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STUDYING TITANIUM CARBIDE EFFECT ON CAST IRON AChS-3 PROPERTIES

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The paper presents the results of studying microhardness and tribological characteristics of antifriction cast iron grade AChS-3 after modification with titanium carbide. Titanium carbide has been used as a nanomodifier to change the structure parameters by forming additional crystallization centers. It has been established that introducing titanium carbide in the amount of 0,2-0,3 % by weight with dispersion of 0,3-0,5 μm leads to increasing its hardness and wear resistance by about 20 %, while the friction coefficient decreases by almost 2 times.

Keywords: cast iron, titanium carbide, nanomodifier, antifriction, hardness.

INTRODUCTION

Antifriction cast iron grades AChS-1−AChS-6 (SS 1885-85) are intended for manufacturing parts operating under friction conditions: bearings for shafts, swivel joints, bushings, worm gears, etc. High antifriction properties of this group alloys are primarily provided by the characteristics of the structure [1]. The quantitative ratio between ferrite and pearlite, the dispersion of these components are of great importance, as well as the amount and characteristics of the graphite phase, which plays the role of a lubricant and thereby reduces the coefficient of friction.

It should be noted that microalloying with some elements (Sb, Cu, Nb, Ni, Ti, etc.) also has a significant effect on the antifriction properties of cast iron, although it does not lead to significant qualitative changes in the structure or phase composition. The effect of microalloying is manifested to a greater extent in the impact on the morphology and dispersion of the graphite phase, which affects decisively the antifriction properties [2].

In work [3], the effect of introducing a modifying mixture (MM) on the parameters of the graphite phase and the properties of cast iron SCh-25 was studied. The modifying mixture consisted of titanium and zirconium oxides and cryolite as a surfactant. The main feature of the MM used was the nanoparticle size, which averaged 0,9 μm. The studies showed that introducing MM in the amount of 0,3 % by weight leads to increasing the strength properties of cast iron, increasing the dispersion of the metal matrix and the graphite phase.

Works [3-5] show that in order to provide a finely dispersed structure in 1 cm^3 of the melt, at least 106 crystallization centers must be formed. Insoluble nanoparticles of modifiers can act as such centers. The calculation given in work [3] shows that with dispersion of 0,9 μm and introducing 0,3 % MM by weight, the number of crystallization centers in 1 cm^3 is $4*10^{10}/cm^3$, which, according to [5], is quite sufficient to develop a finely dispersed structure during cast iron crystallization.

In this case, the finely dispersed structure refers to both the fineness of the metal base and the parameters of the graphite phase.

Thus, introducing nanoscale modifiers as a factor of developing a finely dispersed structure, including the regulation of the interstitial phases or the graphite phase size, is theoretically quite justified. It was experimentally proven [6-9] that the use of nanomodifiers led to increasing the dispersion of the alloy structure and increasing its operational properties.

It is logical to assume that introducing the MM into the composition of antifriction cast iron will also have a significant effect on changing the structure, forming the graphite phase, and changing the properties. In the previous study [7], the effect of titanium carbide on the formation of a graphite phase was studied. It was found that introducing titanium carbide at a certain ratio of chromium-silicon contributed to the graphite phase grinding acting as an additional graphitization center. Titanium carbide (as well as titanium and zirconium oxides) is a refractory compound, it retains its individuality in the melt and promotes the graphitization process and formation of sufficiently fine graphite. In other words, titanium carbide can also be considered as a nanomodifier to increase the cast iron structure fineness.

The purpose of this paper is to study the effect of titanium carbide on the properties of antifriction cast iron and structural changes.

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Table 1 **Composition of AchS-3 cast iron/ wt. %**

Sample*	C	Si	Mn	Ni	Cr	Ti	Cu	S	P
SS	3,2-3,8	1,7-2,6	0,3-0,7	to 0,3	to 0,3	0,03-0,1	0,2-0,5	to 0,12	0,15-0,4
experimental	3,4	1,9	0,5	0,3	0,3	0,1	0,4	0,1	0,2

*Note: SS – the alloy composition in accordance with State Standard 1585-85; experimental – the alloy composition of the experimental laboratory alloy.

Table 2 **The graphite phase parameters of AChS-3, SS 1585-85**

graphite			pearlite		hardness, HV
form	dimension	distribution	area	dispersion	
PGf1-PGf4	PGd15-PGd180	PGd1-PGd3	P85, P70	PD0,3-PD1,6	160-190

MATERIALS AND METHODS

Antifriction cast iron grade AChS-3 has been used as the object of studyl its chemical composition is given in Table 1. Cast iron of this grade is intended for manufacturing bushings or bearing housings working in tandem with a hardened or normalized shaft. The part requires sufficiently high hardness and wear resistance, and at the same time good antifriction properties, the friction coefficient should be no more than 0,4.

The graphite phase plays the role of a lubricant, its parameters are also strictly regulated by SS 1585-85 (Table 2).

Titanium carbide grade F500 (TS 6-09-492-75) has been used as a nanomodifier. According to the specifications, the dispersion of titanium carbide of this grade is 500 microns, not less than 80 %. To improve the efficiency of introducing a nanomodifier as crystallization centers to obtain a finely dispersed structure, the dispersion of titanium carbide has been increased to 0,5 µm according to calculations [3].

Additional grinding has been carried out in a Retsch Emax nanomill with the following grinding parameters: the size of the grinding balls 15 mm; rotation speed 1 200 rpm. After grinding, a fractional analysis of the resulting titanium carbide powder has been carried out on an FSH-6K photosedimentometer. After additional grinding dispersion has been 0,3-0,5 µm with the fraction content of at least 80 %.

Such properties as microhardness, wear resistance and tribology have been studied on prototypes.

Vickers microhardness tests have been carried out on a DuraScan-70 automatic microhardness tester (EMCO-TEST, Prüfmaschinen GmbH).

Tribological tests have been carried out in air using a tribometer (CSM Instruments). There were the following test conditions: a counter-body WC ball with the diameter of 6 mm; the «ball-disk» scheme; load 5N; sliding speed 10 cm/s; run length 500 m.

Wear track profiles have been measured on a Wyko-NT110 optical profilometer (Veeco, USA).

EXPERIMENTAL PART AND DISCUSSION OF THE RESULTS.

Cast iron grade AChS-3 has been smelted in the laboratory furnace UIP-25 with a modernized cooling system. The composition of the charge has been calculated according to the accepted norms of waste, the correction of the composition has been performed by introducing an appropriate amount of ferroalloys. The composition of the alloy has been controlled using a NITONXL2-100G and Argon-5SF spectrometer (Table 1).

The alloy has been poured into CMC crucibles with the volume of 80 ml at the temperature of 1 450 ^{0}C. Different amounts of titanium carbide have been placed in the crucibles in the range from 0,1 % to 0,3 % of the estimated mass of the sample. For uniform distribution of titanium carbide throughout the volume, the crucibles with the melt have been subjected to ultrasonic treatment using a laboratory ultrasonic complex LUK-0,5/20-O at the amplitude of 150 µm and frequency of 125 Hz. Upon completion of cooling, the have been prepared for studying microhardness and tribological properties.

All tests were carried out three times. Table 3 shows the average values that are reflected in the corresponding interface.

Table 3 **Dimensions of wear impact-craters**

Sample	Axe X/ mm	Axe Y/ mm	Height/ mm	Angle/^{0}	R$_a$ / µm
1	0,11	0,12	0,002	12,3	3,12
2	0,05	0,07	0,001	6,04	2,88
3	0,42	0,45	-0,25	48,09	5,28
4	0,29	0,31	-0,12	32,1	6,43

Figure 1 shows a comparison of the wear track profiles of samples before and after modification with different amounts of titanium carbide. The curves have

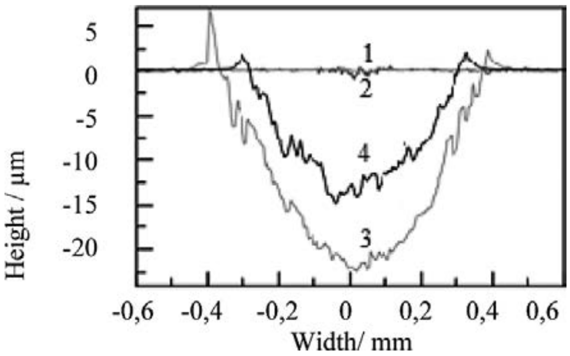

Figure 1 Comparison of the experimental sample wear profile parameters

been obtained on the basis of measuring the impact-crater of the sample according to the following parameters: R_a as well as the height and width of the craters, taking into account the roughness characteristics.

The generalized results of the tests are presented in Table 4. It can be seen from the data in Table 2 and the analysis of Figure 3 that sample No. 2 has the lowest friction coefficient, sample No. 1 also has a fairly low friction coefficient.

Table 4 **The results of the tests carried out**

Sample number	Modifier amount / wt. %	Microhardness / HV	Friction coefficient
1	0,2	310	0,25
2	0,3	319	0,1
3	-	248	0,4
4	0,1	291	0,4

The same samples are characterized by almost zero wear profile and zero crater dimensions.

Samples Nos. 3 and 4 have sufficiently deep and wide wear tracks, high coefficient of friction, the dimensions of the crater vary within -20 microns in height and up to 0,45 mm in width. At the same time, it should be noted that sample No. 3 (unmodified) is characterized by the appearance of protrusions along the edges of the crater, which can indicate brittle fracture at the beginning of wear [10].

Summarizing the results of tribological and microhardness tests, it can be said that introducing titanium carbide in the amount of 0,2-0,3 % by weight leads to increasing hardness and wear resistance, while the friction coefficient decreases. It should be noted that introducing TiC in the amount of 0,1 % has practically no effect on the studied properties, which apparently indicates the insufficiency of additional crystallization centers to ensure the dispersity of the structure.

Increasing the amount of TiC over 0,3 % also does not make sense, because with introducing 0,2 % or 0,3 %, the properties of the alloy remain almost the same.

According to the classical theory of wear, increasing hardness of rubbing surfaces leads, as a rule, to increasing the friction coefficient [2] under the same wear conditions, however, in this case, the opposite phenomenon is observed: the friction coefficient decreases.

This fact can in all likelihood be explained by the presence of structural changes that occur as a result of modification with titanium carbide, for example, by increasing the metal matrix dispersion and the graphite phase, whose role as a lubricant is obviously increasing. To confirm this assumption, it is necessary to carry out a detailed study of the prototype structure, which will be the next step in the research.

CONCLUSION

Introducing titanium carbide in the amount of 0,2-0,3 % by weight with the particle size of 0,3-0,5 μm as a modifier in antifriction cast iron grade AChS-3 leads to increasing its microhardness and wear resistance by an average of 20 %. The coefficient of friction in the WC−ACHS-3 pair is reduced by almost 2 times, which should affect increasing the service life of AChS-3 as an antifriction material. Introducing titanium carbide in another range does not lead to an effective change in the studied characteristics.

REFERENCES

[1] Dryden R., Purdy G.R. The effect of graphite on the mechanical properties of cast irons. Data Acta Metallurgica 37 (1989) 7, 1999-2006.

[2] Sertucha K., Lacaze J., Serrallach J., Suarez J., Osuna R. Effect of alloying on mechanical properties of as cast ferritic nodular cast irons. Materials Science and Technology 28 (2012) 2, 184-191.

[3] Zykova A. P. Effect of Ultradisperse TiO2, ZrO2, and Cryolite Powders on High-Chromium Cast Iron Hardening. Bulletin of the Russian Academy of Sciences: Physics. 80 (2016) 11, 1317–1321.

[4] Rudnitsky F.I. Modification of cast irons with ultrafine nano-additives. Foundry and Metallurgy. 86 (2017) 1, 11-15.

[5] Borodianskiy K., Zinigrad M. Nanomaterials Applications in Modern Metallurgical Processes. Diffusion Foundations (2016) 9, 30-41; doi:10.4028/www.scientific.net/DF.9.30

[6] Kvon SvS., Kulikov V.Y., Issagulov A.Z., Dostayeva A.M., Kovalyova T.V. Studying structure and properties of shaped ingots obtained in various conditions of crystallization. Metalurgija 5 (2018) 4, 313–316.

[7] Bingxu Wang, Yu Zhang, Feng Qiu, Weiwei Cui, Zirui Hu, Gary C. Barber, Ming Hu. Microstructure Refinement and Strengthening–Toughening Mechanisms of Gray Cast Irons Reinforced by In Situ Nanosized TiB2–TiC/Al Master Alloy. Advanced Eng. Materials 24 (2022) 2, 731-736 https://doi.org/10.1002/adem.20210073

[8] Issagulov A.Z., Kvon Sv.S., Kulikov V.Y., Aitbayev N.B. Studying microstructure of heat resistant steel deoxidized by barium ferrosilicon. Metalurgija. 55 (2016) 3, 388–390.

[9] Komarov O.S., Volosatikov V.I. Provarova I.B. Nanosized and ultra-dispersed particles in foundry technologies. Founndry and Metallurgy (2014) 2, 19-25.

[10] Chaikin V.A., Lozov V.S. et al. Comparative analysis of the quality indicators of steel 110G13L, smelted using refining modifying and deoxidizing mixtures. Bulletin of MSTU n.a. Nosov. 16 (2018) 1, 19-25.

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