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Crystallization of Low-alloyed Construction Cast Steel Modified with V and Ti

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Abstract

In this paper crystallization studies of low-alloyed construction cast steel were presented for different additions of chromium, nickel and molybdenum modified with vanadium and titanium. Studies were conducted using developed TDA stand, which additionally enabled evaluation of cooling rate influence on crystallization process of investigated alloys.

Keywords: Low-alloyed cast steel, Primary crystallization, Modification, TDA method

1. Introduction

Castings made of construction cast steel [1-3] should be characterized especially by high mechanical properties, such as: yield strength Re, elastic limit Rs, ultimate strength Rm, fatigue strength Zm etc. Ratio of Rm/Re can be, for example, a good evaluation of proper heat treatment. Other mechanical properties like impact strength U, contraction Z, elongation A are also important because they enable the designer to evaluate the ability of the material to withstand overload and local stress concentration.

Low-alloyed cast steel is used for construction castings because of the possibility of obtaining high mechanical properties at low costs of production and following machining and joining operations (e.g. by welding). Typical low-alloyed cast steels contain several elements, like: Ni, Cr, Mn, Si and Mo, V, W, Ti, Nb, Co, B. Their beneficial influence is mainly connected with heat treatment operations (e.g. they improve hardenability).

Presented work describes the results for new low-alloyed cast steel from construction cast steels, which can find application in heavy machinery industry thanks to its high mechanical properties. Its chemical composition is close to L20HGSNM cast steel standard, additionally subjected to modification with use of vanadium and titanium. One of the aims was the description of used modifiers influence on crystallization parameters [4] of presented new low-alloyed construction cast steel.

2. Material and methodology

Studies were conducted for low-alloyed cast steel with additions of Cr, Ni and Mo. First cast of the alloy (K1) was performed without modification [7]. All other casts included modification with vanadium and titanium. For alloy preparation typical charge materials were used. In Table 1 the chemical composition of prepared alloys was presented. Casts were performed with use of electrical inductive furnace with capacity of 20 kg and neutral lining. Prepared pure and annealed charge material was melted according to cast steel standards. After melting the liquid alloy was deoxidized with ferrosilicon and aluminium. Modification was conducted with use of ferrovanadium and ferrotitanium. Liquid metal was heated up to 1650°C and poured into TDA testers (ATD-C, ATD-Is) [5, 6]. Their construction and used materials enabled significant diversification of cooling rates in range of primary crystallization. For ATD-C tester the cooling rate is about

100 K/min. and for ATD-Is 50 K/min. The crystallization process registration was performed with use of TDA stand, which scheme was shown in Fig. 1. The chemical composition was analysed using Emission Spectrometer LECO GDS 500A.

Table 1.
Chemical composition of studied low-alloyed construction cast steels, in %wt.

No.	cast	C	Mn	Si	P	S	Cr	Ni	Mo	Al	Cu	V	Ti
1	**K1**	0,24	0,797	0,812	0,015	0,004	0,638	0,296	0,248	0,025	0,459	0,006	0,003
2	**K2**	0,22	0,735	0,916	0,014	0,002	0,628	0,295	0,247	0,005	0,464	0,031	0,009
3	**K4**	0,23	0,739	0,930	0,014	0,002	0,618	1,340	0,781	0,005	0,514	0,041	0,014
4	**K7**	0,24	0,586	0,950	0,011	0,006	1,250	2,830	0,480	0,010	0,190	0,075	0,028

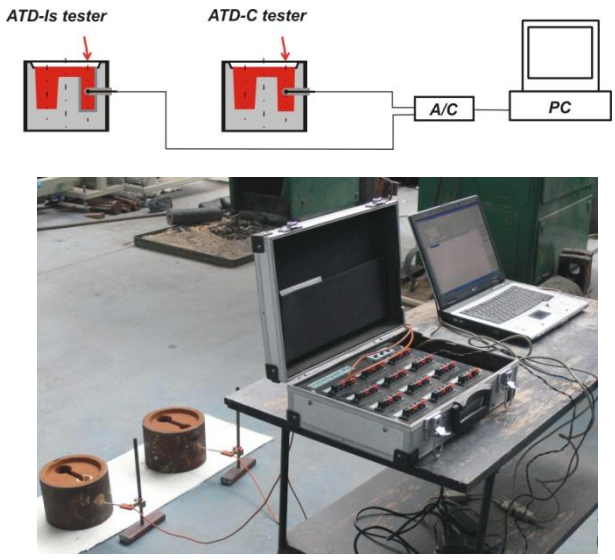

Fig. 1. The experimental TDA stand (scheme and real fot.)

In Fig. 2 a part of Fe-C phase equilibrium diagram was shown with indicated probable paths of crystallization, which can be written as follows:

Cast steel I
with peritectic transformation

$$\mathbf{L \rightarrow L{+}\alpha \rightarrow L{+}\gamma \rightarrow \gamma}$$

Cast steel II
without peritectic transformation

$$\mathbf{L \rightarrow L{+}\gamma \rightarrow \gamma}$$

where: L – liquid, α – ferrite phase, γ – austenite phase.

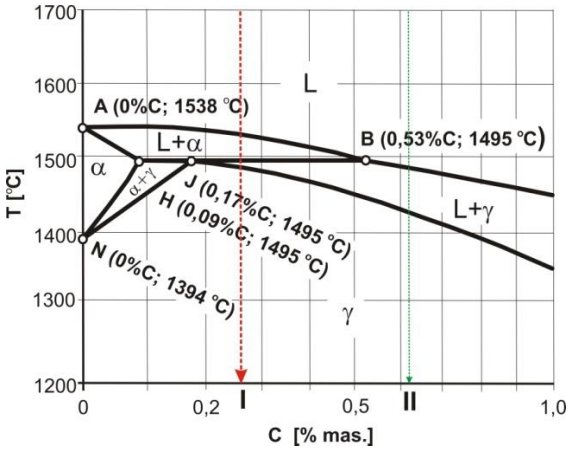

Fig. 2. Part of the Fe-C equilibrium phase diagram with indicated paths of crystallization for cast steels I and II, L – liquid, α – ferrite phase, γ – austenite phase

3. Studies results and analysis

Although great progress of computational technique the numerical modelling does not enable taking into account all factors influencing the crystallization process of the casting [8, 9]. Results of physical experiment can give answers to many technological issues, because it includes many variables of the real process.

In Fig. 3 – 6 diagrams of TDA curves for studied alloys were shown, in range of primary crystallization. In Fig. 3 the characteristic points were indicated on crystallization curve. Table 2 contains the values of crystallization parameters for studied low-alloyed construction cast steels.

Table 2.
Selected parameters of crystallization of low-alloyed construction cast steel

description	TA °C	KA K/s	TB °C	KB K/s	TH °C	KH K/s	SH-SA s
K1	1496	-0.1	1484	-.58	1410	-2.87	78
K1i	1499	0.05	1478	-0.17	1401	-2.36	204
K2	1492	-0.03	1480	-0.61	1391	-3.08	85
K2i	1502	0.03	1480	-0.19	1406	-2.33	202
K4	1500	-0.006	1482	-0.71	1436	-3.27	71
K4i	1503	0.3	1479	0.16	1417	-2.19	217
K7	1478	-0.02	1468	-0.56	1392	-3.44	79
K7i	1489	0.04	1475	-0.37	1373	-1.69	229

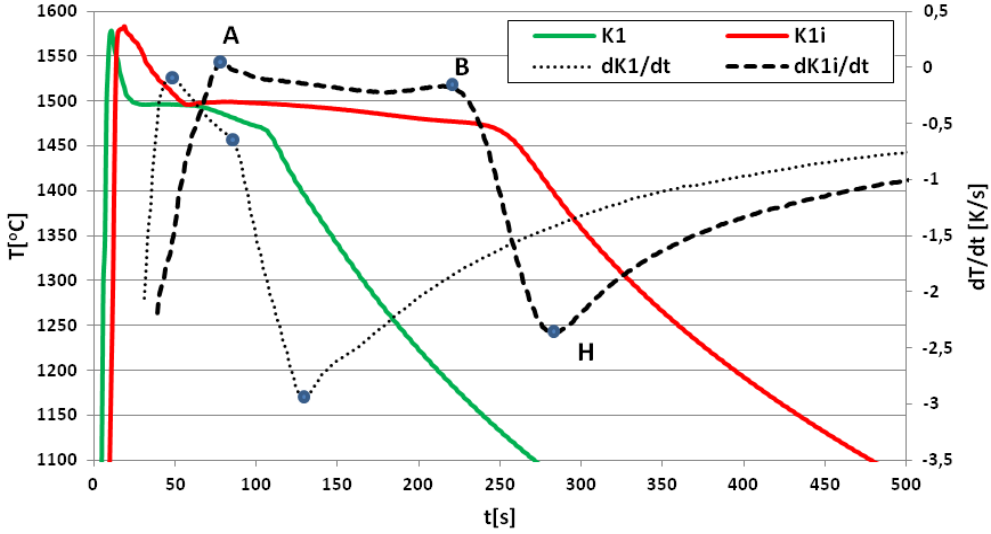

Fig. 3. Cooling and crystallization curves for low-alloyed cast steel K1 at different cooling rates, in function of time

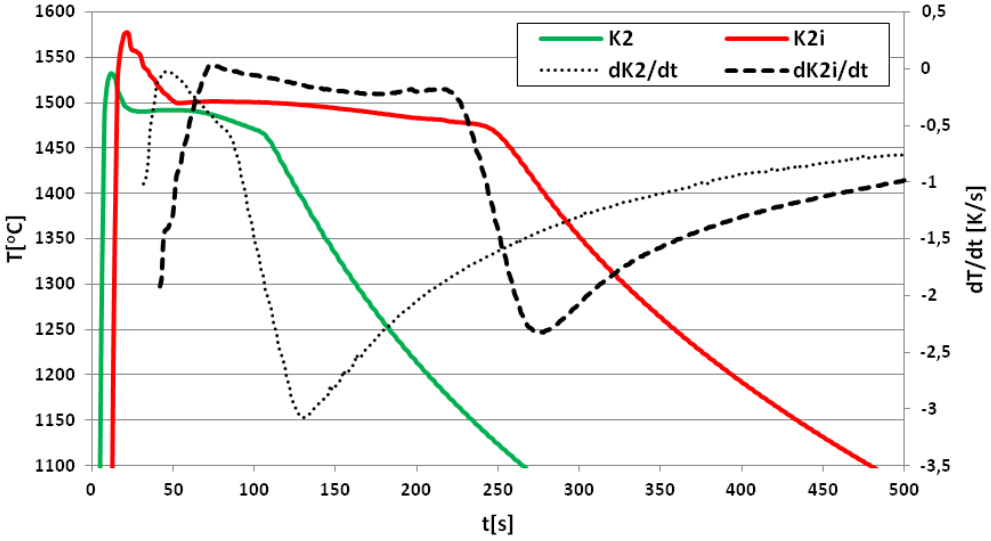

Fig. 4. Cooling and crystallization curves for low-alloyed cast steel K2 at different cooling rates, in function of time

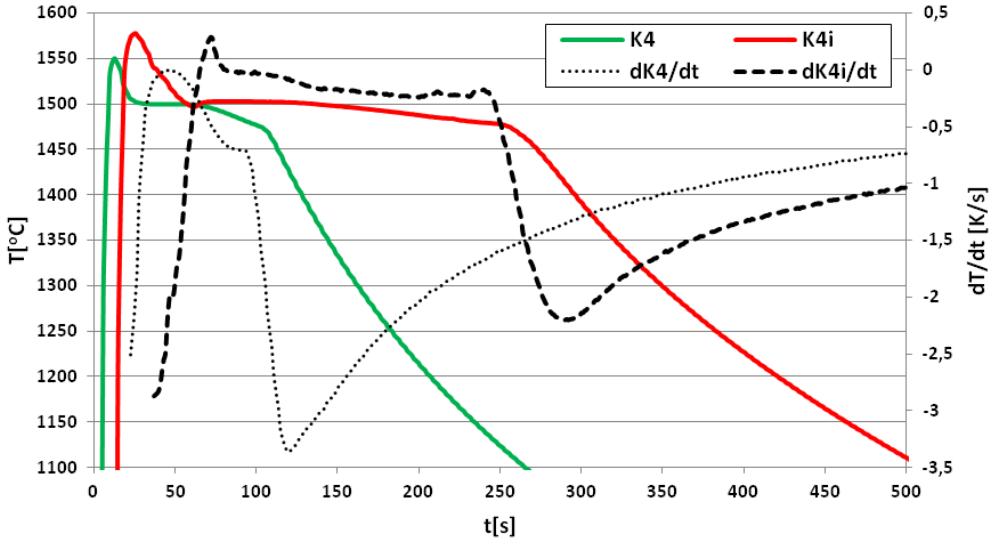

Fig. 5. Cooling and crystallization curves for low-alloyed cast steel K4 at different cooling rates, in function of time

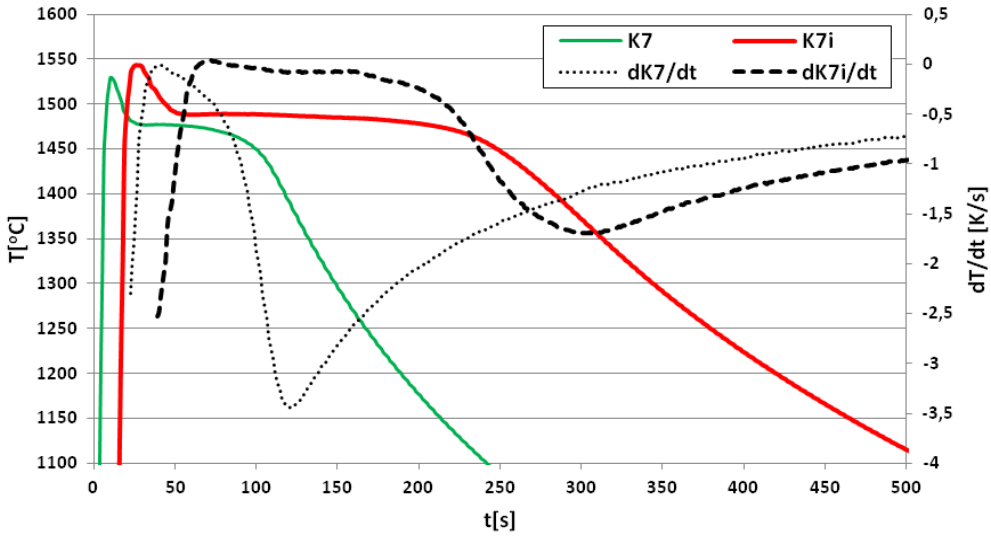

Fig. 6. Cooling and crystallization curves for low-alloyed cast steel K7 at different cooling rates, in function of time

4. Conclusions

In case of cast steels: K1, K2, K4 the primary crystallization involves the peritectic transformation. It can be seen in crystallization curves diagrams (dT/dt), which include two stages of primary crystallization. The first stage is the α phase precipitation from the liquid. The second stage is the peritectic reaction of γ phase nucleating on α phase precipitants.

For cast steel K7, which contains higher amount of introduced additions, the primary crystallization is connected only with austenite crystallization. The dT/dt curve does not indicate crystallization of other phases from the liquid.

Based on conducted studies it can be clearly stated that the cooling rate influenced the liquidus and solidus temperature of low-alloyed cast steels. In Fig. 7 the cooling rate influence on these temperature points is shown for analysed construction cast-steels.

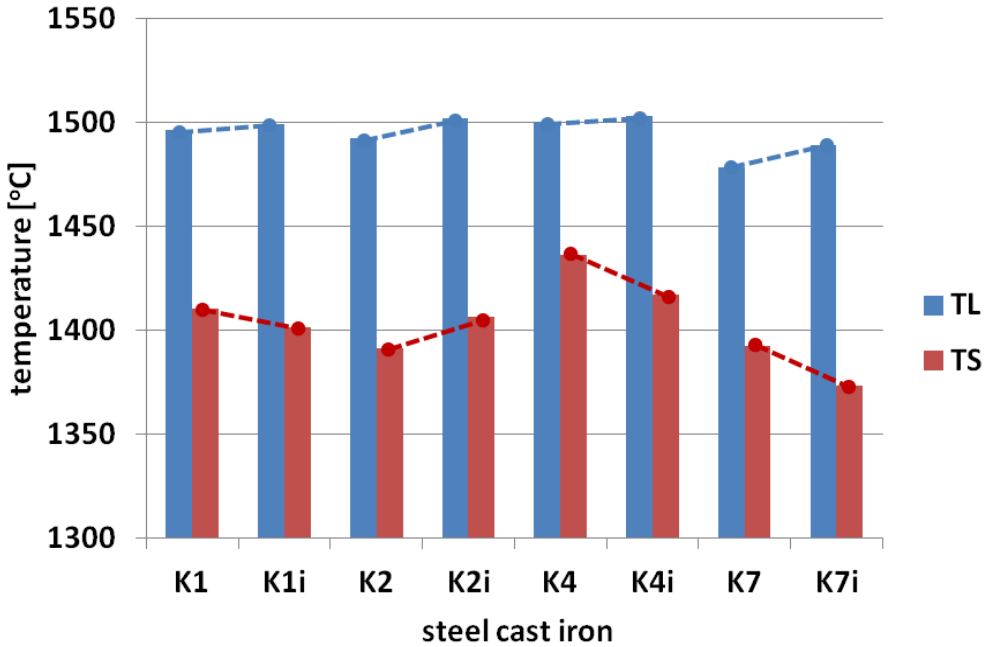

Fig. 7. Influence of cooling rate on liquidus and solidus temperature for studied low-alloyed cast steels

Acknowledgements

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References

[1] Kniaginin, G. (1972). *Cast steel. Metallurgy and Founding*. Katowice: Publisher Śląsk.

[2] Sakwa, W., Jura, S. & Sakwa, J. (1980). *Wear resistance iron alloys. Part II Cast steel*. Kraków: Publisher ZG STOP.

[3] Dobrzański, L.A. (2004). *Metal engineering materials.* Warszawa: WNT (in Polish).

[4] Fraś, E (2003). *Metals crystallization*. Warszawa: WNT.

[5] Gawroński, J. (2004). Professor Stanisław Jura the creator of theory and the industrial uses of diagnostics and the wear of metals and alloys. *Archive of Foundry Engineering*. 4(spec. 16).

[6] Cholewa, M., Jura, Z. & Studnicki, A. (2009). The development of thermal analysis and derivative method in Department of Foundry Silesian University of Technology. *Progresses Theory and The Casting Practice*. Katowice: Publish. PAN Katowice, Paragraph 4, 49-70.

[7] Own works, Department of Foundry Engineering, Faculty of Mechanical Engineering, Silesian University of Technology in Gliwice (not published).

[8] Stadnicki, A., Kondracki, M. & Szajnar, J. (2013). Primary Crystallization of Chromium Cast Steel in Metastable Conditions. Metal 2013, Conference Proceedings, Brno, 2013.

[9] Studnicki, A., Kondracki, M. & Szajnar, J. (2012). Primary Crystallization of High Chromium Cast Steel in Metastable Conditions. *Archives of Foundry Engineering*. 12(spec. 2), 59-66.