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Primary and secondary crystallization of modified hypoeutectic chromium cast iron

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Abstract

The paper presents investigations of crystallization of modified hypoeutectic wear resistant chromium cast iron which contains carbon about 2% and chromium on three levels (12%, 18% and 25%). Three substances were applied to the modification (boron carbide (B_4C), ferroniobium (FeNb) and mixture of ferroniobium and mischmetal (RE)). The investigations of crystallization were conducted the DTA method in DTA-C and DTA-Is testers. The influence on the course of the process of primary and secondary crystallization was observed.

Keywords: Chromium Cast Iron, Crystallization, Modification, DTA Method

1. Introduction

Chromium cast irons are specific group of cast materials which characterizing very high resistance on the abrasive wear among the iron alloys, particularly in the working environment of mineral materials [1÷3]. The resistance on the abrasion is not however the only criterion of the selection of the constructional material. In the practice the principle of materials selection are the function of many parameters, among others the load condition, crack resistance, tensile strength, crushing strength, workability, weldability, costs of the production, etc. Serious technical problem causing large limitations in applying of chromium cast irons on elements is subjected during exploitation with high impacts comparatively low resistance on cracking of these cast irons. In spite of defects what chromium cast irons possess, they find the wide use as casting materials resistant on the abrasive wear. Numbering them to the group of materials about the very high resistance on the abrasive wear many countries in one's norms capture these cast irons.

The degree of the impact-abrasive wear of materials depends from one side on their susceptibility on the abrasion and from second side on the easiness of budding in them cracks and their propagation. Generally, the wear resistant materials are hard but simultaneously are brittle and not resistant on impacts. Is the compromising solution of this contradiction possible? The use of materials the most profitable solution of this problem seems about large hardness and plasticity (ductility), that is structurally heterogeneous materials. One should now fold the structure of resistant materials on the impact-abrasive wear from hard particles disposed in the ductile matrix. The best cases, hardness of particle was higher than the grinding medium and the resistance which was expressed by the coefficient of the intensity of tensions K_{IC} on cracking is possibly large.

From the professional literature and practice [1÷3] follows that in chromium cast iron by suitable chemical composition and the technology is possible to get a various metallographic structures which have better or bad useful to the work in abrasive conditions or even impact-abrasive. It seems, that the stereological of carbides phaze is the main problem restrictive the wide use of chromium cast iron in impact-abrasive conditions because this determining resistance of the cast iron on cracking. To concile of these two conflicting properties of chromium cast iron, i.e. hardness and ductility by refinement

and unification of distribution of carbides phaze in austenitic matrix or the products of his transformation. Modification is one of the founding technologies for the formative of the casting structure.
The authors of papers from the range of the modification of chromium cast iron and introducing various alloys additions got interesting results, however the absence is good industrial solutions. The researchers introduced to chromium cast iron among others the niobium [4÷5], the cerium [6], the vanadium [7, 8], the boron [9], the titanium [10, 11], the metals of rare-earth [10÷12], the boron carbide [13]. These elements often were introduced to the cast iron in quantities about 1% of weights of casting.
The authors of this paper realize systematically the investigations [14÷16] of the process of the crystallization of wear chromium cast iron subjected the various interventions of modification (various modifiers and the techniques of the modification). The results of the investigations of the crystallization of hypoeutectic chromium cast iron modified by introduction of boron carbide, ferroniobium and mixture of ferroniobium and mischmetal are presented in paper. It was put in investigations that the part of a single modifier should not cross 0,3% of the mass of the charge and the mixture of modifiers should not cross 0,5% of the mass of the charge.

2. Experiment

Studied chromium cast iron was composed from following added components:

- exit cast iron (2,8% C and 18% Cr) smelted in the industrial arc furnace from standard added materials applied to the industrial melting of wear chromium cast iron,
- steel scrap-iron, pig iron,
- ferrochromium low- and high carbon,
- the modifiers: B_4C, FeNb, mischmetal (RE).

The plan of melts made during the series of investigations are presented in Table 1.

Experimental melts were conducted in the induction crucible furnace about laying out indifferent and the capacity 20 kg. All melts were made with the same procedure of remelting. The temperature of the metal bath which should be 1540°C was measured before the tapping. The tapping of liquid cast iron was executed after the obtainment of the proper temperature to warmed well casting ladle. Melts nN0, nS0 and nW0 were not modified. Remaining melts were conducted with the modification of the cast iron during tapping of liquid metal according to put plan (Table 1).
The testers were flooded after finishing the tapping and waiting about 10 seconds in the turn DTA-C and DTA-Is. The registration of the temperature was led till moment of her fall below 500°C in testers. Such registration made possible later the analysis of primary and secondary crystallization of studied chromium cast iron. The scheme of the research stand is presented on Figure 1. Second tester DTA-Is differ oneself from the standard tester DTA-C only measuring cavity which is lined with the aluminosilicate material isolating (Sibral 300). The use of the isolating material lengthens about twice the time of crystallization, what makes possible the observation of crystallization of the studied material free cooling down the cast. The construction of the DTA-Is tester was introduced on Figure 2.

Table 1.
The plan of melts of studied chromium cast iron

Mark	% weight		modifier *X* % weight			
	C	Cr	-	B_4C	FeNb	FeNb+RE
			X=0	*X*=1	*X*=2	*X*=3
nN*X*	2	12	-	0,25	0,25	0,2+0,2
nS*X*	2	18	-	0,25	0,25	0,2+02
nW*X*	2	25	-	0,25	0,25	0,2+0,2

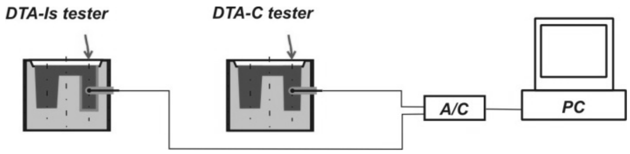

Fig. 1. The research stand

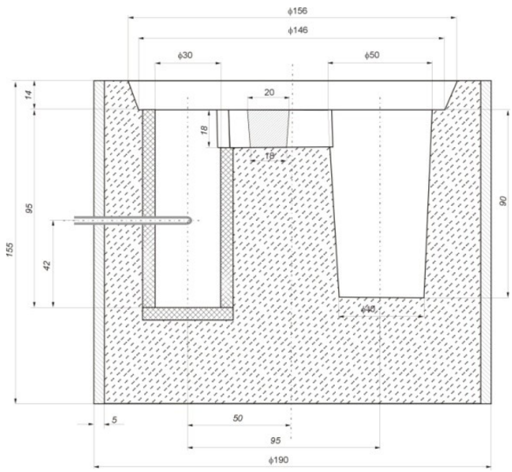

Fig. 2. DTA-Is tester

3. The structure, cooling and crystallization curves

Full review of cooling and crystallization curves (curves DTA) of studied hypoeutectic chromium cast iron was introduced on figures 3÷14 with representing them metallographic structures. Metallographic samples were made on the perpendicular section to the axis of the measuring cast in the distance 20 mm from its bottom. All made metallographic samples by 30 seconds were etched in 3% Nital.

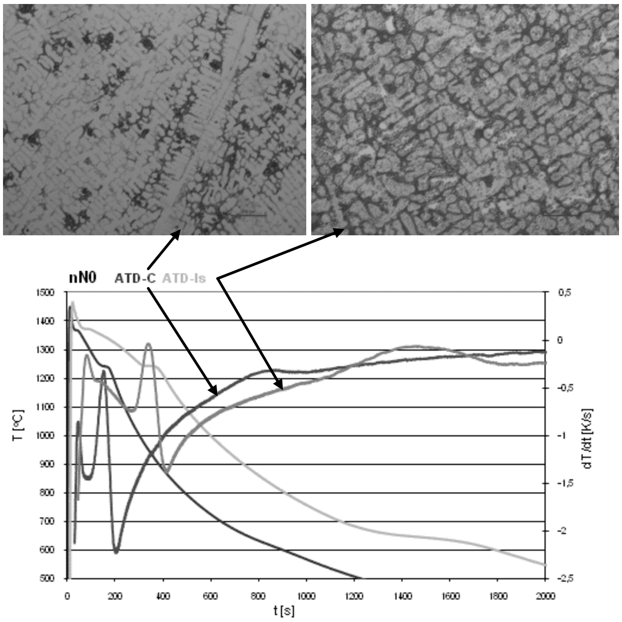

Fig. 3. Structure, cooling and crystallization curves of chromium cast iron nN0 (2% C, 12% Cr, unmodified)

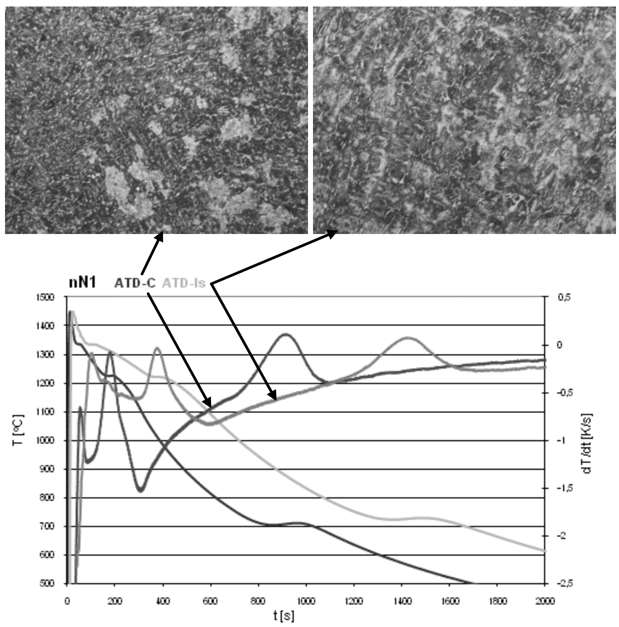

Fig. 4. Structure, cooling and crystallization curves of chromium cast iron nN1 (2% C, 12% Cr, modified B_4C)

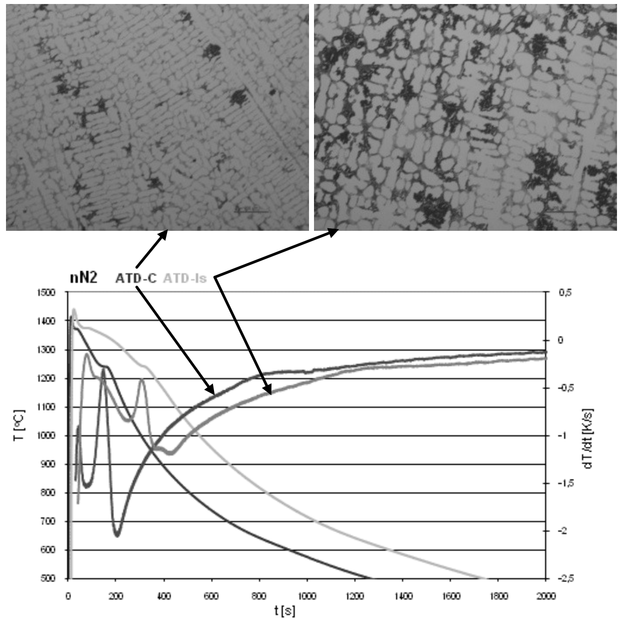

Fig. 5. Structure, cooling and crystallization curves of chromium cast iron nN2 (2% C, 12% Cr, modified FeNb)

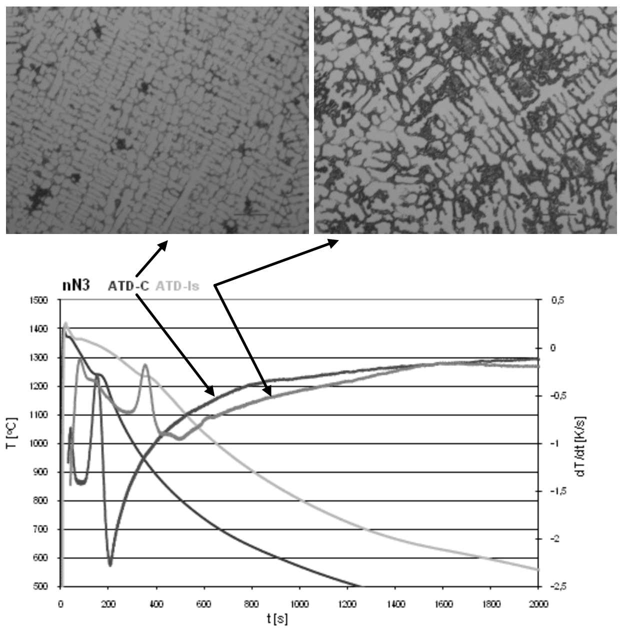

Fig. 6. Structure, cooling and crystallization curves of chromium cast iron nN3 (2% C, 12% Cr, modified FeNb+RE)

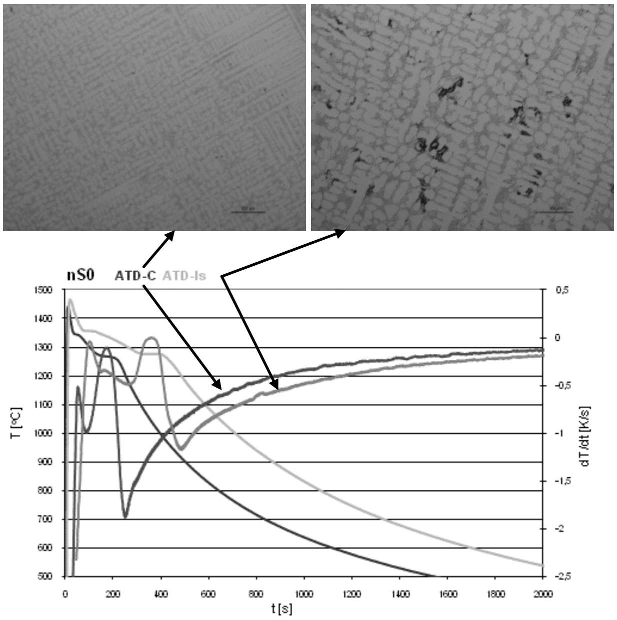

Fig. 7. Structure, cooling and crystallization curves of chromium cast iron nS0 (2% C, 18% Cr, unmodified)

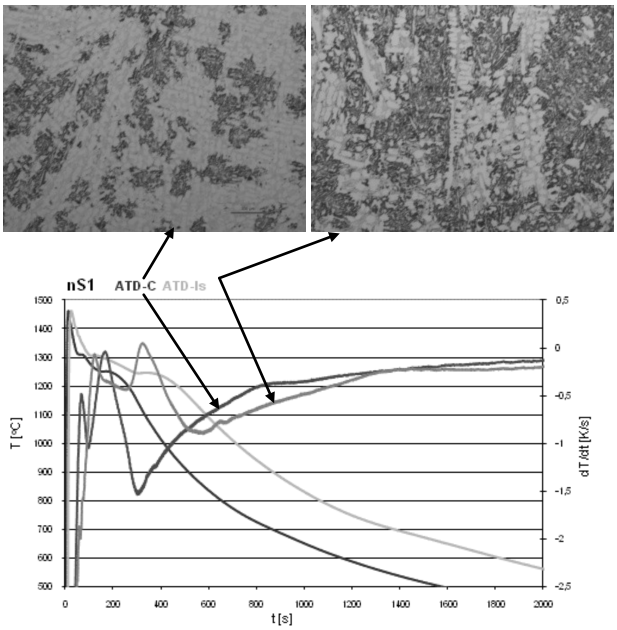

Fig. 8. Structure, cooling and crystallization curves of chromium cast iron nS1 (2% C, 18% Cr, modified B_4C)

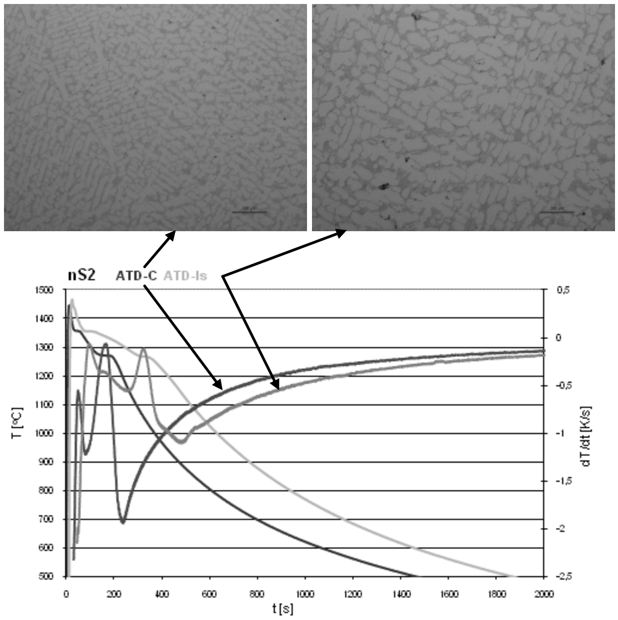

Fig. 9. Structure, cooling and crystallization curves of chromium cast iron nS2 (2% C, 18% Cr, modified FeNb)

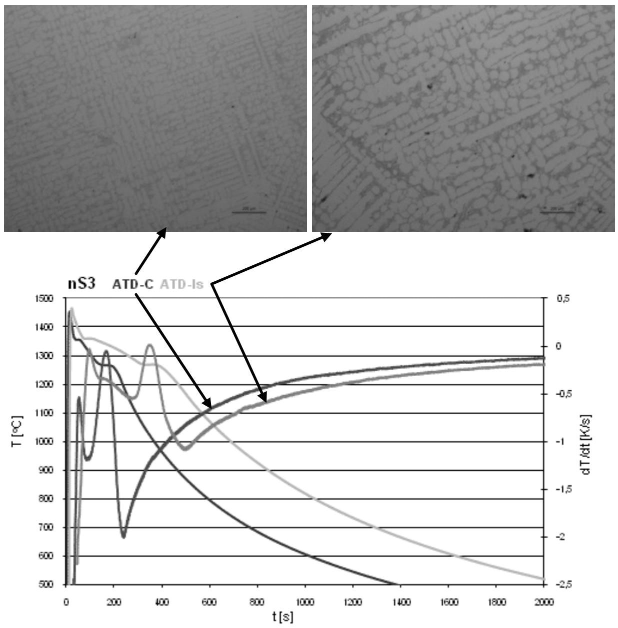

Fig. 10. Structure, cooling and crystallization curves of chromium cast iron nS3 (2% C, 18% Cr, modified FeNb+RE)

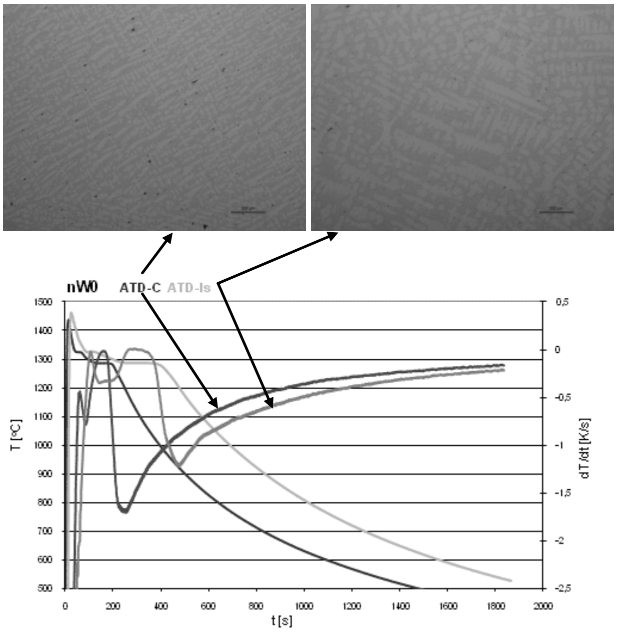

Fig. 11. Structure, cooling and crystallization curves of chromium cast iron nW0 (2% C, 25% Cr, unmodified)

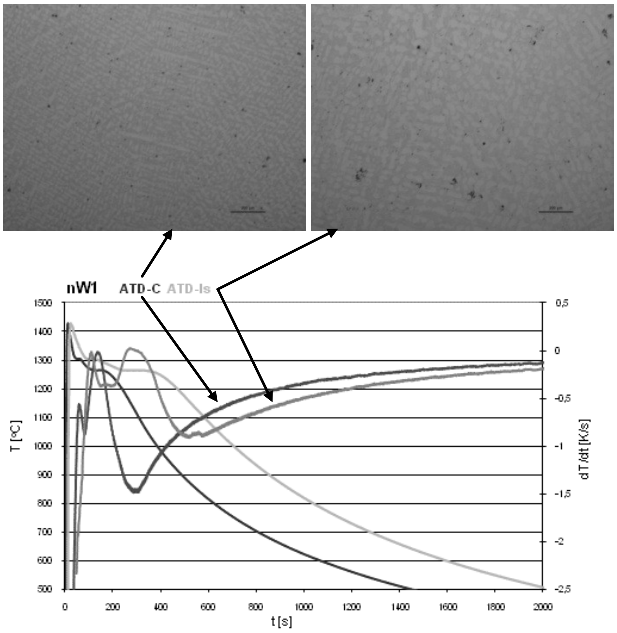

Fig. 12. Structure, cooling and crystallization curves of chromium cast iron nW1 (2% C, 25% Cr, modified B_4C)

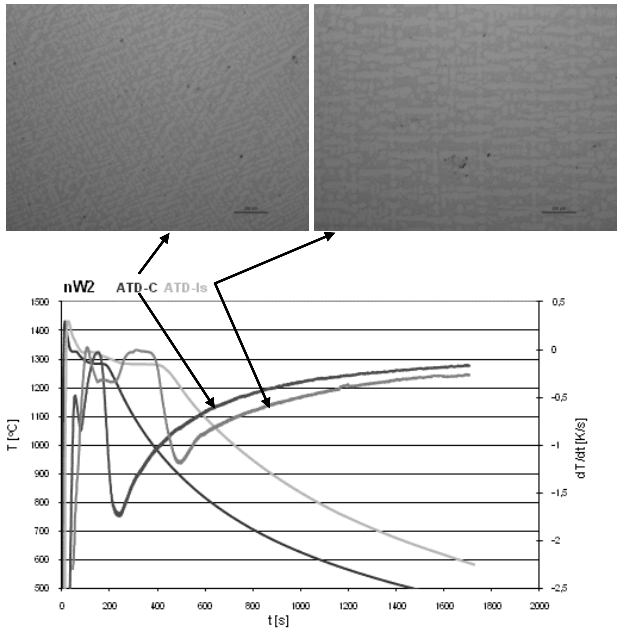

Fig. 13. Structure, cooling and crystallization curves of chromium cast iron nW2 (2% C, 25% Cr, modified FeNb)

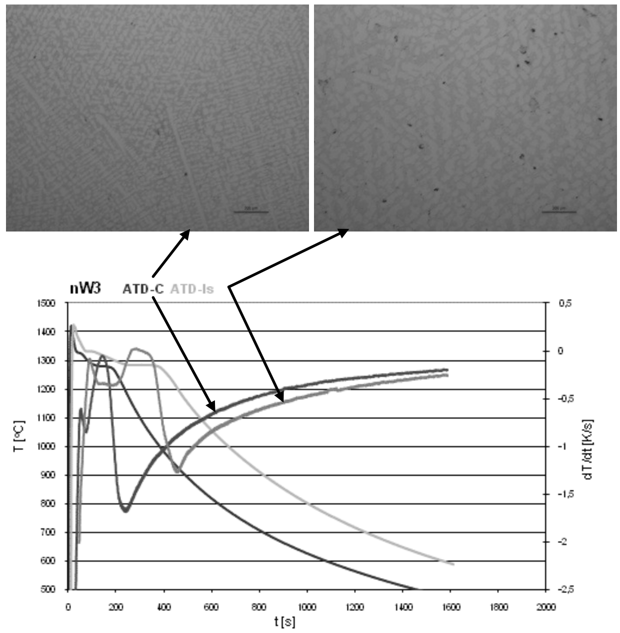

Fig. 14. Structure, cooling and crystallization curves of chromium cast iron nW3 (2% C, 25% Cr, modified FeNb+RE)

Analysing the first group (Fig. 3÷6) of studied chromium cast irons that is the considerable part of the primary austenite in cast irons about the lowest content of chromium about 12% in the of primary crystallization perceptible range in structure (first peak on curve crystallization). Second peak illustrating eutectic crystallization (γ+M_7C_3), its shape changes in the function of the addition of the modifier. The addition of the boron carbide clearly enlarges the range of eutectic temperature, reducing temperature of the end of eutectic crystallization (Fig. 4). The additions of niobium and RE effect probably on crystallization of two eutectic (γ+M_7C_3 and γ+M_3C), what visible is clear arises on curve crystallizations of two peaks (Fig. 5, 6). The influence of the modification the is most clearly in first group of studied chromium cast iron appears on the secondary crystallization which you should mainly attribute phase changes relating to matrix. Matrix of unmodified alloy nN0 (Fig. 3) undergoes the partial eutectoid transformation. Slow cooling of the casting favours the fuller transformation. Modifier in the form of the boron carbide causes still the larger intensification of this process (look peaks on curve crystallizations and the picture of structures – Fig. 4). The additions of niobium and RE work however inversely, stabilise of the austenite. Peaks on curve crystallizations are hardly perceptible, and few areas etched (Fig. 5 and 6) step out on metallographic samples.

In second (Fig. 7÷10) and third (Fig. 11÷14) group of studied chromium cast irons cooling and crystallization curves have the similar course. With increase in chromium content increases of eutectic content is observed. The eutectic homogeneity also increases, what show lack of second peak in range of eutectic crystallization (Fig. 13 and 14). In range of secondary crystallization also are present changes about increase of chromium content and addition of niobium and RE which stabilize austenite. The boron carbide strengthened by the fall of the cooling rate of casting influences strongly on destabilisation of austenite (Fig. 8). Its influence is scarce (Fig. 12) near the highest content of chromium, about 25%.

The introduced results of investigations show that the tenderness of the DTA method makes possible give the opinion of the processes of the crystallization of modified chromium cast iron. The small quantity of the modifier changes the parameters of primary and secondary crystallization.

On the basis of conducted investigations can affirm that the modification by the boron carbide influences most strongly on primary crystallization of studied chromium cast iron, however on secondary crystallization influences ferroniobium and RE.

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