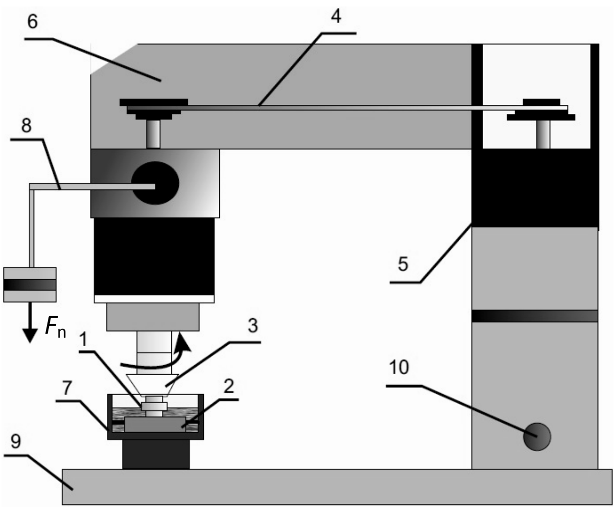

Figure 2. Device for wear study under lubricated conditions: 1 – specimen; 2 – counter-body; 3 – specimen holder; 4 – belt; 5 – motor; 6 – case; 7 – lubricant tray; 8 – arm; 9 – footstall; 10 – motor switch

The dimensions of the specimen and the counter-body are given in Figure 3. The surface of all specimens was grinded prior to the testing to the roughness of Ra = 0.453 µm.

Before, during and after each test, specimens were degreased and cleaned, and weighed in order to calculate the mass loss. Parameters of the experiment were as follows: normal load F_n = 39.24 N; apparent contact area A_a = 78.54 mm^2; apparent contact pressure p = 0.5 MPa; peripheral sliding speed v = 0.26 m/s; test duration t = 60 minutes; counter-body material: structural steel S460QL (EN 10025-6), heated at 840 °C and cooled in oil up to hardness of 60 HRC.

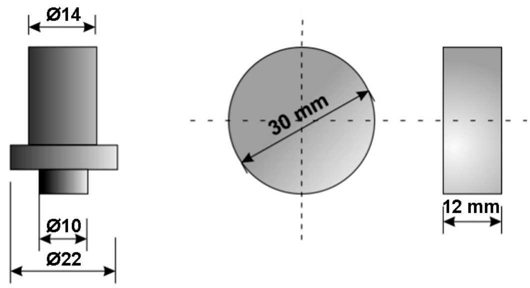

Figure 3. Dimensions of the specimen and the counter-body

3. RESULTS

Using the above described device and procedure, experimental results are obtained for three different lubricants, each of them without and with Valena additive, and five different specimens (different wt. % Sn). Some of the results (transmission oil SAE 80W-90) of those tests are already published [10].

The obtained results of the mass loss, for different lubricants and wt. % Sn, are shown as a function of sliding time, in the form of the comparative wear curves (Figs. 4 to 9). Wear curves were formed with the following method: mass of test specimens was measured at the beginning of the test and at each pause in testing (after 20, 30, 40, 50 and 60 minutes), so the mass loss could be calculated for the mentioned sliding time. Wear curves of the tested specimens were in correlation with the theoretical wear curves [19].

As the first comparison of the tested specimens, the total wear (after 60 min) was presented (Figs. 10 to 12), although the steady-state wear would be more reliable.

3.1 Wear of spheroidal graphite cast iron microalloyed with Sn under boundary lubrication with lithium grease, without and with Valena additive

The influence of Sn content in the high-strength cast iron on its wear, in case of lubrication with lithium grease, exhibits highly nonlinear and uncertain character. The increase of Sn content up to 0.032 wt. % mainly leads to

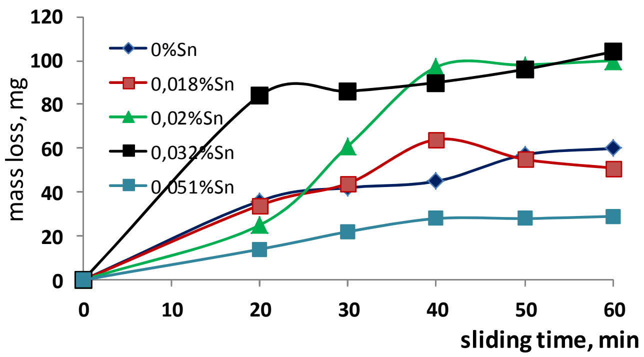

Figure 4. Wear curves with lithium grease NLGI 3 without Valena additive

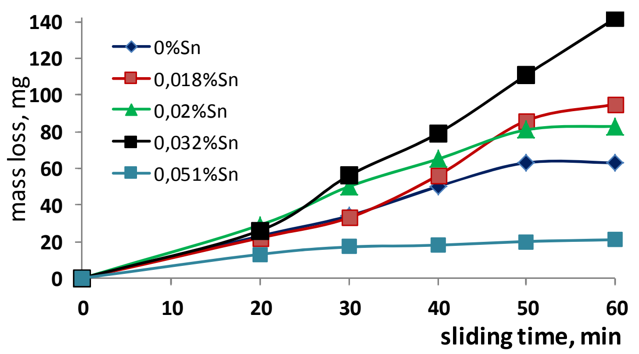

Figure 5. Wear curves with lithium grease NLGI 3 with Valena additive

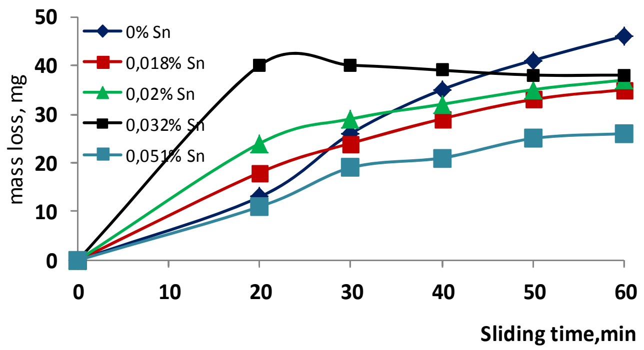

Figure 6. Wear curves with motor oil SAE 15W-40 without Valena additive

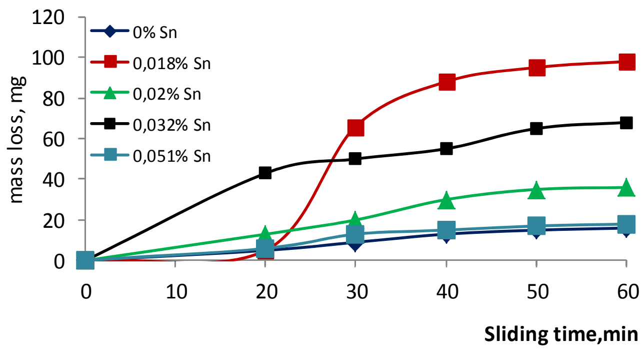

Figure 7. Wear curves with motor oil SAE 15W-40 with Valena additive

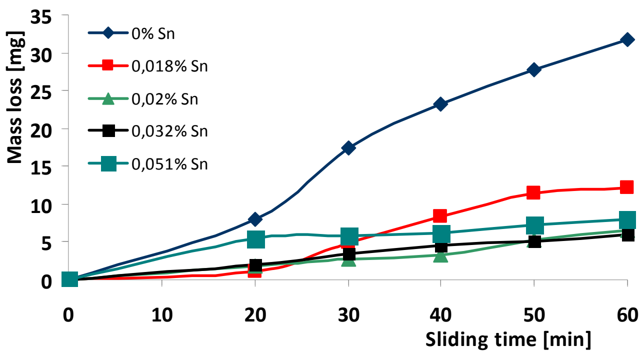

Figure 8. Wear curves with transmission oil SAE 80W-90 without Valena additive [10]

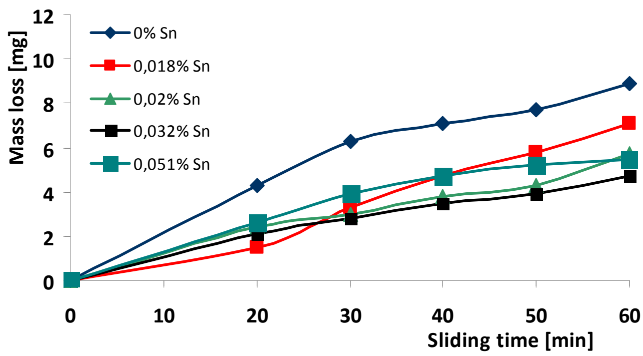

Figure 9. Wear curves with transmission oil SAE 80W-90 with Valena additive [10]

wear increase, with the significant decrease of wear for the 0.051 wt. % Sn (Fig. 10).

The addition of the Valena additive to the lubricant shows hesitant influence on wear of cast iron microalloyed with Sn (Fig. 10). For specimens with 0 to 0.032 wt. % Sn, the addition of Valena showed small influence on wear resistance, and mainly has negative influence, i.e. reduces the wear resistance. Only for specimen with the highest Sn content of 0.051 wt. %, the addition of Valena increased significantly wear resistance. For this specimen addition of Valena also shorten the running-in period (Figs. 4 and 5).

The highest wear resistance shows the cast iron microalloyed with 0.051 wt. % Sn and lubricated with grease with Valena additive, which was approximately 2.9 times higher compared with that of nonalloyed cast iron lubricated with grease without the additive.

3.2 Wear of spheroidal graphite cast iron microalloyed with Sn under boundary lubrication with motor oil, without and with Valena additive

The influence of Sn content in the high-strength cast iron on its wear, in case of

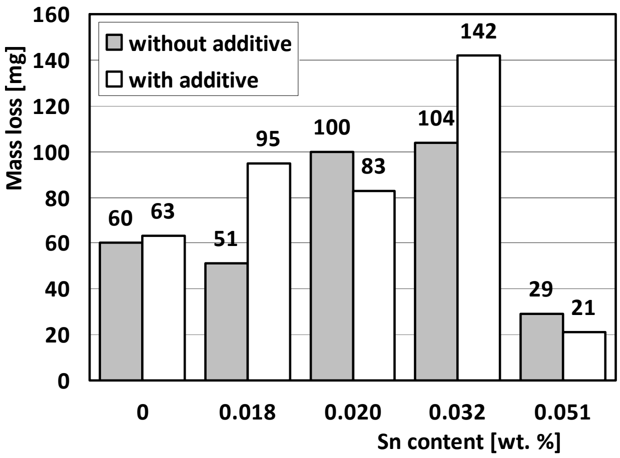

Figure 10. Total wear vs. Sn content for lithium grease without and with Valena additive

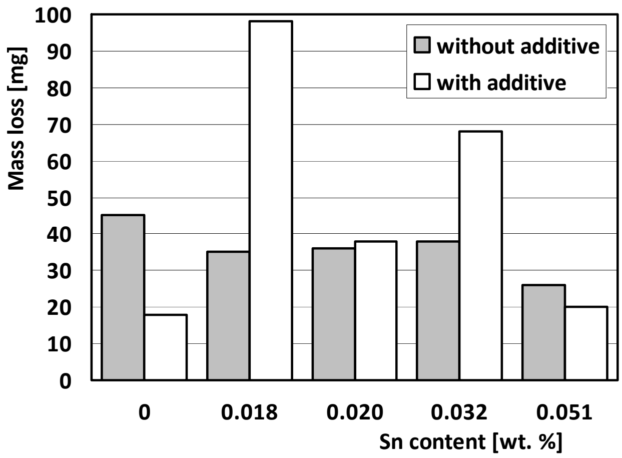

Figure 11. Total wear vs. Sn content for motor oil without and with Valena additive

lubrication with motor oil, also exhibits highly nonlinear and uncertain character. For the case of lubrication with motor oil with Valena additive, influence of the wt. % Sn is stochastic, while for the case of lubrication with motor oil without Valena additive, the increase of Sn content induced slight increase of wear resistance (Fig. 11).

The presence of Valena additive in motor oil was highly favourable to wear resistance of only two types of cast iron: without Sn and with 0.051 wt. % Sn. The wear resistance in these two cases was the highest and approximately 2.4 times higher compared with that of nonalloyed cast iron lubricated with grease without the additive (Fig. 11).

3.3 Wear of spheroidal graphite cast iron microalloyed with Sn under boundary lubrication with transmission oil, without and with Valena additive

As opposite to the first two lubricants (lithium grease and motor oil), experiments with transmission oil showed clear influence of both variables: content of Sn and absence/presence of Valena additive. The increase of Sn content leads to almost linear increase of the wear resistance up to the 0.032 wt. % Sn. With addition of 0.051 wt. % Sn, there is a slight decrease of wear resistance in both cases, i.e. by using transmission oil without and with the additive (Fig. 12).

The presence of Valena additive in transmission oil has favourable effect on the

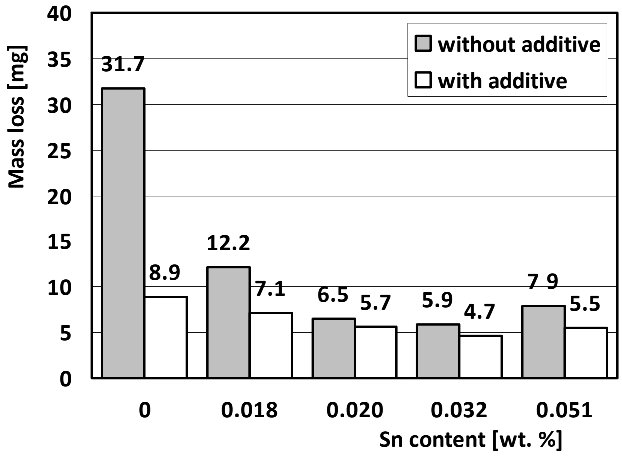

Figure 12. Total wear vs. Sn content for transmission oil without and with Valena additive [10]

wear resistance of all specimens. The highest wear resistance shows the cast iron microalloyed with 0.032 wt. % Sn and lubricated with grease with Valena additive, which was approximately 6.7 times higher compared with that of nonalloyed cast iron lubricated with grease without the additive (Fig. 12).

4. CONCLUSION

The increase of Sn content in the spheroidal graphite cast iron leads to increase of hardness, which is related to the increased perlitization of the matrix.

There is no direct connection between the hardness of spheroidal graphite cast iron microalloyed with Sn and its wear resistance under the boundary lubrication in the various lubricants, i.e. the increment of hardness with Sn content increase does not result in the wear resistance increase.

Wear, i.e. wear resistance depend on the mutual influence between Sn content and the presence/absence of Valena additive. Nevertheless, the presence of Valena additive seems to have beneficial effect, since the highest wear resistance, for all three lubricant, are shown for cast iron lubricated with the lubricant containing additive, i.e. cast iron with 0.051 wt. % (for lithium grease), cast iron with 0 wt. % Sn (for motor oil) and cast iron with 0.032 wt. % Sn (for transmission oil).

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