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STUDYING THE GRAPHITE PHASE IN ANTIFRICTION AChS-2 CAST IRON

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Preliminary Note – Prethodno priopćenje

The paper presents the data of studying the characteristics of graphite inclusions in various samples of AChS-2 cast iron. The metallographic analysis was carried out using the Thixomet Pro software, the length of the graphite inclusions, their shape and the occupied area were estimated. The slip coefficient and hardness were measured on the same samples. It was found that the characteristics of the graphite phase affect the antifriction properties of the alloy.

Keywords: cast iron, graphite inclusions, properties, slip coefficient, hardness

INTRODUCTION

For manufacturing the parts operating under conditions of friction with lubrication, there are used materials with sufficiently high hardness, wear resistance, and good antifriction properties: the friction coefficient should be no higher than 0,12 - 0,5 in the absence of lubrication and 0,001 - 0,02 with lubrication [1]. In a number of cases, bronzes are used for manufacturing castings that operate under friction conditions, but they are quite expensive; therefore, other antifriction materials, in particular, gray cast irons of the AChS 1 - 6 grades, are widely used.

Cast irons of this group have the pearlite or pearlite-ferrite base without free cementite and necessarily contain free lamellar graphite in the structure.

The shape, the size and the quantity of free graphite in fact determine the coefficient of friction (or slip coefficient), since graphite acts as a lubricant. It should be noted that hardness and wear resistance of antifriction cast irons, all other things being equal, are mainly determined by the structure of pearlite: the less dispersion of pearlite, the higher the material hardness and strength.

A lot of parts of mining equipment (sleeve bearings, bushings, bushing inserts, etc.) are made of AChS-2 antifriction cast iron. Table 1 shows the chemical composition of AChS-2 cast iron, Table 2 shows the requirements to AChS-2 graphite inclusions [2].

RESEARCH METHODOLOGY

AChS-2 grade cast iron is used in conjunction with steel hardened or normalized surfaces, i.e. they must have sufficient hardness. According to [1], its hardness is 180-229 HB. In order to increase hardness and resistance to wear, chromium is introduced into cast iron that also promotes chilling, which is undesirable in antifriction cast iron [2-6]. Titanium contributes to the production of small inclusions of graphite and also increases the metal base strength, silicon provides good casting properties of the alloy and the course of the graphitization process at a certain Cr:Si ratio. Nickel promotes graphitization and formation of small inclusions of graphite, prevents chilling and improves machinability of cast iron [2, 7-12].

Thus, AChS-2 cast iron has a balanced composition, which provides fairly good performance properties. According to [1], the variation of the shape and the size of graphite inclusions is quite wide: from 15 μm to 250 μm. It is obvious that such a wide range of shapes and sizes of graphite leads to instability of the properties of cast iron and consequently, the uncertainty of the service life of the same batch of castings [12-15].

Table 1 **Chemical composition of AChS-2 cast iron / wt. %**

C	Si	Cr	Mn	Ni	Cu	Ti	P	S
3,0-3,8	1,4-2,2	0,2-0,5	0,3-1,0	0,2-0,5	0,2-0,5	0,03-0,1	0,15-0,4	≤ 0,12

Table 2 **Requirements to AChS-2 graphite inclusions**

Shape of graphite inclusions	Size of graphite inclusions	Distribution of graphite inclusions
PGf14	PGd15, PGd180	PGr1-PGr3
rectilinear, winding, nest-shaped	up to 15 μm 120-250 μm	uniform, uneven, in colonies

EXPERIMENTAL STUDIES
Equipment and tools

The purpose of this study was to establish the relationship between the graphite phase characteristics and some properties (slip coefficient and hardness) of the alloy.

Ye. P. Chsherbakova, Sv. S. Kvon, V. Yu. Kulikov, A. M. Dostaeva, S. K. Arinova (e-mail: sherbakova_1984@mail.ru, KTU), Karaganda Technical University, Karaganda, Kazakhstan

The samples of AChS-2 cast iron from different batches were used as the object of research. The samples were cut from various retired castings. On the basis of the prepared samples, thin sections were prepared to study the graphite phase; the metal base was not etched and was not studied.

When studying the graphite phase, the length of the graphite inclusions, the characteristics of the shape of the inclusions, and the area occupied by the graphite phase were estimated. The Thixomet Pro software was used for the analysis, the studies were carried out in at least 3 fields of view. An example of using the program is shown in Figure 1.

The shape factor was calculated using the formula:

$$F = \frac{4A}{\pi D_{\max}^2}$$

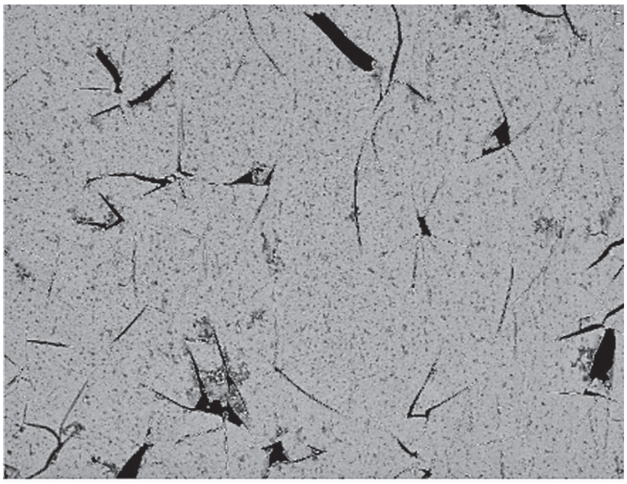
where A is the inclusion area;
D is the inclusion diameter.

The shape factor is one of the inclusion parameters and characterizes the tendency of the inclusion shape to develop towards spherical. In other words, the higher the value of the shape factor, the closer to the sphere the shape of this inclusion.

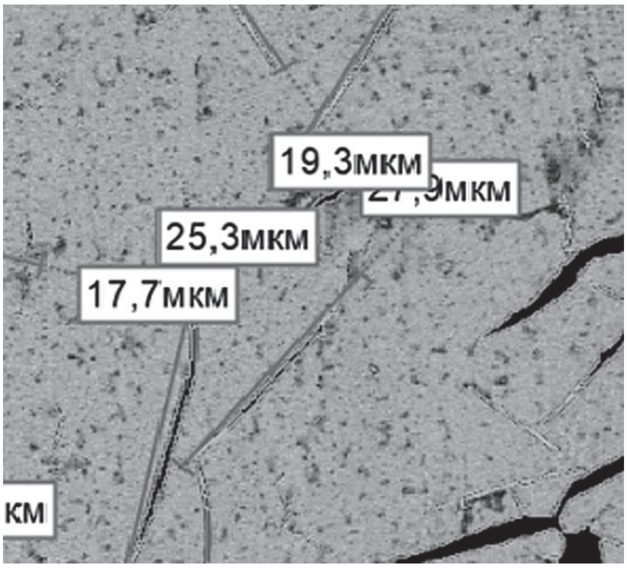
The slip coefficient was determined on the COF - P01(M) instrument with the following characteristics: dry friction (without lubrication), the angle of inclination 15^0; the angular velocity 10 ^{0}/s. The measurements were performed with three doubles. The results are presented in Table 3.

If it compare the data in Table 3 with the requirements for the AChS-2 graphite inclusions (Table 2), it is obvious that in all the samples under study the parameters of the graphite inclusions meet the required characteristics. It can be seen from the data in Table 3 that the variation of the data of the alloy hardness is about 10 %, the variation of the data of the slip coefficient is more than 70 %, while all the characteristics of the graphite inclusions of the samples under study meet the requirements. It should be expected that with such a variation of the data, the service life and wear resistance of the materials certified as AChS-2 will definitely be different despite their full compliance with the GOST.

The analysis of Figure 2 shows that increasing the length of graphite inclusions has a negative effect on the value of the slip coefficient (Figure 2a). The distribution of graphite inclusions also has a negative effect on the antifriction properties: the distribution of graphite in the form of colonies is the least favorable from the point of view of the slip coefficient value. Increasing the area of graphite inclusions leads to decreasing the alloy hardness as a whole (Figure 2b).



a)



b)

Figure 1 Example of using the Thixomet Pro: a) analysis of the graphite inclusions shape; b) analysis of the graphite inclusions length

A number of studies [3-5] have shown that additional alloying of the basic composition of gray cast irons has a positive effect on the shape and content of the graphite phase and thus, on the properties of cast iron as a whole. The introduction of such alloying agents as nickel, vanadium, molybdenum, and others contribute to increasing the metal phase hardness by increasing the dispersion of pearlite and refining the graphite phase and increasing the uniformity of distribution.

Table 3 **The results of studies**

Sample No.	Graphite inclusions length / μm	Distribution	Shape factor	Area occupied by graphite	Slip coefficient	Hardness / HB
1	18	PGr1	0,048	4,12	0,49	203
2	126	PGr3	0,066	6,46	0,33	176
3	84	PGr3	0,072	3,78	0,65	220
4	65	PGr2	0,05	5,02	0,51	190
5	202	Pgr3	0,039	6,13	0,27	183

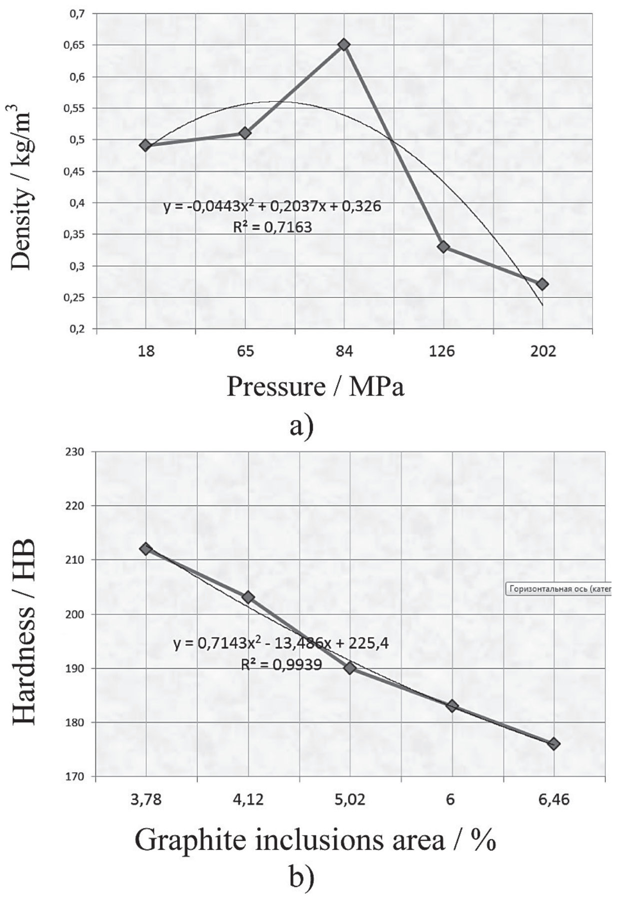


Figure 2 Graphite inclusions characteristicsimpact on the alloy properties: a) the graphite inclusions area effect on hardness; b) the graphite inclusions length effect on the slip coefficient

Adjusting the AChS-2 basic composition with such elements can be considered as one of the ways to affect the parameters of the graphite phase and consequently, the slip coefficient and increasing antifriction properties.

CONCLUSION

Based on the results obtained, it can be unambiguously asserted that from the point of view of the slip coefficient and therefore, the efficiency of the AChS-2 alloy as an antifriction material, it is necessary to obtain sufficiently small graphite inclusions of the order of 65-80 microns, which corresponds to PGd45, PGd90 grades. Reducing the length of graphite inclusions below these values do not make sense, because with decreasing the length of the graphite inclusions the slip coefficient does not practically change.

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Note: Responsible for the English language is Natalya Drak, Karaganda, Kazakhstan