Serbian Tribology Society

SERBIATRIB '11

12th International Conference on Tribology

Faculty of Mechanical Engineering in Kragujevac

Kragujevac, Serbia, 11 – 13 May 2011

INFLUENCE OF TIN ON THE STRUCTURE AND PROPERTIES OF SPHEROGRAPHITIC CAST IRON

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Abstract: *Spherographitic (high strength) cast iron is construction material with complex of properties, due to which it is different from the traditional Fe-C alloys. Its mechanical and tribological properties are determined by the structure – form and distribution of graphite inclusions, dispersity and composition of the metal base in the bulk and the surface layers. The paper aims study of the relationship between wearresistance and the amount of tin in spherographitic cast iron. Results are obtained about wear, wear rate and wearresistance of high strength cast iron with different concentration of Sn.*
The study is related to the first stage of the International Contract № ДНТС 02/12 of scientific-technical collaboration between Romania and Bulgaria for 2010 in the topic „Tribotechnological study and qualification of composite materials and coatings lubricated by biodegradable fluids" lead by Assoc. Prof. Mara Kandeva and financed by the Fund Scientific Research at the Bulgarian Ministry of Education and Science.

Keywords: *High strength cast iron, Sn influence, tribotechnologies, wearresistance*

1. INTRODUCTION

Cast irons are natural composite materials of steel metal base and imbedded graphite phase. Mechanical and tribologcal properties of cast iron are determined by its structure – form and distrubution of graphite inclusions, dispersity and structure of the metal base in bulk and surface layers. The various combinations of different microstructures of matrix and, on the other hand, the form, size and distrubution of graphite phases determine the great reserve of structures and properties of these alloys with huge application in industry.

Spherographitic (high strength) cast iron is construction material with a complex of properties, due to which it is different from the traditional Fe-C alloys. Spherographitic cast iron has very high tensile strength, high plasticity, lower sensitivity to stress concentration, good wearresistance and good casting properties.

Adding tin in greater amounts has anti-spheroidal action [1], [2], which requires some supplementary studies giving idea of the behavior of the material under operating and exploitation conditions.

The paper aims study of the relationship between wearresistance and the amount of tin in spherographitic cast iron.

2. ANALYSIS

Results obtained by the authors in previous studies have shown the influence of tin on the structure of the metal base for molded samples of spherographitic cast iron [3].

The paper proposes an investigation of wear on samples with different contents of Sn: 0,003 %, 0,01 %, 0,026 % and 0,062 % under conditions of fixed abrasive wear. Sample characteristics are given in Table 1.

Table 1. Chemical contents of the specimens

Chem. element [%] / Specimen № / Hardness [HB]	0	1	2	3	4
	183	152	209	217	244
C	3.8	3.8	3.8	3.8	3.8
Mn	0.23	0.14	0.14	0.14	0.14
Si	1.84	1.28	1.28	1.28	1.28
P	0.037	0.02	0.02	0.02	0.02
S	0.008	0.017	0.017	0.017	0.017
Cr	0.036	0.01	0.01	0.01	0.01
Ni	0.027	0.013	0.013	0.013	0.013
Cu	0.088	0.012	0.012	0.012	0.012
Sn	0	0.003	0.01	0.026	0.062

2.1 Method and device for abrasive wear study

The study is realized using the procedure and device of the type „pin-disk" in the Laboratory of Tribology at the Technical University Sofia – Faculty of Machine Technology [4], [5]. The procedure follows the requirements of the acting standards, especially the Bulgarian State Standard БДС 14289-77 [6], which is harmonized to ISO.

The functional scheme of the device is given in Figure 1.

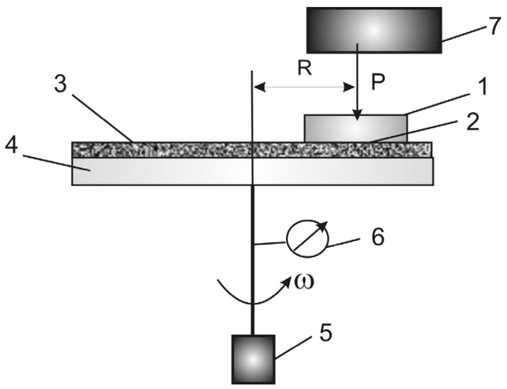

Figure 1. Functional scheme of the device for abrasive wear study

The specimen 1 (the body) has the form of parallelepiped with dimensions of the base 10x10 mm and height 25 mm. Counterbody 3 is the abrasive surface, which is being modeled by impregnated $A\ell_2O_3$ corundum with given characteristics – hardness 60% higher than the microhardness of the surface layer of the samples and definite average size of the abrasive particles.

Counterbody 3 is fixed on the supporting horizontal disk 4 and is changed at each measurement. This guaranties equal initial conditions of contact interaction between the butt surface 2 of the tested specimen and the abrasive surface 3. Near the friction path is the nozzle of a pump in order the wear waste be sucked during the process of wear.

The supporting horizontal disk 4 along with the abrasive surface 3 rotates with constant speed $\omega = const$ around its vertical axis. The rotational speed is given by a motor 5, and the number of cycles N, respectively the friction way L is read on the counter 6. The specimen 1 is fixed in the loading head 7 providing the desired normal load P in the center of gravity of the specimen 1 by a system of leverages. The average sliding speed is given and calculated by the variation of the distance R between the axes of disk 4 and specimen 1.

The procedure of the test represents the following:

1. The surfaces of all specimens, which are of equal form and size are subjected to mechanical treatment in three stages – rough treatment, grinding and polishing up to attaining equal roughness $Ra = 0{,}4 \div 0{,}6\ \mu m$. This is the necessary and obligatory condition to provide equal initial conditions in the comparative study of the wearresistance of the specimens.

2. Specimens' mass is measured before and after a given friction way (number of cycles of interaction) by means of electronic balance type WPS 180/C/2 with accuracy 0,1 mg. Before each measurement the specimens are cleaned by solution neutralizing the static electricity.

3. Specimen 1 is fixed in the loading head 7 in a given position and the central load P is set by means of the leverage system.

All specimens are tested at equal conditions: normal load in the center of the specimen, sliding speed and counterbody surface.

2.2 Basic parameters of the study

The basic parameters of the study are:

- *absolute mass wear* m, $[mg]$ - the destroyed mass of the surface layer of the specimen as difference between the specimen's mass before and after the given time t of contact interaction (number of cycles N).
- *mass wear rate* $\dot{m}$ $[mg/\min]$ - the destroyed mass of the surface layer in one minute time.
- *wear intensity* i - the destroyed thickness of the surface layer in a unit friction way. It is a dimensionless quantity, expressed by the destroyed mass and calculated by the formula:

$$i = \frac{m}{\rho . A_a . L} \left[\frac{kg.m^3}{kg.m^2.m} \right] \qquad (1)$$

where:

ρ is the density of specimen's material - $\rho = 7,8.10^3 \left[kg/m^3\right]$;

A_a is the apparent contact area of interaction, in that particular case $A_a = 10.10^{-4} \left[m^2\right]$;

L is the friction way calculated by the corresponding number of cycles N of the contact interaction as per the formula:

$$L = 2\pi.R.N \quad [m] \tag{2}$$

Here R is the distance between the rotation axis of the supporting disk and the mass center of the specimen according to Figure 1.

- *absolute wearresistance* I - a dimensionless quantity calculated as reciprocal value of wear intensity, i. e.

$$I = \frac{1}{i} = \frac{\rho.A_a.L}{m} \tag{3}$$

- *nominal contact pressure* p_a, $\left[N/cm^2\right]$ which is the normal load distributed on unity apparent contact area of the interaction A_a, i.e.

$$p_a = \frac{P}{A_a} \tag{4}$$

For the given conditions of the experiment $p_a = 10,5 \left[N/cm^2\right]$

- *comparative index of wearresistance* ε_{ie} - represents the ratio between the wearresistance of the tested specimen I_i and the wearresistance of a sample specimen I_e, i.e. it is a dimensionless quantity, which shows how many times the wearresistance of the tested coating is higher than that of the sample specimen at equal conditions of contact interaction:

$$\varepsilon_{ie} = \frac{I_i}{I_e} \tag{5}$$

The sample specimen is a sample of basic cast iron.

2.3 Experimental results

The described procedure and device gave the possibility to obtain experimental results about the relationship of the mass wear m and the number of cycles N and about the dependence of the wear rate $\dot{m}$ on time t of the contact interaction, given in Tables 2 and 3 and graphically in Figures 2 and 3.

Table 2. Relationship between mass wear and number of cycles $m = m(N)$

Sn [%]	*N* 500	*N* 1000	*N* 1500	*N* 2000	*N* 2500	*N* 3000
0	55,0	46,5	34,5	29,3	24,0	23,9
0,003	16,2	15,4	14,2	14,6	14,85	14,9
0,01	46,4	32,4	20,3	18,4	16,8	16,5
0,026	37,4	37,1	36,7	35,7	34,6	33,9
0,062	36,3	24,2	19,0	15,5	12,7	12,6

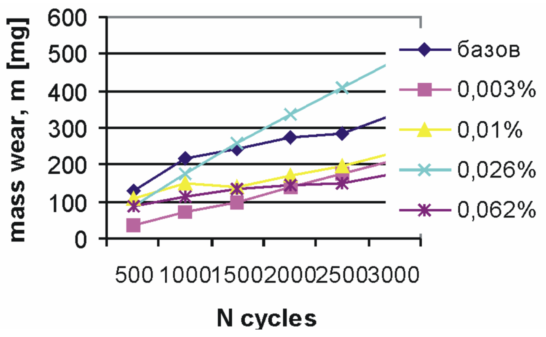

Figure 2. Relationship between mass wear m and number of cycles N (friction way)

Table 3. Relationship between wear rate $\dot{m}$ and time t

Sn [%]	t=2,35 [min]	t=4,7 [min]	t=7 [min]	t=9,4 [min]	t=11,7 [min]	t=14,1 [min]
0	55,0	46,5	34,5	29,3	24,0	23,9
0,003	16,2	15,4	14,2	14,6	14,85	14,9
0,01	46,4	32,4	20,3	18,4	16,8	16,5
0,026	37,4	37,1	36,7	35,7	34,6	33,9
0,062	36,3	24,2	19,0	15,5	12,7	12,6

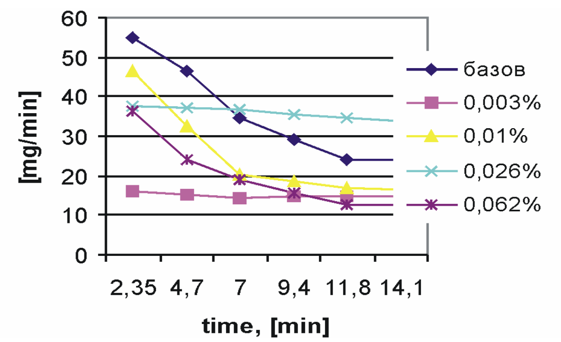

Figure 3. Relationship between wear rate $\dot{m}$ and time t

Table 4 gives experimental data about the variation of wear intensity i with time t calculated as per formula (1). Figure 4 shows this relationship graphically for all specimens.

Table 4. Relationship of wear intensity i on time t

Sn	0 %	0,003 %	0,01 %	0,026 %	0,062 %
t=2,35 [min]	0,25	0,07	0,21	0,17	0,17
t=4,7 [min]	0,42	0,14	0,30	0,34	0,22
t=7 [min]	0,47	0,19	0,28	0,50	0,26
t=9,4 [min]	0,53	0,27	0,34	0,67	0,28
t=11,75 [min]	0,55	0,34	0,38	0,77	0,29
t=14,1 [min]	0,66	0,42	0,45	0,90	0,34

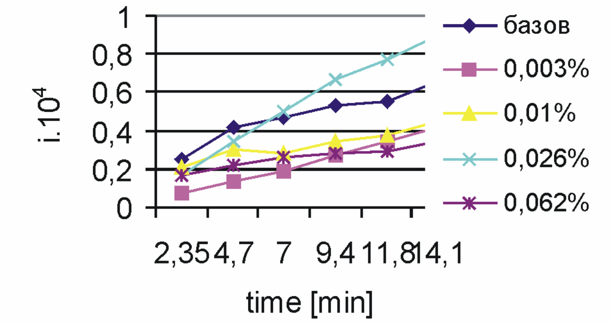

Figure 4. Variation of wear intensity i with time t

Table 5 shows the wearresistance I and the comparative index of wearresistance ε determined by formulae (3) and (5) for $N = 3000$ cycles, i.e. at friction way $L = 659{,}40\ [m]$. The data of Table 4 are presented graphically in Figure 5.

Table 5. Wearresistance I and comparative index of wearresistance ε

Sn [%]	I	$\varepsilon = \frac{I_i}{I_e}$
0	1,5 10^4	1
0,003	2,4. 10^4	1,6
0,01	2,2. 10^4	1,47
0,026	1,1. 10^4	0,73
0,062	2,9. 10^4	1,93≈2

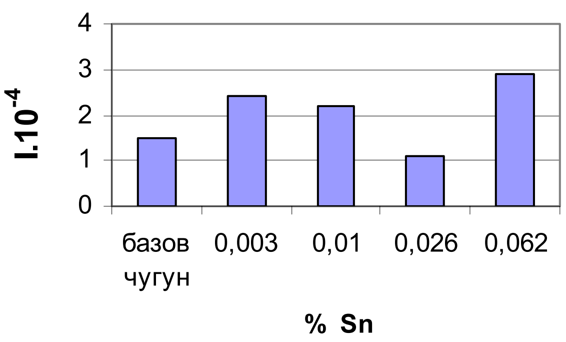

Figure 5. Chart of wearresistance I

3. ANALYSIS OF THE RESULTS, DISCUSSION AND CONCLUSIONS

The results in previous authors' investigation show that the various content of tin influences the hardness of the cast iron [3].

The obtained in this paper experimental results lead to following basic findings and conclusions:

- There is a direct dependence between hardness and wearresistance of cast iron in the frames of the tested Sn contents.
- Deviation of this dependence is found for specimen with Sn content of 0,026%. At the present stage of the study this fact can be taken as a result related to the non-homogeneity in the distribution of the graphite phase in the structure of the specimen. Wear and wearresistance are highly sensitive to the structure and the duration of wear. It is possible that at given stage of the wearing process, in the contact zone exists a structure with high graphite contents.
- Maximum wearresistance is observed for the specimen with Sn contents of 0,062%.
- The presence of Cu (0.008%) in the basic sample has greater influence on hardness than the amount of Sn (0.003) in sample № 1.

The obtained results would justify future systematic and complex investigations on tin by the authors, including also testing of high strength cast irons alloyed by Cu, Ni and Mo, which are produced in the factory of high strength cast irons „Osam" in the city of Lovetch, Bulgaria.

The study is related to the first stage of the International Contract № ДНТС 02/12 of scientific-technical collaboration between Romania and Bulgaria for 2010 in the topic „Tribotechnological study and qualification of composite materials and coatings lubricated by biodegradable fluids" lead by Assoc. Prof. Mara Kandeva and financed by the Fund Scientific Research at the Bulgarian Ministry of Education and Science.

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