International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 05, May-2015

Influence of Technological Factors on the Kinetics of Melting Ferrochrome in Thermite Mixtures

Dr. Olexiy A. Tchaykovsky,
Senior Professor,
Department of Foundry of ferrous and non-ferrous metals,
National Technical University of Ukraine "KPI"
Kyiv, Ukraine, Peremohy av., 37

Abstract— **The use of castings with differentiated features to significantly reduce operating costs, but their production is always fraught with difficulties. Direct use of in-mold process for alloying iron refractory ferroalloys is not possible because of their low dissolution. To intensify proposed to use iron aluminum thermite. The paper established the main factors influencing the melting ferrochrome in the thermite reaction. Investigated two factions 1..3 and ferrochrome 3..5 mm. Diameter cylindrical slot ferrochrome was 5, 10, 15, 20 mm. The influence of the ferrochrome fraction and contact area ratio on the speed of thermite reaction front moving were established. The conditions and characteristics of ferrochrome-termite system, which is achieved complete melting of ferrochrome were investigated.**

Keywords—Nodular iron; double-leyer cast, in-mold process; iron aluminum thermites; termite burning time; iron termite process kinetics; ferrochrome melting kinetics

I INTRODUCTION

1.1. Production of doubl-layer castings

In terms of impact-abrasive wear long-term operation of machines and overhaul mechanisms provide details of shock-resistant viscous matrix substrate core and durable working surface layer of a certain thickness.

Differentiation of the structure and properties of cast iron casting in different sections is achieved; by pouring liquid residue, followed by topping up the core of the overall shape mold centrifugal casting and gravity or some other less common methods. The main drawback of most of these methods is the need simultaneous melting of diverse chemical composition of two cast iron melting unit to start filling the form or mold [1].

In [2, 3, 4] is proposed differentiation properties of individual pieces by dividing melted iron in two flow during mold filling, one of which goes directly into its cavity, and another – first treated graphitize, nodulize or stabilize modifiers in the reaction chamber of gating system, and then goes to another part of the mold. It is also possible modification of the two iron streams in two reaction chambers with differ in functionality modifiers or alloyes.

1.2. In-mold process

At the present time approximately 10% (more than 1.5 mln. tons per year) ductile iron cast in the world is produced by in-mold process. The idea of this technology is in the casting of iron in green-sand mold and dissolution modifying additives in the reaction chamber gating system.

There are many advantages and of this technology. Benefits:

- Reduces the number of manufacturing operations
- - No fade effect modification
- - High assimilation and fewer modifier
- - Low capital costs
- - The minimum impact on the environment

The process of dissolving a modifier in liquid iron comprises the steps of heating, melting and dissolution. It is believed that the dissolution process ends in step diffusion or transfer of modifying alloying elements through the surface concentration boundary layer that is formed on the surface of modifier [5]. Atoms modifying elements that diffused by limiting concentration layer distributed in the volume of melt and come to chemical interaction of its ingredients, modifying the structure and properties of liquid iron.

Features intensification of heat and mass transfer processes in the modification of iron in the mold by increasing the melt temperature are very limited. Increasing melt contact surface with grainy interfacial modifier determined by the nature of interaction is one of the main factors that determine the kinetics of switching of modifying or alloying elements in iron during alloying or modification in mold.

1.3. Thermite mixture

Aluminothermic reactions are widely used for a large number of clean carbon-free metals: chromium, manganese and others. The process takes place in the next reaction

$$3Fe_3O_4+8Al=9Fe+4Al_2O_3+774\ \text{kCal}$$

The characteristic features that distinguish the process of burning termite from other pyrotechnic mixtures are:

- Absence during combustion of gaseous reaction products;
- High temperature combustion reaction, for most of termites is 2000…2800 °C;
- Formation liquid molten slag during combustion.

Regular composition iron aluminum thermites: 22-25 % 75-78% aluminum and iron scale.

1.4. Chromium

Chrome refers to the alloying elements that increase the solubility of carbon in liquid metal and lower the carbon content of eutectic, solid solutions and perlite.

Chromium is concentrated mainly in carbide. Ration of chromium content in the carbides to the ferrite content is 3-5 [[6, 7]. When the content is excess of solubility in cementite in iron chromium forms special carbides of various types [8].

Alloying iron by chromium increases the susceptibility to the formation of iron carbides in the structure.

Chrome is not affected on graphite spheroidising process, but the strong carbide element it significantly increases the probability of formation of structurally free carbides.

1.5. Conclusions

- For double-layer iron castings with a maximum hard surface of bleached cast iron from iron carbide and chromium expedient use of ferrochrome.
- Ferrochrome is high-temperature ferroalloy with a melting point 1600-1730 °C, which significantly hampers its dissolution in the flow of liquid iron. To increase the temperature in the reaction chamber is advisable to use termites.
- Iron aluminum termite forming liquid slag, which is a significant advantage by doping iron in the reaction chamber shape.

The aim is to study the kinetics of melting ferrochrome among aluminum termite, namely:

- Set the influence of fractional composition of ferrochrome, its relationship to Iron aluminum termites on speed of moving the reaction front and efficiency of dissolving ferrochrome.
- Set optimal values of process parameters to ensure the full and uniform ferrochrome melting.

2 EXPERIMENTAL METHODOLOGY

THE STUDY WAS PERFORMED USING BRAND FECR025 (GOST 4757-91). THE CHEMICAL COMPOSITION IS SHOWN IN TABLE 2.3.

TABLE 2.1 CHEMICAL COMPOSITION OF FERROCHROME FECR025

Element	Cr	C	Si	S	P
Content, %	≥65	≤0,25	≤2	≤0,02	≤0,05

2.1. Research iron aluminum thermite mixture

To establish the rate of burning thermite used green-sand mold. (Fig. 2.1). Produced in the form of cylindrical cavity height of 50 mm and a diameter of 15, 25 , 35, 50 mm. Used iron aluminum thermite composition Fe_3O_4 - 75 %, Al - 25%. To measure termites time burning using two tungsten-rhenium thermocouple grade VR5/20, junctions which were installed above and below the charge. Temperature sensors served as tungsten- molybdenum thermocouple junction which was set in the middle of charge termites, on the border termite-mold. To register used ADC and PC.

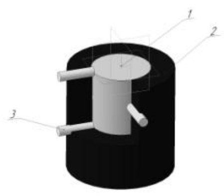


Fig. 2.1 Mold to study burning rate iron-aluminum termite. 1 - iron aluminum termite; 2 – green-sand mold; 3 - thermocouple.

The influence of the number of ferrochrome in the iron-aluminum termite on the kinetics of the reaction used open form of a cylindrical hole d = 50 mm , h = 50 mm with a same mixture. In the middle of mold placed ferrochromium in a cylinder shape with height of 50 mm and diameter samples from 5 to 20 mm in increments of 5 mm. The remaining mold space was filled by iron aluminum termites (Fig.2.2). Ferrochrome particle size was 1...3 mm and 3...5 mm.

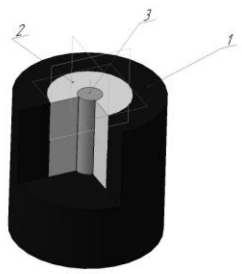


Fig. 2.2 Mold for study the influence quantity (the diameter of the sample) of ferrochrome on termite burn rate. 1 - green-sand mold; 2 - iron aluminum thermite; 3 - ferrochrome.

3 EXPERIMENT

3.1 Influence iron aluminum termite geometric dimensions on burning time

Research burning time iron aluminum termites showed that the burning thermite sample is directly proportional dependence on its height. At a height of 25 mm uncompacted sample burning time is 4 seconds, and at the height of sample 50 mm - 7.8 sec. For compacted samples with a diameter of 16 mm and height 25 mm burning time is 5.6 sec. The obtained experimental data are presented in Table 3.1.

TABLE 3.1

№	Samples high, mm	Samples diameter, mm	Burning time, s	Speed of moving reaction border, mm/s	Reaction temperature, °C
1	25	16	4	6,3	1800
2	50	15	7	7,1	2000
3	50	25	8	6,2	2000
4	50	35	7	7,1	2100
5	50	50	8	6,2	2200

3.2 Effect of ferrochrome quantity on burning time of iron aluminum termite

Options ferrochrome samples given in Table 3.2. For fractions ferrochrome 1 ... 3 mm time fluctuated within 6 to 14 sec, with a diameter of 5 mm specimen of ferrochrome a burning thermite time is 6 sec, and for the sample of 20 mm – 14 sec. For the fraction of 3..5 mm from 8 to 12 s, at 5 mm ferrochrome - 8 sec and at 20 mm - 12 sec (Fig. 3.2). Extending the burning time of termites because at increasing the diameter of the sample ferrochrome its quantity per unit area of interaction increases, and therefore the heat which is released during termite combustion is absorbed by ferrochrome more intensively, that reducing the rate of reaction between iron and aluminum. Increasing burning thermite time from a fraction from 1...3 mm relative to the fraction 3...5 mm due to the fact that the smaller fractional composition has higher packing of ferrochrome, and therefore present greater number of ferrochrome per unit volume, which reduces the reaction rate.

TABLE 3.2 OPTIONS SAMPLES FERROCHROME, THE STUDY TIME BURNING IRON ALUMINUM TERMITES.

№	Samples high, mm	Samples diameter, mm	Samples mass at different fraction, g		Termite , g
			1…3 mm	*3…5 mm*	
1	50	5	6	5	200
2	50	10	13	10	200
3	50	15	31	30	200
4	50	20	50	50	200

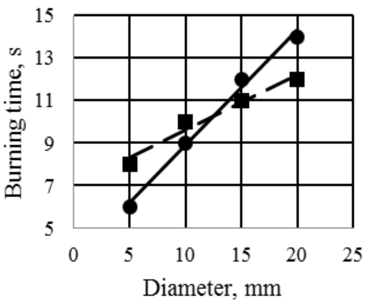


Fig. 3.2 Impact ferrochrome quantity (sample diameter) on the burning termites time.

3.3. Ferrochromium melting by burning iron aluminum termite

During the examination of samples after knocking shape with a diameter of 5, 10 and 15 mm, for a fraction of 3...5 mm, filling ferrochrome were melted completely, and even samples at 20 mm were melted only at 70 % (Fig. 3.3). In fractions of ferrochrome 1...3 mm all specimens were melted completely.

Efficiency dissolving ferrochrome determined by visual estimation, weighing on the chemical composition and "tablets", formed as a result of the combustion of iron aluminum termites. The resulting sample after the combustion of iron from aluminum termite fracture is shown in Figure 3.4.

As a result of the samples received following the chemical composition of the sample "tablet", which are shown in Table 3.3.

TABLE 3.3 CHEMICAL COMPOSITION OF SAMPLES, OBTAINED AFTER THE COMBUSTION OF IRON ALUMINUM TERMITE.

Diameter FeCr025, mm	Element content in samples, %				
	Fe	*Cr*	*Si*	*Cu*	*Al*
5	94,06	3,38	2,13	0,25	-
20	83,58	12,86	2,63	0,23	0,36

Instead of a 20 mm sample used two samples of 14 mm diameter identical total area. Doubling the number of samples was done to increase the contact surface of the iron aluminum termites and ferrochrome. It received 80% of melting ferrochrome (Fig. 3.3).

Because the linear burn rate termites is constant, then heat layer termites will depend on the diameter of thermite mixture. Therefore, the determining factor is the ratio of the cross -sectional sample of ferrochrome to the cross-sectional area filling termites.

Rations for ferrochrome samples are given in Table 3.4. These ratios for samples ferrochrome 5, 10, 15 and 20 mm diameter and constant filling iron 50 mm aluminum termites is 0.04; 0.19; 0.56 and 1.77 units, respectively (Fig. 3.5).

Found that the sample with diameter 20 mm ferrochrome melted partially. So for complete melting ferrochrome value cross-sectional area of ferrochrome and termites must be less than 1.77 (Fig. 3.6).

TABLE 3.4 THE RATIO OF THE CROSS SECTIONAL AREA FOR THE RESPECTIVE DIAMETERS OF SAMPLES FERROCHROME.

Cross-sectional area	Sample ferrochrome diameter, mm			
	5	*10*	*15*	*20*
FeCr25, mm2	19,6	78,5	176,6	314,0
Termite, mm2	471,0	412,1	314,0	176,6
Area ration ΦFeCr/termite, unit.	0,04	0,19	0,56	1,77

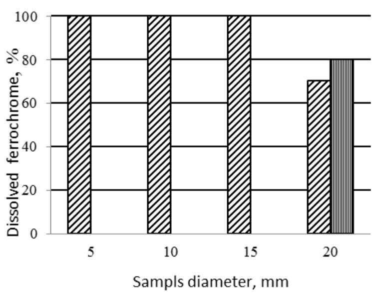
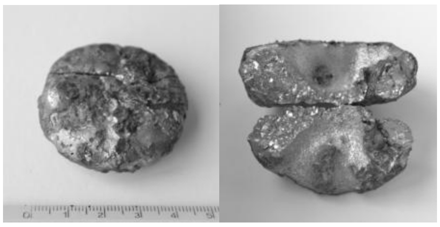


Fig. 3.3 Effect diameter insert the number of ferrochrome, which dissolved (for fractions 3...5 mm).



a b

Fig. 3.4 Sample obtained after the combustion of iron aluminum termites adding FeCr025 . a - exterior design; b – broken sample.

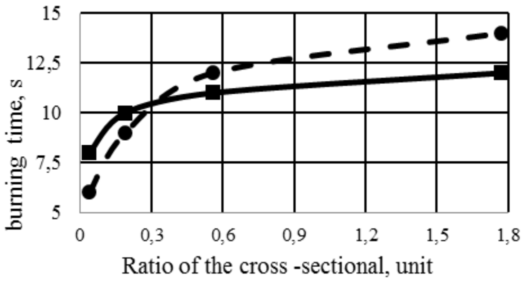


Fig. 3.5 Effect of the ratio of the cross -sectional sample of ferrochrome to the cross-sectional area at the burning termite time.

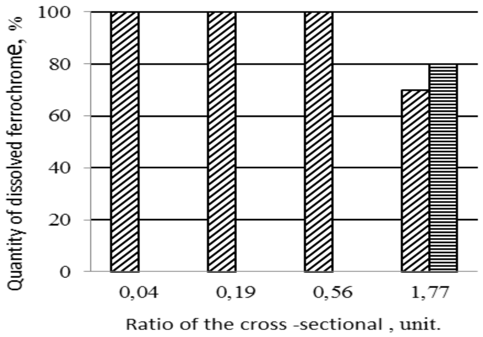
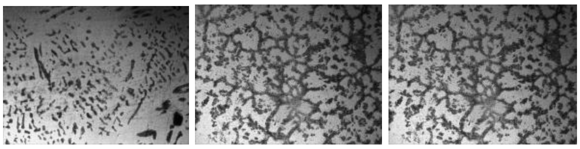


Fig. 3.6 Effect of the ratio of the cross -sectional sample of ferrochrome to the cross-sectional area termites on the quantity of dissolved ferrochrome (fractions 3...5 mm).

When adding ferrochrome can be seen following change of the microstructure of samples obtained after the combustion of iron aluminum termites, without adding ferrochrome and with the addition of 2.5 % and 25% of ferrochrome (fig. 3.7).



a b c

Fig. 3.7 Microstructures of samples obtained after the combustion of iron aluminum termites. a - without adding FeCr025 ; b - the addition of 2.5% FeCr025 ; c - adding 25% FeCr025

4 MATHEMATICAL MODEL

Mathematical model describing the change of the iron aluminum termite burning time and amount of dissolved ferrochrome built on the results listed in Table 3.7, containing the value factors, as planned experiment and reviews.

TABLE 3.7 - IRON ALUMINUM TERMITE TIME BURNING AND MELTED FERROCHROME AMOUNT IN DEPENDING ON THE VALUE OF TECHNOLOGICAL PARAMETERS.

№	Diameter of the ferro-chrome sample , mm	Faction of ferro-chrome, mm	Density of the sample, kg/ m^3	Burn ing time, s	Melted ferro-chrome, %
1	10	3	2000	9	100
2	5	5	2000	8	100
3	15	3	3200	14,4	100
4	5	5	3200	9,6	100
5	15	3	2000	12	100
6	10	3	3200	10,8	100
7	20	5	2000	12	70
8	5	5	3200	9,6	100
9	15	3	2000	12	100
10	10	3	3200	10,8	100
11	20	5	2000	12	70
12	5	3	2000	6	100
13	15	5	3200	13,2	100
14	10	5	2000	10	100
15	20	3	3200	13,2	100
16	5	5	2000	8	100

Below is a mathematical model in coded parameter describing the change of time burning iron aluminum termite.

y=10.7021+2.65279x1+1.03125x3-0.658519z1---0.616805u1+0.168626u1x2–1 .99018x2x3,

where:

x1 = 0.118519*(X1 -11.5625);

z1 = 2.25924*((x1^2)-0.130761*x1-0.426612);

u1 = 5.37495*((x1^3)-0.309787*(x1^2)-0.6839*x1+0.0763744);

x2 = 1*(X2 -4);

x3 = 0.00148148*(X3 -2525);

Natural values of the factors^

X1 – Diameter of the ferrochrome sample mm;

X2 – Faction of ferrochrome, mm;

X3 – Density of the sample, kg/ m3.

Statistical characteristics of the model are shown in Table 3.8 and in Figure 3.9.

TABLE 3.8 - STATISTICAL CHARACTERISTICS OF THE MATHEMATICAL MODEL.

Coefficient Name	Regression coefficient	Standard error of regression coefficient	Sshare of influence
x1	2.65279	0.0558239	0.656688
x3	1.03125	0.0558239	0.180927
z1	-0.658519	0.0558239	0.0579764
u1	-0.616805	0.0558239	0.0465402

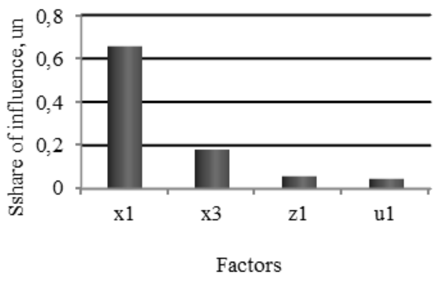


Fig. 3.9 - Parameters share of influence on the iron aluminum termite burning time.

Statistical characteristics of the mathematical model indicate that the greatest influence on the burning termite iron aluminum time has a diameter of ferrochrome (almost 66%).

5 CONCLUSION

- With increasing charge ferrochrome diameter from 5 to 20 mm the iron aluminum termite burning time increases from 6 s to 14 s.
- For ferrochrome fractions are 1...3 mm it is complete meltdown regardless of the diameter of the charge.
- For ferrochrome faction 3...5 mm full meltdown occurs only for charges that have a diameter of 15 mm or less.
- Complete melting ferrochrome fractions 1 ... 5 mm occurs at a ratio of cross-sectional area of ferrochrome to insert cross-sectional area filling iron aluminum termites below the 1.77 units., and density of termites within 2000 ... 2200 kg / m3.

references

[1] Kosyachkov V.A., Fesenko M.A., Denisenko D.I. Prospects of bimetallic castings modification of cast iron in the mold casting process .// Casting Processes - 2004 - № 4 - P. 80-84 .

[2] Kosyachkov V.A., Fesenko M.A., Tchaikovsky A.A. Differentiation of the structure and properties of the wall section castings of cast iron by modifying in mold . // Casting Processes - 2006 - № 1 - P. 85-90 .

[3] Fesenko M.A. Differentiation modifying properties of casting iron parts in the mold // Dysert . on muffin. Science. Stupa. Kandy . Technical science . Sciences - Kyiv - 2007 - 184 p.

[4] Pat. 3196 (51) Ukraine , S21S1 IPC / 00 // Method modification of cast iron Kosyachkov VA, Makarevich A.P., Platonov E.O., Ageev K.V., Denisenko D., Sych M.C. - Publish. 15.10.2004 , Bull. Number 10.

[5] Noskov AS, Zavyalov A.L., Zuchkov V.I. To determine the rate of melting ferroalloys in metal melts // USSR. Institute of Metallurgy , Ural Branch . - Preprint . - Sverdlovsk, 1983. -49s .

[6] Bunin K.P., Lev I.E, Snagovsky V.M., Taran Y.N. On the structure of chromium white irons // Foundry . Manuf . - 1965. - № 9. - S.23-24 .Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[7] Wittmosser A. und Gras W.D. Über die Zussammensetzung einiger Gefügebestandteile in weiss erstarten Eisen – Khlenstoff – Legierungen. „Gies. techn.. – wiss. Beih.". 1963, №2, s. 75-88. E.I. 1963, № 448.

[8] Girshovich N.G. Crystallization and Properties of the cast iron. - M .; A .: Engineering . - 1966. - 430c .