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WEARFIRMNESS THERMITE CAST IRON

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ЗНОСОСТІЙКІСТЬ ТЕРМІТНОГО ЧАВУНА

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The present paper the basic solutions to the problem of obtaining wearfirmness thermite cast iron examined the use of thermite cast iron, the benefits of combining thermite steels with metallotermic methods of getting is showed. The advantages of metallotermic synthesis methods include: autonomy of processes, independence of energy sources, simplicity of equipment, high-performance process and easy transition from experimental research to industrial production. The need to developed the technology of synthesis wearfirmness thermite cast iron, as a result of aluminothermic reactions and establishment of technological features’ of synthesis it all led. At the first phase of the study of chemical composition of the synthesized wearfirmness thermite cast iron is determined. In continuation of studies microstructure, mechanical and technological tests were performed. Technological features of the synthesis process and the impact of components exothermic reaction were revealed. The result of comprehensive research was the development of fusion technology wearfirmness thermite cast iron “ОИ-1”, “ОИ-3”, “ИЧХ4Г7Д”, “ИЧХ3ТД”, setting of the charge for the synthesis of the specified cast iron, revealing the microstructure and mechanical properties of thermite steels, the research of technological properties of steel, namely the casting of properties and effects on the structure of individual alloying elements. In addition, the authors have set the limits and boundaries of creep for thermite cast iron and their dependence on temperature.

Keywords: *metallothermy, mechanical properties, thermite, wearfirmness cast iron.*

В даній роботі розглянуті основні рішення проблеми зносостійкості термітного чавуну з використанням термітного чавуну, показано переваги поєднання термітних сталей з металотермічними методами отримання. Переваги методів металотермічного синтезу включають: автономність процесів, незалежність джерел енергії, простоту обладнання, високопродуктивний процес та легкий перехід від експериментальних досліджень до промислового виробництва. Все це призвело до необхідності розробки технології зношення міцності термітного чавуну в результаті алюмотермічних реакцій та встановлення технологічних особливостей синтезу. На першому етапі дослідження хімічного складу синтезованої зносостійкості визначається термітний чавун. У продовженні досліджень мікроструктури виконані механічні та технологічні випробування. Виявлено технологічні *особливості процесу синтезу та вплив екзотермічної реакції компонентів. Результатом комплексного дослідження була розробка технології термоядерного синтезу зносостійкості термітного чавуну "ОИ-1", "ОИ-3", "ИЧХ4Г7Д", "ИЧХ3ТД", встановлення заряду для синтезу зазначеного чавуну, виявлення мікроструктури та механічних властивостей термітних сталей, дослідження технологічних властивостей сталі, а саме відливання властивостей та впливу на структуру окремих легуючих елементів. Крім того, автори встановили межі та кордони повзучості для термітного чавуну та їх залежність від температури.*

Ключові слова: *металотермія, механічні властивості, терміт, зносостійкість чавуну.*

That is why the synthesis of materials on the basis of metallothermic processes as well as the investigation of the influence of new technological methods of getting metal on microstructure, chemical composition, mechanical properties of manufactured castings got great practical importance. Metallothermic reactions further and further become of great appliance in science and technology. Under the lack of energetic and raw basis, of special melting and cast equipment such technological processes of creating the materials become economically expedient, and their usage in already existed methods of casting production e.g. in technique of producing steel and cast iron castings with thermite addition greatly rises the efficiency of production. Creating of the alloys on the basis of combined metallothermic processes allows getting materials with new technological properties the study of which has both scientific and practical importance.

While organizing the process of synthesis of steels and cast irons classic [1] thermite reactions based on oxidation of aluminum and renovation of iron are used:

$$\mathrm{Fe_3O_4 + Al \rightarrow Fe + Al_2O_3}\,.$$

The task was to work up the method of calculating of burden composition on the basis of stoichiometric relationship of reaction components with the introduction of suitable coefficients taking into account the component activity and the coefficients of its adoption by metal. The method allows to establish the composition of metallothermic burdens and to calculate adiabatic temperature of its combustion. The main condition of the process is the necessity to have real temperature of burden combustion higher than the temperature of slag melting [2, 3] (for Al_2O_3 2400 K). The main structure components in thermite cast irons that influence greatly the wear resistance are the carbides. First of all, these are cementite and more wear resistanceable carbides *Cr*, *W*, *Mo*, *Ti* and others.

If we assume that synthesized thermite cast irons of carbide class have one-type phase composition, then to determine its ware resistance will be possible using the scheme: the more is their hardness, the more is the wear resistance. But while investigating the components of the structure and their influence on wear resistance it is necessary to use the principle of Sharpi-Bochvar, and, taking into account the necessity to shape the construction part the technological form (we mustn't forget that the rise of hardness leads simultaneously also to the deterioration of machining by cutting). Wear resistance of synthesized cast irons under abrasive wear resistance depends on microhardness, form, replacement and quantity of structural components.

The grey cast irons is most convenient to get by metallothermic or combined (metallotherming) methods because of the high temperature within the zone of reacting of the components that leads under synthesis of alloys in conditions of micromelting to fast cooling and that in its turn gives the speeds of cooling higher than the critical ones and simultaneously martensite or needle-shape microstructure. These are the structures that are of the highest wear resistance. Grey thermite cast iron is being manufactured very well by cutting, much better than chilled and white cast irons. The burden composition for synthesis, chemical composition and components of the burden for getting wear resistant thermite cast iron and its mechanical properties are shown in table 1 and 2 (tempering was being done under 550°C during 12 hours). Within cast irons 1, 2 martensite is formed just during metallothermic melting without certain temomanufacturing which is furthermore connected with replacement of critical point regarding alloying of *Ni*. Cast irons 4, 5 (table 2) contain great amount of austenite but after tempering we get the structure of martensite of tempering with hardness being 280-310 *HB*. Cast iron 3 is being got with substantial chilled layer of material. Martensite in grey cast iron is being got without additional thermomanufacturing (tempering) and this effect decreases with the increasing of mass of the burden for melting [4]. In fact, it gives the possibility for thermite micromelting to decrease greatly the content of alloyed elements (*Mn* and *Mo*) not making tempering cracks while doing this.

Table 1

Chemical composition of the burden for synthesis of grey thermite cast iron

№	Electrode powder, per cent	Ferrosilicium (ФС 75)	Ferro-manganese (ФМн 75)	Ni powder	Ferrochrome	Ferroalu-minium thermite
1	4,0–4,2	1,6–2,0	1,3–1,6	4,2–4,8	0,4–1,1 FeCr	the rest
2	4,0–4,2	3,3–3,8	1,0–1,5	4,0–4,5	0,7–1,4 FeCr	the rest
3	4,0–4,2	1,6–2,0	3,8–4,3	4,8–5,3	0,9–1,6 FeCr	the rest
4	4,0–4,2	1,6–6,0	4,0–4,3	5,5–6,1	–	the rest
5	4,0–4,2	2,0–2,7	4,3–5,1	5,5–6,0	0,7–1,4 FeMo	the rest

Table 2

Chemical composition and hardness of martensite grey cast iron

№	Element content, per cent							HB	
	C	Si	Mn	S	P	Ni	Cr and Mo	In alloyed state	After tempering
1	3,0–3,2	1,2–1,5	1,0–1,2	<0,05	<0,1	4,2–4,8	0,3–0,8 Cr	390–430	–
2	3,0–3,3	2,5–2,8	0,7–1,1	<0,05	<0,1	4,0–4,5	0,5–1,0 Cr	370–440	–
3	3,0–3,2	1,2–1,5	2,7–3,2	<0,1	<0,1	4,8–5,3	0,7–1,2 Cr	270	390–400
4	3,0–3,2	1,2–1,5	3,0–3,2	<0,1	<0,1	5,5–6,1	–	280–292	–
5	3,0–3,3	1,5–2,0	3,2–3,8	<0,05	<0,1	5,5–6,0	0,5–1,0 Mo	290–310	–

Wear resistance of manufactured cast irons may be compared using table 3. Cast iron manufactured by thermite method may to some extend be classified as a grey iron not lower than «СЧ 30», and after tempering in cast irons 4 and 5, the limit of tension strength has been established at the level not less than 500 MPa.

Table 3

Wear resistance of special cast irons

№	Thermite material	Conditional value of resistance
1	Carbon steel (analogue of steel «У8»)	100
2	Thermically manufactured thermite alloyed cast iron	85
3	Martensite thermite cast iron	50
4	Alloyed Mn and Mo martensite cast iron	40

Table 3 data witness the increasing of conditional resistance for martensite thermite cast irons and rather great increasing for thermically manufactured cast iron. Pearlite matrix of such cast iron contains carbides Cr and Fe. Using roentgenostructural analysis method in the structures of these cast irons carbides Fe_3C and $(Fe,Cr)_3C$ as well as carbides $(Fe,Cr)C_3$ and others were detected, that provides the hardness of ~ 15000 MPa. Microhardness of carbides $(FeCr)_3C$ – *HV* 10000–10500 MPa, $(FeCr)_7C_3$ and $(Fe,Cr)_{23}C_6$ 14500–17500 MPa. Chemical composition of burden and composition of ingots, the properties of some marks of thermite cast irons are shown in tables 4, 5 and 6.

It is necessary to mention that mechanical properties of thermite cast iron are better than the properties of highly-chromium cast iron because of additional microalloying by aluminium, which must be introduced into the burden composition.

Table 4

Chemical composition of burden for synthesis of grey thermite cast iron

Mark	Electrode powder, per cent	Ferrosilicium (ФС 75)	Ferromagnese (ФМн 75)	Powder Ni, B, Cu	Ferrochromium (ФХ 100А); Ferrotitanium (ФТи 055А)	Feroaluminium thermite
“ОИ-1”	2,6–3,1	1,6–2,4	0,2	0,1–0,4	–	The rest
“ОИ-3”	2,6–3,1	1,3–2,0	0,7–1,3	0,1–0,4	2,0–2,6 FeTi	The rest
“ИЧХ4Г7Д”	2,6–3,1	2,0–2,6	8,0–10,0	>0,8Ni, Cu	10,0–12,9 FeCr	The rest

Table 5

Chemical composition and the properties of medium alloyed thermite cast irons

Mark	Element content, per cent										Mechanical properties		
	C	Si	Mn	S	P	Cr	Ni	B	Ti	Cu	$\sigma_\text{в}$, MPa	σ_u, MPa	Hard-ness
“ОИ-1”	2,5–3,0	1,2–1,8	>0,1	0,1	0,1	–	–	0,1–0,4	–	–	230	550–710	47–52 HRC
“ОИ-3”	2,5–3,0	1,0–1,5	0,5–1,0	0,1	0,1	–	–	0,1–0,4	0,7–0,9	–	210–250	580–700	47–52 HRC
“ИЧХ4Г7Д”	3,0–3,5	1,5–2,0	6,0–7,5	0,05	0,1	3,5–4,5	>0,5	–	–	>0,7	175	370	500–550HB
“ИЧХ3ТД”	2,5–3,0	1,0–1,5	0,5–1,0	0,05	0,1	2,0–3,0	–	–	0,5–0,9	0,5–0,9	250	510	500–570HB

Within cast irons with a considerable content of manganese disregarding high temperatures of synthesis one can see the aggravation of fluidity under the keeping of shrinkage within the range of 1,6–2,2 per cent. One must bear in mind that the treatment of cast irons with high content of chromium is complicated though it is on satisfactory level.

Table 6

Mechanical properties of thermite highly-alloyed cast irons

Mark cast irons	HRC	σ_u, MPa
“И4Х12М”	65–67	670
“ИЧХ12Г5”	64–66	680
“ИЧХ28Н2”	53–57	620
“ИЧХ2Н4”	60–62	660

Cast irons «ИЧХ15М3», «ИЧХ12М» and «ИЧХ12Г3М» are annealed (for getting the structure of grain perlite) with further hardening. Cast irons «ИЧХ28Н2М2» and «ИЧХ12Г5» with the structure of alloyed austenite are hardened in an open air and «ИЧХ28Н2» are treated under the medium-temperature tempering. High speed of cooling under getting of not big castings or the castings with wall thickness to 25-30 mm allow to get at once austenite-martensite structure. In other cases, the loading into furnace after hardening of casting at temperature 950ºC, endurance 2–3 hours and cooling together with furnace or hardening in an open air is used. The probability of graphitization of castings under synthesis of alloy by aluminothermic way decreases considerably because of considerable gradient of temperatures and high speed of heat abstraction, i.e. getting of martensite structure under casting goes considerably simpler.

Thus we may make a conclusion that aluminothermic ways can be used for producing of special thermite alloyed cast irons expect for high-chromium cast irons during the synthesis of those the problems of technological character appear. Other types of special cast irons have in some cases even better properties than in cast irons produced by ordinary methods. Designed compositions of thermite mixtures are also suitable for technology of thermite casting additives of high-temperature gradient.

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СФЕРИЧЕСКИЙ ОПТОЭЛЕКТРОННЫЙ СЕНСОР ДЛЯ ИЗМЕРЕНИЯ КОНЦЕНТРАЦИИ МЕТАНА В ВОЗДУХЕ

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SPHERICAL OPTOELECTRONIC SENSOR FOR MEASUREMENT OF METHANE CONCENTRATION IN AIR

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Предложена конструкция оптоэлектронного сенсора газа на метан (CH_4) учитывающая особенности спектральных характеристик источников и приемников среднего ИК-диапазона спектра. Показана возможность использования оптоэлектронного сенсора для измерения концентрации CH_4 в диапазоне 0–3 об.%. Минимально измеренная концентрация газа в воздухе ограничивается только отношением сигнал/шум и составляет 200–250 ppm.

Ключевые слова: *ИК-излучения, оптоэлектронные сенсоры, фотоприемники, оптоэлектронный сенсор, газ.*