Static and Dynamic Friction of Sphero-graphite Cast Iron with Sn Microalloy

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1. Introduction

The sphero-graphite cast iron is a composite construction material with very good mechanical characteristics – tensile strength, high plasticity, low susceptibility to stress raising and good foundry. Along with the improvement of strength, hardness, etc., alloying of spheroidal cast iron by limited quantities of Sn affects also friction and wear n the contact joints [1-4].

The study is carried out in the Tribology Center of the faculty of Industrial Technology at the Technical University – Sofia, Bulgaria. The paper aims study of the influence of Sn quantity in sphero-graphite cast iron specimens during two contact interaction states: preliminary displacement (static friction) and motion (dynamic friction). The following tasks are solved:

- Development of procedures and devices for static and dynamic dry friction study at various normal loads and sliding velocity;
- Study of friction force and coefficient at static friction and dynamic friction.

2. Materials, procedures and devices

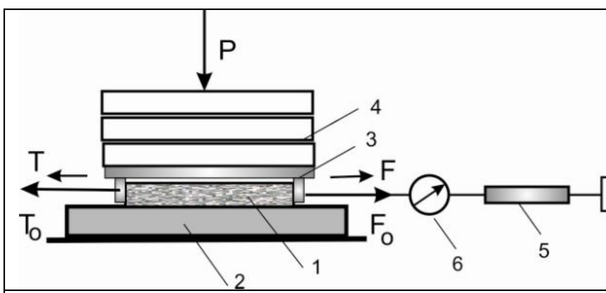


Fig.1. *Scheme of the device for static friction study*

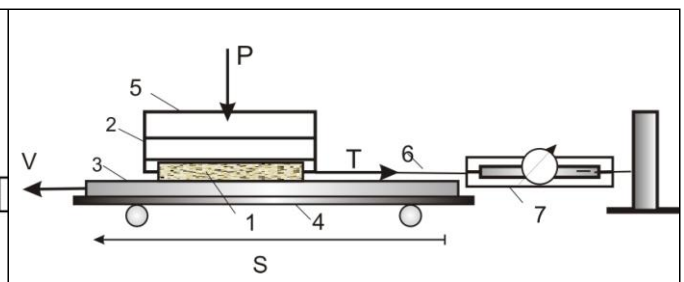
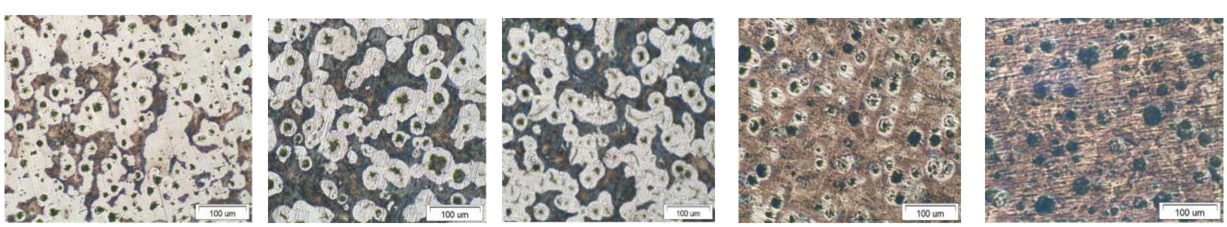


Fig.2. *Scheme of the device for dynamic friction study*



a *b* *c* *d* *e*

Fig.3 *Microstructure of the specimens: (a) –* 0% Sn , *and with microalloy 0,018 % Sn (b), 0,020 % Sn (c), 0,032% Sn (d) u 0,051% Sn (e).*

Specimen №	0	1	2	3	4
Sn, %	0	0,018	0,020	0,032	0,051
HB	179	197	203	262	277

Table 1: *Specimens' Sn content and hardness HB*

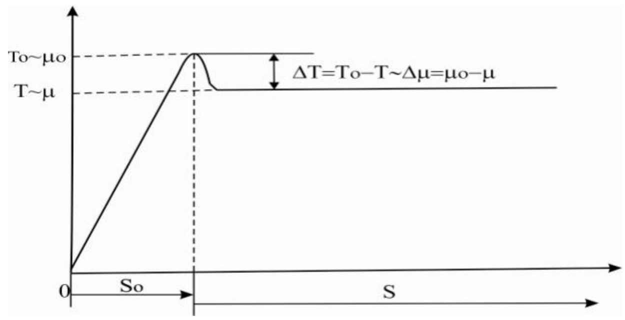


Fig.4. *Friction force and COF vs sliding way (classical)*

Five type sphero-graphite non-heated cast iron specimens (produced in "Osam" cast iron factory, city of Lovech, Bulgaria) are studied (Table 1), a basic one (0% Sn) and 4 others with various Sn mass %; size of specimens 30 x 20 x 6 mm. Microstructure of the specimens is shown in Fig. 3. Steel alloy counetrbody of HB 450 and roughness Ra = 0,432 μm has been used.

Experimental procedures and devices developed in the Tribology Center – Sofia for the study of both static and dynamic friction force and friction coefficient, and of the friction coefficient jump at static friction at different loads and sliding velocities are shown schematically in Figs. 1 and 2. Fig. 4 shows the classical curve friction force and friction coefficient versus sliding way.

3. Results and discussion

3.1. Static friction

The five above types specimens with one and the same counterbody were tested by means of the device in Fig. 1 at normal loads P_1 = 98,1 N; P_2 = 196,2 N; P_3 = 245,25 N; P_4 = 294,3 N.

Fig. 5 and 6 show, respectively, the variation of the static COF with load for various Sn content, and with Sn content for various loads.

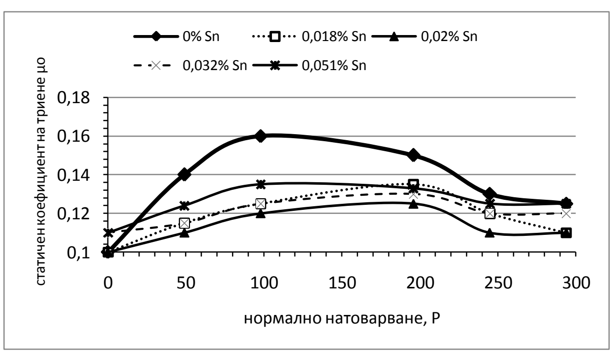


Fig.5. *Static COF μ_o vs normal load P*

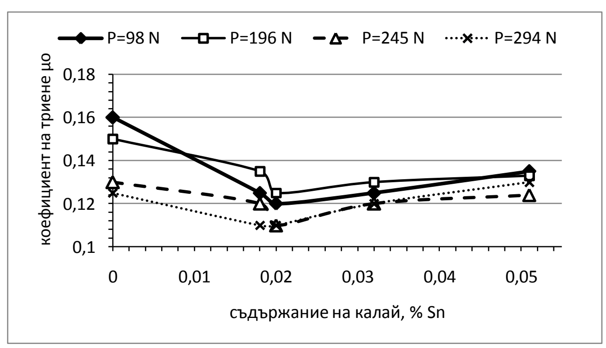


Fig.6. *Static COF μ_o vs Sn content*

The diagrams show a maximum at 98 N of the COF with increasing load for all specimens. Triple load increase from 98 to 294 N leads to COF decrease from 0,160 to 0,123, i.e. with 22%. The presence of Sn decreases the maximum, which is exhibited at the same load. COF minimum with Sn mass % for all P values is in the interval 0,018% to 0,02%, see Fig. 6. After that the functions increase almost linearly and COF increment of is possibly due to the increment of the adhesion component of friction with increasing Sn content [5-7].

Figs. 7 and 8 show the highly nonlinear variation of the friction coefficient jump both with load and with Sn mass %. Two maximal values are observed in Fig. 7, at P = 98 N and at 2,5 times higher load. The possible reason of COF decrease after the maximum is likely to be found in the increasing of the real contact area (increase of contact spots number) at the higher load decreasing the contact pressure and, thus, the deformation component of friction.

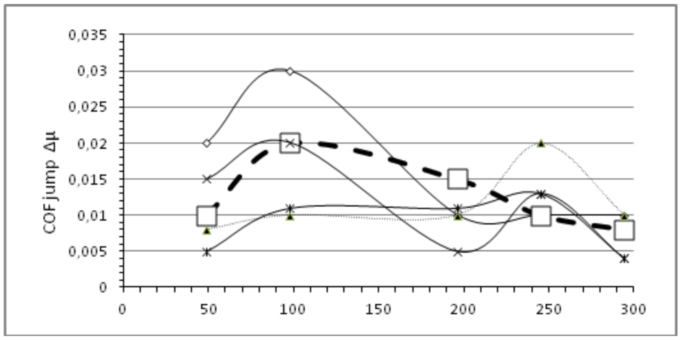


Fig. 7. *COF jump Δμ vs load P*

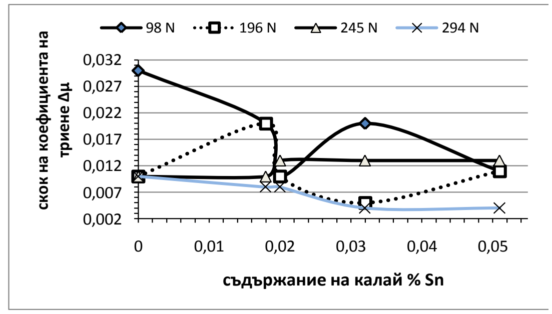


Fig. 8 . *COF jump Δμ vs Sn content*

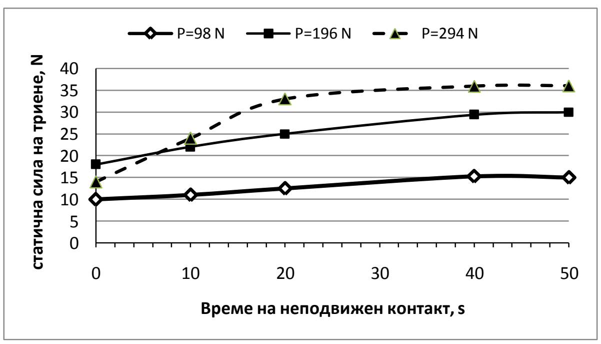


Fig. 9. *Static friction force T_o vs static contact duration for specimen without Sn*

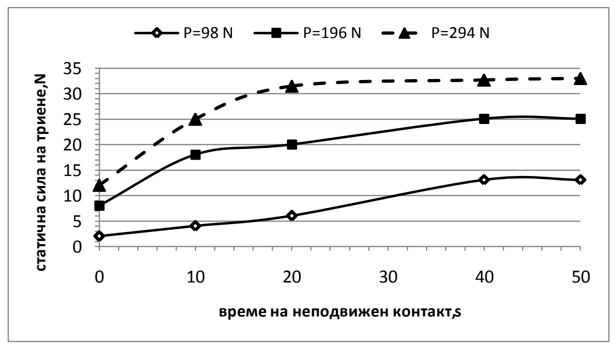


Fig.10. *Static friction force T_o vs static contact duration for specimen with 0,051% Sn content*

The static friction force increases gradually with the static contact duration in all studied cases (Figs. 9 and 10).

3.2. Dynamic friction

Fig. 2 shows schematically the device for studying a.m. specimens under conditions of one way translation at various loads and sliding speeds.

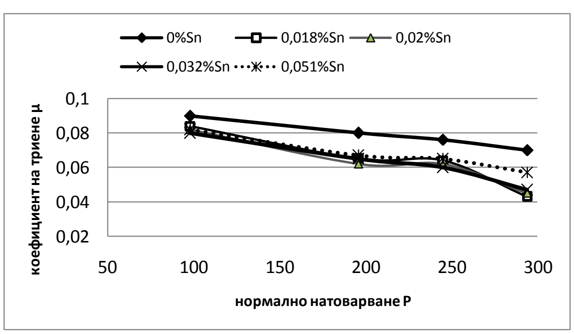
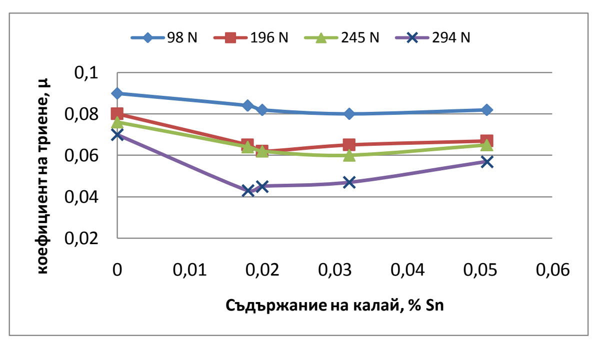


Fig.11.*COF vs load P at sliding speed V = 7,2 cm/min*



Фиг.12 *COF vs Sn content P at sliding speed V = 7,2 cm/min*

Fig.11 gives the decrease of COF with load for the specimens of various Sn content. The influence of Sn content at various loads is shown in Fig. 12. The diagrams exemplify the study, which embraces also different sliding speeds. Figs. 13 and 14 show the variation of COF with sliding speed for specimens without and with 0,051% Sn, respectively for two sliding speeds.

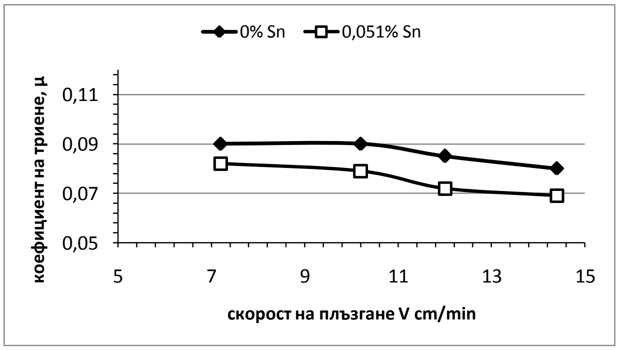


Fig.13. *COF vs sliding speed at P = 98 N load*

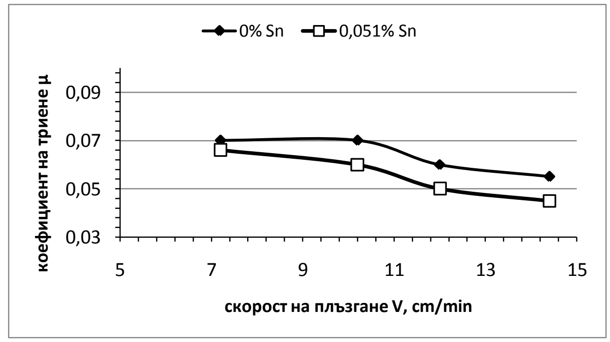


Fig.14. *COF vs sliding speed at P = 294 N load*

4. Conclusion

Results are obtained for the variation of static and dynamic friction coefficient in function of load and Sn content in the cast iron. Increasing of Sn leads to nonlinear decrease in static COF and friction jump passing through a minimum. A minimum is also observed in the variation of the dynamic COF at small sliding speeds.

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References

[1] Я.Е. Гольдштейн, В.Г.Мизин, Модифицирование и микролегирование чугуна и стали, М., Металлургия,1986. Ya.E. Goldstein, W.G.Mizin, Modifying and micro-alloying of cast iron and steel, Moscow, Metallurgy,1986 (in Russian).

[2] С.Бондаренко, И. Гладкий, Повышение эксплоатационных свойств чугунов, работающих в условиях гидроабразивного износа, Віснuк харківськ. державн. техніч. Университету, Харків, 2003, вып. 14, с. 388-391(in Russian).

[3] M. Kandeva, B. Ivanova, Abrasive wear and wear-resistance of high strength cast iron containing Sn microalloy, Journal of The Balkan Tribological Association, Vol. 19(4), 2013, pp 559-547.

[4] B. Ivanova, M. Kandeva, Structure and properties of ductile iron microalloyed by Sn, Journal Engineering Sciences, BAS, L, 2013, No. 4, pp 64-72.

[5] И. Крагельский, Н. Михин, О природе контактного предварительного смещения твердых тел, Москва, ДАН СССР, т. 153 №1,1963, pp 78-81 (in Russian).

[6] E. Assenova, Contact displacement of solids. Doct. Dissert. Thesis, TU - Sofia, 1979 (in Bulgarian).

[7] M. Kandeva, Kinetics of contact spots in technical joints, 26th International Scientific Conference "65 Years Faculty of Machine Technology", 13-16 September, 2010, Sozopol, Bulgaria, pp. 591-598 (in Bulgarian).