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Effect of boron carbide on primary crystallization of chromium cast iron

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Abstract

In the paper results of the influence of boron carbide (B_4C) as inoculant of abrasion-resisting chromium cast iron (about 2,8% carbon and 18% chromium) on primary crystallization researches are presented. Boron carbide dispersion was introduced at the bottom of pouring ladle before tap of liquid cast iron. In this investigations were used three different quantities of inoculant in amounts 0,1%; 0,2% and 0,3% with relation to bath weight. It has been demonstrated that such small additions of boron carbide change primary crystallization parameters, particularly temperature characteristic of process, their time and kinetics.

Keywords: Solidification process, Wear resistant alloys, Chromium cast iron, Crystallization, Modification, Boron carbide

1. Introduction

The chromium cast iron belongs to excellent high wear resistance casting materials [1,2].

It mainly follows that its high functional properties, particularly works in medium wear condition of work including mineral materials, e.g. in mining and processing industry.

Very high wear resistance of chromium cast iron depends on composition and morphology of its metallographic structure. Properly chosen wear resistance chromium cast iron, during time of cooling should be crystallize two-phase structure that composed of hard chromium carbides in a matrix of ferrite, austenite or its transformation e.g. martensite. The best carbides are carbides of type M_7C_3 (where M represents the metallic species, Fe and Cr mainly), which have the best application parameters i.e. high hardness (up 1500 HV) and good mechanical properties (among others: reserved fracture toughness).

More widespread of chromium cast iron application in medium wear condition of work is much reduced because this cast iron has much inclination to cracking. This negative quality eliminates chromium cast iron to use for elements, which work under impact load. Responsibility for this hold structure because it has hard and relatively brittle carbides about big size, wrong morphology and often form continuity network. In the structure initiation and propagation of cracks is very easy.

All activities in scope of modification are not only made towards increase wear resistance but increase mechanical properties too. [8-14].

Author of this work also makes such activities. Fundamental of assumption of his activities is searching the methods which influence on primary crystallization process of chromium cast iron in aim to obtain beneficial carbide phase to increasing alloy ductility. Beneficial carbide phase here understands as carbides of type M_7C_3 with large dispersion, evenly distributed in matrix and have good shape (shape factor). Approximately good form carbides should be understands by analogy to graphite shape in ductile cast iron.

Marketing of new chromium cast iron on elements which work in impact-wear conditions will be possible when will succeed increase plastic properties (ductility) of chromium cast iron, which increase its fracture toughness.

2. Aim, material under investigation and research methods

The main aim of investigation was search essential parameters of primary crystallization of wear resistance chromium cast iron that show effect of modification with the aid of boron carbide, particularly crystallization of carbide phase.

For investigation hypoeuetectic chromium cast iron with concentration about 2,8 % carbon and 18% chromium was selected. As inoculant more dispersion boron carbide in different amounts i.e. 0,1%; 0,2% and 0,3% with relation to bath weight of cast iron was used. Select of boron carbide (melting temperature about 2600^{o}C) was set up that its activate will be mainly to produce base for crystallization.

Chromium cast iron was melted in an electric furnace with inert liner and 20 kg capacity. The base mettalic charge was chromium cast iron (K0), which was melted in industry arc furnace. After melting charge (K0) in induction furnace was executed deoxidation (Fe-Ti) and desulfurization (CaC_2). Inoculation of cast iron was made in ladle where dispersion boron carbide was introduced to bottom of pouring ladle before tap of liquid cast iron. Tapping temperature was 1550 ^{o}C. Then was poured into set of testers (first DTA tester and next DTA-K3 testers -ϕ30, ϕ60, ϕ100) on the research stand. The research stand scheme is presented in figure 1. On the research stand can be realize investigation cycle according prof. Jura DTA method [3-5] and DTA-K3 method [15-17], which is development of DTA method (analisys influence of cooling rate on crystallization). In table 1 results of chemical analisys of base chromium cast iron (K0) and following melts and amounts of inoculant for each melts are presented.

Table 1.
Chemical composition of researched chromium cast iron

	concentration wt %						
melt	C	Cr	Mn	Si	P	S	mod. B_4C
K0	**2,82**	**17,69**	0,11	0,35	0,035	0,018	**0**
K1	**2,90**	**17,52**	0,15	0,34	0,036	0,013	**0**
K3	**2,88**	**18,06**	0,12	0,33	0,036	0,018	**0,2**
K5	**2,71**	**17,61**	0,11	0,40	0,039	0,018	**0,3**
K6	**2,62**	**17,93**	0,15	0,40	0,041	0,016	**0,1**

Cooling curves were recorded to temperature 300^{o}C. It was enabled to analise primary crystallization process and in the future, it will enable next analisys of crystallization process in solid state.

Figure 2 shows all recording cooling curves for melt K5.

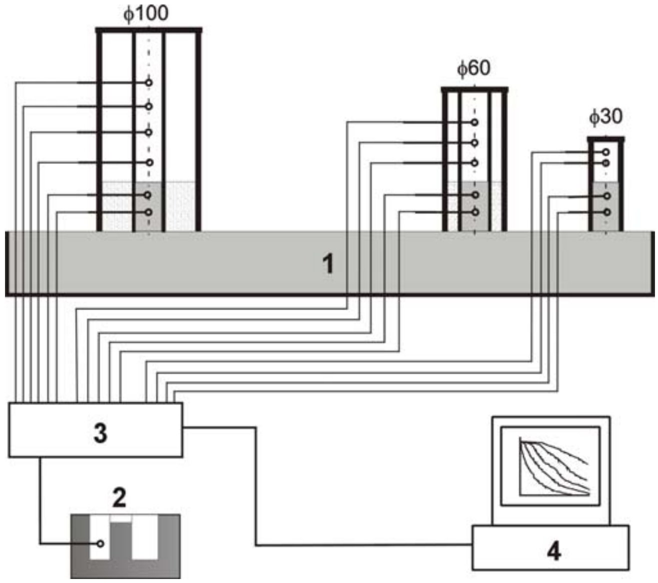

Fig. 1. Research stand scheme: 1 – DTA-K3 set of testers, 2 – DTA tester, 3 – multi-channel converter A/C M-24, 4 – PC

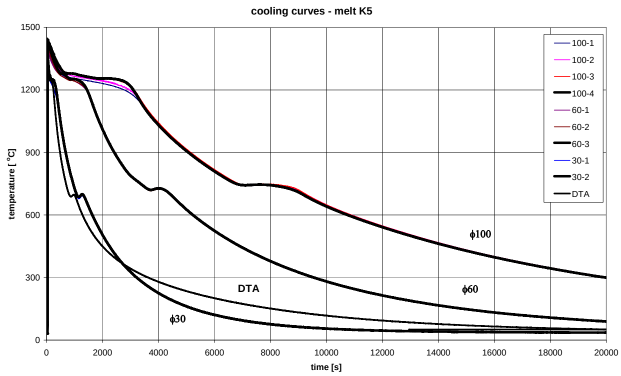

Fig. 2. Cooling curves for melt K5

3. Primary crystallization parameters analysis

Basis on recorded cooling coorves the analysis of crystallization process of researched chromium cast iron was made. In first stage attention was concentrated only on the primary crystallization of cast iron in other words cooling curves from pouring tester was analised to full disappearance liquid phase.

Crystallization process according to other researchers is the best and more exactly at the course of cooling curves which are recorded in heat center of research casting. Figure 3 shows cooling and crystallization curves of researched cast iron for casting ∅100 which was recorded near the heat center.

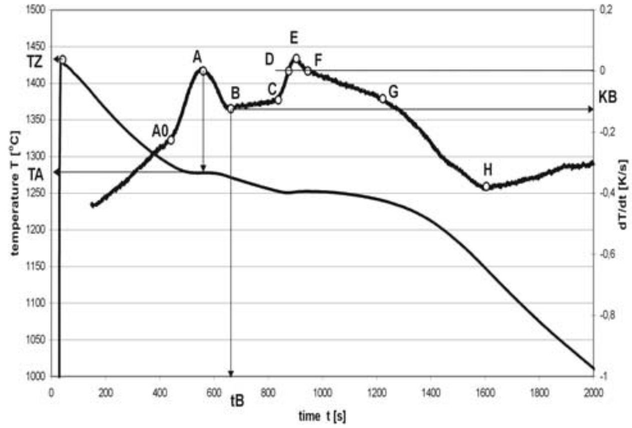

Fig. 3. Cooling and crystallization curves of chromium cast iron – characteristic point marked and read-out of crystallization parameters

Figure 3 shows description of characteristic points and read-out method of primary crystallization parameters. Crystallization curve was described method according professors Jura [3-5] and Pietrowski [6,7] (in point marked A0 the primary crystallization starts).

Table 2 gives recording primary crystallization parameters of chromium cast iron for melt K5

Figure 4 shows how the cooling and crystallizaton curves of research cast iron in casting ∅100 after modification process changes. For the best visualization how crystallization curve changes point A, which show maximum heat effect of primary austenite crystallization, removed to one time point (fig.4 - see arrow).

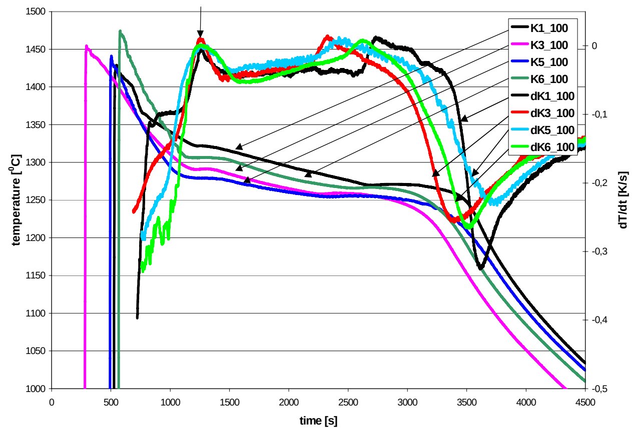

Fig. 4. The effect of amounts B_4C inoculant on cooling and crystallization curves for cast ∅100

Table 2
Statement of crystallization parameters of research cast iron Tester ∅100 – melt K5

point	temperature T , ^{0}C	derivative K , K/s	time t , s
	TZ=1428		56
A0	1328	-0,09	643
A	1322	0,002	762
B	1317	-0,034	934
C	1271	-0,038	2116
D	1269	0	2203
E	1271	0,013	2238
F	1270	0	2383
G	1260	-0,057	2885
H	1209	-0,330	3117

TZ – pouring temperature, i.e..maximal temperature on cooling curve

4. Summary and conclusions

After analisys of non-modified and modified by boron carbide chromium cast iron, essential changes of primary crystallization during their course were observed. This changes are attributed mainly activities of inoculant and its amounts. The best perceptible are changes of transformation temperatures. Figure 5 shows changes of selected transformation temperatures under boron carbide activity. Tendency of this change (decreasing when amount of inoculant grow up) proceed for all cooling rate of castings, particularly it is seeing for castings with big solidification module.

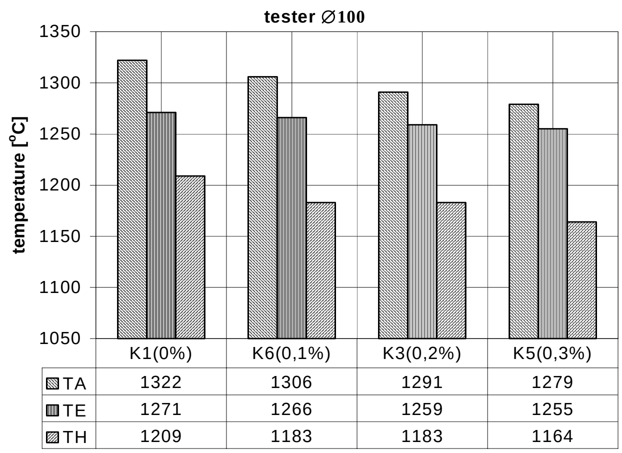

Fig. 5. The influence of inoculant amounts on some temperatures TA –liquidus temperature by S. Jura, TE – solidus temperature by S. Jura, TH – end of solidification temperature

The activity of boron carbide was ascertained on durations of stages of primary crystallization process. Figure 6 shows the influence of inoculant amount on time of period between temperatures liquidus (point A) and solidus (point E)

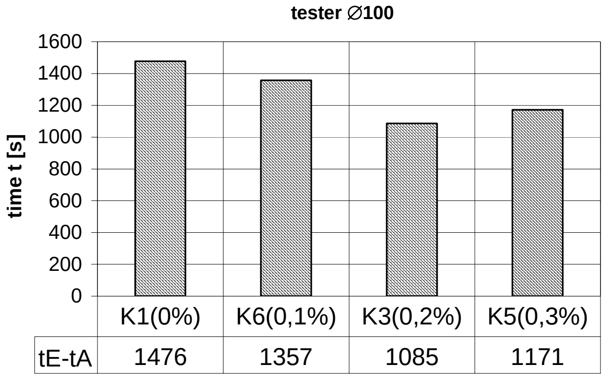

Fig.6. The influence of inoculant amount on time of period between temperatures liquidus (point A) and solidus (point E)

Based on conducted studies following conclusions and remarks to next investigations have been formulated:

- boron carbide as inoculant of chromium cast iron change clearly primary crystallization parameters,
- modification particularly reduce following temerature parameters: liquidus temperature (TA), finish of primary crystallization process (TH),
- addition of boron carbide increase super cooling of chromium cast iron and so maybe importance influence on structure size reduction,
- supposed that optimum amount of inoculant should be maximum 0,2% with relation to bath weight of cast iron,
- modification effect of chromium cast iron should be confirm during mechanical and structure investigations,
- should be make an analysis and check different methods introducing boron carbide into liquid cast iron.

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