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Special thermite cast irons

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Abstract

The given paper deals with the problems of the synthesis of cast iron by metallothermy synthesis. On the basis of investigated method of calculations structures of charges have been arranged and cast iron has been synthesized further. Peculiarities metallothermic smelting were found, mechanical properties and structure of received cast iron were investigated and different technologies for cast iron receiving were worked out.

Keywords: Metallothermy; Cast iron; Smelting; Properties.

1. Introduction

The important problem for modern production is not only making up new materials and improving the properties of traditional ones but also supplying of the production with spare parts and tools of non-common applying, the need of selfpropagating of those appears at small enterprises and in the shops where required base is absent.

Deep studying of the question makes it possible to consider that the problems mentioned above can be solved successfully when using as machine-building alloys the materials got by the process of burning of exothermic powder mixtures.

This method can be successfully used also for metal economy at the plants of large scale and mass production of machine-building parts and tools.

That is why the synthesis of materials on the basis of metalthermic processes as well as the investigation of the influence of new technological methods of getting metal on microstructure, chemical composition and mechanical properties of manufactured castings got great practical importance.

Metalthermic 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 (metalthermic+SHS) processes allows getting materials with new technological properties the study of which has both scientific and practical importance.

2. The methods of experiment

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 $Fe_3O_4+Al \rightarrow Fe+Al_2O_3$.

The task was to work up the method of calculating of burden composition on the basis of stechiometric 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 metalthermic 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 then 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, talking 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). Metal base of the alloy must contain a hard component and must prevent brittle break.

Wear resistance of synthesized cast irons under abrasive wear resistance depends on microhardness, form, replacement and quantity of structural components.

3. The directions of studies

Synthesized thermite wear resistant cast irons in analogy with the cast irons dot by ordinary methods, can be divided into the following groups: grey, white, including non-alloyed, low-alloyed, nickel-chromium-plated; martensite and high chromium-plated.

Grey special thermite cast irons. It is the most convenient to get grey cast irons by metaltermic or combined (metalloterming+SHS) 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.

Within cast irons 1, 2 martensite is formed just during metalthermic melting without certain temomanufacturing which is furthermore connected with replacement of critical point regarding alloying of Ni.

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	Ferroalumini-um 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	–

*Tempering was being done under 550ºC during 12 hours.

Table 3.
Wear resistance of special cast irons

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

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 termomanufacturing (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.

Wear resistance of manufactured cast irons may be compared using table 3.

Cast iron mamufactured 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 then 500 MPa.

Table 3 data witness the increasing of conditional resistance for martensite thermite cast irons and rather great increasing for termically manufactured cast iron.

Chilled thermite cast iron. Chilled cast has increased wear resistance [5] and is easy to get under conditions of micromelting.

Chemical composition of chilled thermite cast irons and composition of burden are shown in tables 4 and 5.

The analysis shows that in the surface layer of thermite cast irons the content of cementite is not less than 50 per cent that leads to microhardness from 1000 to 1050 HV.

Table 4.
Chemical composition of chilled thermite wear resistant cast iron

№	Element content, per cent							HB
	C	Si	Mn	Cr	Ni	S	P	
1	3,4–3,5	1,5–1,9	0,5–0,8	0,5	0,5	<0,1	<0,2	–
2	3,5	1,1	0,8	0,5	0,5	<0,1	<0,2	–
3	3,5	0,9	0,5	1,0	–	<0,1	<0,3	440–470

Table 5.
Burden composition for synthesis of chilled thermite wear-resistant cast iron

№	Electrode power, per cent	Ferrosilicium (ФС 75)	Ferromanganese (ФМн 75)	Powder Ni	Ferrochromium (ФХ 100A); Ferromolibdenum (ФМ 055A)	Ferroaluminium thermite
1	4,2–4,4	2,0–2,6	0,7–1,1	0,5	0,7	The rest
2	4,4	1,5	1,1	0,5	0,7	The rest
3	4,4	1,5	0,7	–	1,4	The rest

With the increasing of alloying element content consecutive changes in the structure, which comes from perlite to martensite take place, which in its turn leads to increasing of hardness as well as to the increasing of wear resistance.

White thermite cast iron. Under the synthesis of white thermite cast iron the necessity to get high temperature in the zone of reacting of burden components is considered, that is why Cr and Mn are introduced not in the shape of ferroalloys but like oxides Cr_2O_3, CrO_2, MnO, MnO_2 [6, 7].

Perlite matrix of such cast iron contains carbides Cr and Fe. Under considerable gradient of temperatures under thermite conditions micromelting white cast iron is produced in large measure simply, simultaneously it is the cheapest among the cast irons mentioned above, but its wear resistance is less then that of the alloyed one.

Introducing additionally into the burden even a small quantity of chromium in powder state or in the state of low carbon ferrochromium using breakage of graphite electrodes increase greatly wear resistance of mentioned cast iron. 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 ~ 15000MPa. 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 6, 7 and 8.

Table 6.
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 100A); Ferrotitanium (ФТи 055A)	Ferroalumi-nium 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 7.
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	$\sigma_в$, MPa	σ_u, MPa	Hardness
«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

Table 8.
Mechanical properties of thermite highly-alloyed cast irons

Mark*	HRC	σ_u, MPa
«И4Х12М»[1]	65–67	670
«ИЧХ12Г5»[1]	64–66	680
«ИЧХ28Н2»	53–57	620
«ИЧХ2Н4 (nickhard)»	60–62	660

*After proper thermal treatment

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 aluminum, which must be introduced into the burden composition.

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. For improving foundry properties and the quality of casting form thermite cast iron, the form was heated to 150–200ºC. Considerable gradient of temperatures connected with the technology of synthesis of thermite special cast irons, leads to the necessity of carrying out thorough thermal treatment. It must be carried out with the loading into the furnace at 250ºC and endurance not less than 2 or 3 hours providing heating velocity ~100ºC/hour.

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. Machining and wear resistance of some marks of investigated white thermite cast irons are given in tables 9, 10.

The probability of graphytization of castings from nickhard under synthesis of alloy by aluminotermic 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.

Hardness of these cast irons is in the limits of 9300–12000 MPa (per HV).

Table 9.
Thermite alloyed cast iron workability

№	Mark	HRC	Velocity of cutting***, m/min
1	«ИЧХ28Н2»*	57–59	9,2
2	«ИЧХ12М»**	38–40	24,8
3	«ИЧХ2Н4[1]»	58–62	10,1
1	«ИЧХ28Н2»*	57–59	9,2

*Tempering at 350 ºC, 3 hours.
**Unnealing.
***Cutting velocity at 90 minute resistance of cutting tool at S=0,3 mm/rev; t=2mm.

4. Conclusion

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 [8].

Designed compositions of thermite mixtures are also suitable for technology of thermite casting additives of high-temperature gradient. The work that has been carried out allows making a conclusion that for their mechanical properties synthesized specialized cast irons don't yield to "common" and the methods themselves are available for synthesis in principle of any black alloy.

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