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The influence of solidification speed during heating on allotropic transformations of chromium cast iron casting

M. Przybył*, A. Studnicki*
Department of Foundry, Institute of Engineering Materials and Biomaterials, Faculty of Mechanical Engineering, Silesian University of Technology, Towarowa 7, 44-100 Gliwice, Poland
*Corresponding author. E-mail address: marian.przybyl@polsl.pl, andrzej.studnicki@polsl.pl

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Abstact

The unique stand to founding dilatometric samples ("on ready”) which solidify with different cooling speeds was presented. The dilatometric investigations, X-ray, metallographic they disclosed the occurrence in matrix of chromium cast iron of considerable quantity of austenite in dependence from concentration of chromium (18% and 23%) and the speed of solidification. Castings these despite large part of austenite mark with high hardness in raw state.

Keywords: Chromium cast iron, Allotropic transformation, Dilatogramy, Solidification

1. Introduction

The matrix of wear resistance chromium cast iron in raw state in support about arrangements of phase equilibrium it does not contain austenite in matrix [1,2,3]. However in industrial castings, and particularly small austenite meets the most probably, which during observation on light microscope be definite as bright phase which is hard to etching. However with attention on comparatively large hardness of quickly cooling castings (about 45-55 HRC), austenite matrix seems little probable.

The use of dilatometric investigations and the occurrence the austenite can confirm the X-ray analysis also, are make up the test of qualification of part phase α and γ in cast iron which cooling with different speeds.

It with attention on small dimensions of dilatometric samples as well as the high hardness of studied materials strongly making difficult their processing cutting off, studies of method of receiving these samples were undertaken was with mould, assuring simultaneously the crystallization with different speeds the cast iron directly. It the earlier experiences of Department of Foundry of Silesian University of Technology were used in regulated speed the cooling of castings [4,5,6,7].

2. Stand to founding dilatometric samples

The possibility of realization was the main foundation of study of stand to founding the dilatometric samples on him the cylindrical samples (the rods) about required the diameter and suitable quality of surface side without necessity of her mechanical processing. It was allowed cutting the samples on required length as well as realization of incision of one part of front sample on introducing the thermocouple.

It mould projecting was accepted:

– dimension of dilatometric sample ϕ 6 x 35 mm,
– dimensions of cast rods (the diameter ϕ 6 mm x the multiplicity of length of dilatometric sample);
– three sets of cast rods for different crystallization speeds;
– founding the rods in thin-walled quartz tubes (the internal diameter of tube ϕ 6 mm).

This stand is suitable to realization of dilatometric samples for casting wear resistance alloys particularly to which we contain also the chromium cast iron also.

It the founding in sand classic moulds with use of thin-walled quartz tubes as facing mass were decided on technology, eliminating in this the way the direct influence of mould material on smoothness surface of casting of rod. It for assurance of different cooling speeds the next sets of samples were designed in construction of form two "heaters", which they are flooded with separate inlet arrangement first. This part of form be executed according to technology of lost foam. In result of use "heaters" about different dimensions (mass) adjacent directly to as well as plates heat-insulating quartz tubes, the different speed of crystallization of dilatometric samples was got.

After flood "heaters" then second, syphon inlet arrangement were flooded tubes quartz ϕ 6 mm. The patern of model set was shown on figure 1.

Executed casting on figure 2 was introduced after knocking out with mould.

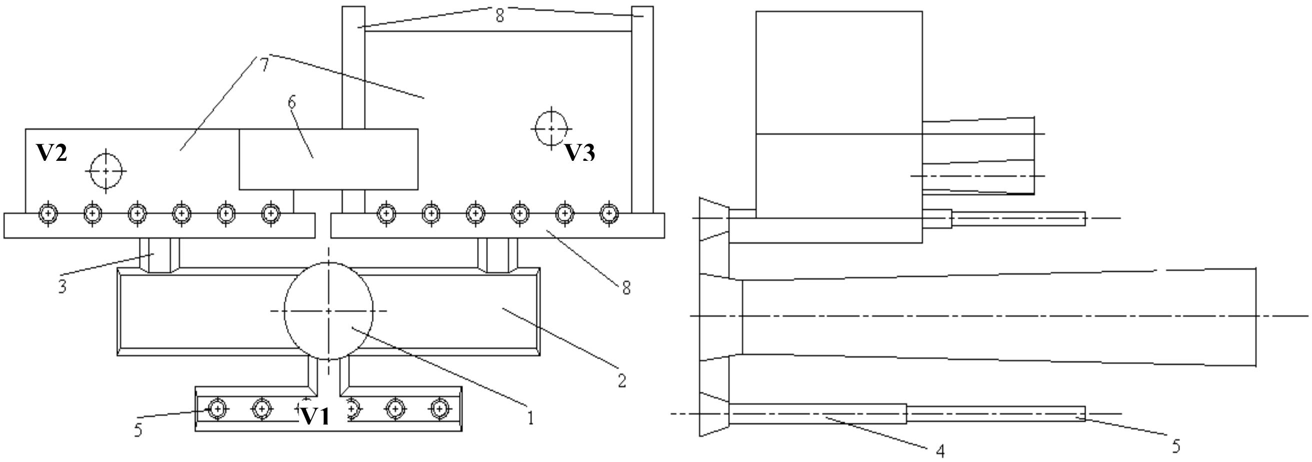


Fig. 1. Pattern set to realization of mould
1 – pouring gate of casts of dilatometric samples; 2 – cross-gate; 3 - ingate; 4 - tube quartz ϕ 6; 5 - metal rods; 6 – gating system for "heaters"; 7-"heaters"; 8 - heat-insulating plates (Sibral).
V1, V2, V3 - the solidification speed of casts (in turn - large, average, small)

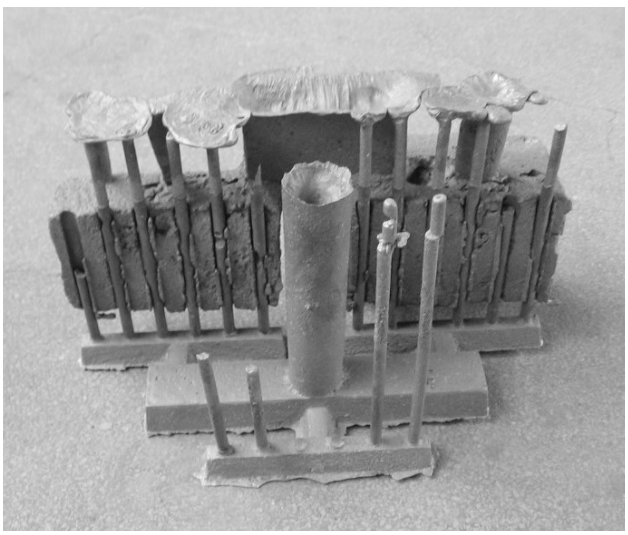


Fig. 2. Cast after knocking out with mould

3. The aim of investigations and their course

The qualification of influence of crystallization speed on matrix of wear resistance chromium cast iron was the aim. The investigations were conducted on two melting of cast iron which applied on wear resistance castings often. The chemical composition of studied chromium cast iron was introduced in table 1.

Table 1.
Analyse of research chromium cast iron

melt	composition wt %					
	C	Cr	Si	Mn	Ni	Mo
M1	2,48	18,50	0,30	0,11	0,66	0,08
M2	2,44	23,50	0,84	0,13	0,61	0,07

P<0,040; S<0,020

Melting were executed in laboratory inductive crucible furnace.

Dilatometric samples from poured rods were had cut out, one about length 35 mm and executed on one front surface incision abrasive shield on depth 1,5 mm in which during dilatometric investigations be placed themocouple. The dilatometric investigations were conducted on automatic dilatometer DA-2 [8]. It warming samples was led with speed 0,5 ^{o}C/s, then hold in a in temperature 950 ^{o}C by 45 minutes and then cool with speed 1 ^{o}C/s. Moreover for chosen of samples (it concerns then melting M2) renewed cycle of warming was applied and the cooling on dilatometer. It for tracing possible changes connected from very small the speed of warming was applied renewed warming with speed 0,05 ^{o}C/s.

It the method was conducted the investigations of hardness Rockwella in scale C on the grind off side surfaces of dilatometric samples in state raw and after investigations dilatometric.

It metallographic investigations on light microscope for magnification 100÷600 were conducted on polished section which cut perpendicularly to axis of dilatometric sample.

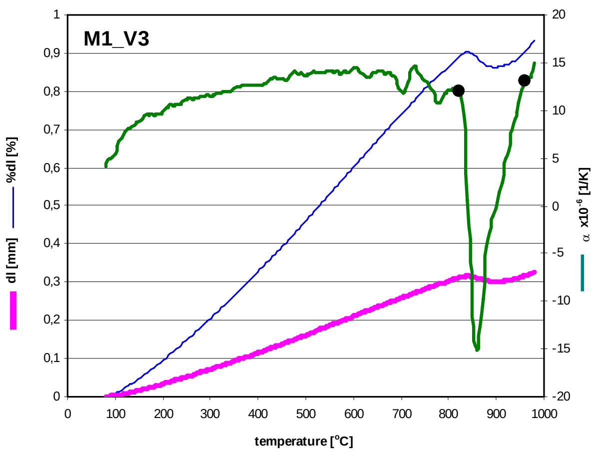
It preliminary (identification) X-ray investigations were conducted on diffractometer the having on aim accomplishment of phase analysis DRON 2,0 from goniometer HZG -3 from radiation cobaltic lamp.

4. Results of investigations and their discussion

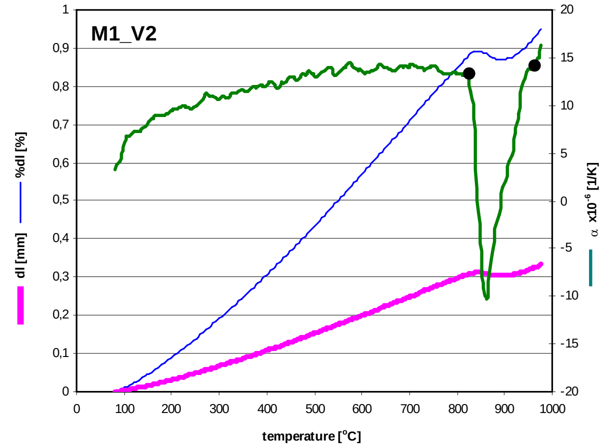
Elongation and percentage elongation of sample in function of heating and cooling temperature in dilatometric investigations was recorded for every melting and every crystallization speed. It for precision results, the derivative of dilatometric curve was marked. Chosen dilatograms and their derivatives during heating samples on figure 3 was presented.

It the temperatures of beginning and of ending of allotropic transformation on basis of clear changes of value derivative on

a)



b)



c)

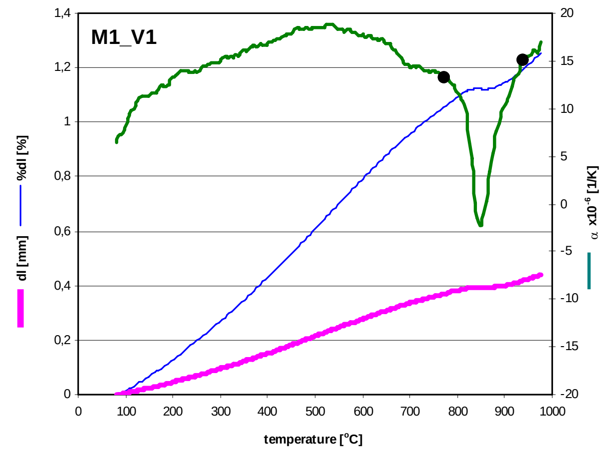


Fig. 3. Chosen dilatograms for melting with different cooling speeds M1 : a) small V3, b) average V2, c) large V1

dilatometric curve were marked (alternatively the process of secretion of carbides). Notices in course of dilatometric curve and her derivative the clear differences above temperatures 800 ^{o}C for solidification with different speeds samples, which testifies about different degree the setting the transformation $\alpha \rightarrow \delta$. The course of typical transformation $\alpha \rightarrow \delta$ manifests clear with getting smaller to length of sample, which illustrates then the dilatometric curve of melting M1 the most slowly cooling - figure 3a.

It however on dilatogramy of high chromium cast iron which rapidly cooling the changes do not were notice in course of curve in temperatures of allotropic transformation (fig. 4a). It with course of derivative was been possible only to judge that transformation sets $\alpha \rightarrow \gamma$ in small degree. This suggests that the considerable part of austenite in raw state this cast iron steps out in structure. Transformation in track renewed heating this sample sets in larger degree $\alpha \rightarrow \gamma$ what is on dilatogramy visible, e.g. on figure 4b.

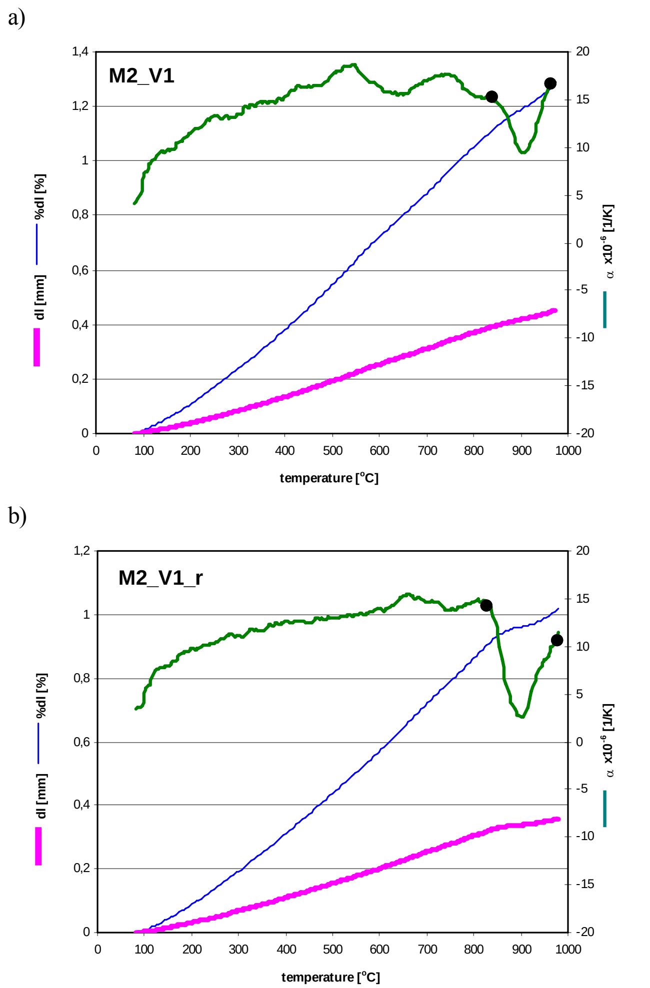


Fig. 4. Dilatograms for melting with large cooling speed M2: a) with raw state, b) after earlier 1 cycle heating

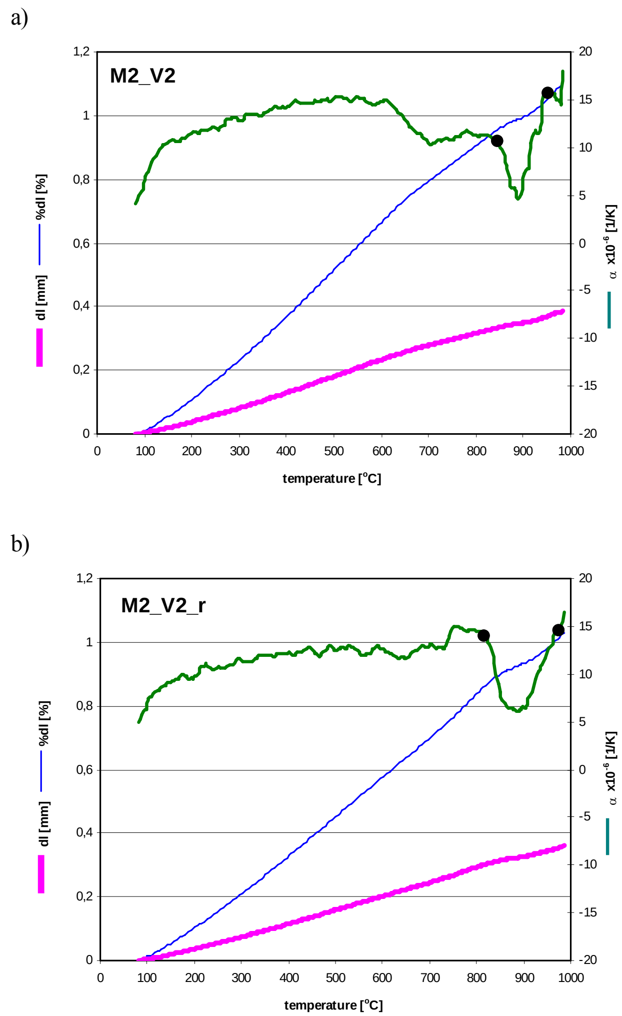


Fig. 5. Dilatograms for melting M2 with average cooling speed: a) with raw state, b) after earlier 2 cycle heating

Additional cycle of investigations in dilatometer and with reduced speed heating displays incident transformation $\alpha \rightarrow \delta$ yet in larger degree, and her beginning - A_{C3} is in somewhat lower temperatures (fig. 5). It was been possible to suppose that emissions from austenite secondary carbides in every cycle of thermal processing follow, causing the same change of his chemical composition and destabilizing him.

The hardness of studied melting in raw state has carried out for about 45 to 55 HRC - table 2.

Table 2.
Results of measurement of hardness castings in raw state

melt ⟶	M1	M2
solidification speed	hardness HRC	
V1 large	**53,2**	**54,2**
V2 average	**43,1**	**54,2**
V3 small	**45,5**	**44,5**

The largest speed of cooling casts favours stabilization of matrix and in temperature of surroundings of austenite predominates. The decrease of crystallization speed of average chromium cast iron (melt M1) it favours the transformation of austenite and it does not notice in cooled samples the most slowly. However in high chromium melting M2 cooled austenite even slowly the austenite stays in considerable degree in matrix.

It the structure of cast iron in raw state was observed on light microscope (fig. 6).

With analysis of results of investigations: the hardness, dilatometric and structural the observations push surprising enough, that the hardness of the most quickly cooling casts showing the austenite matrix it is so high, in comparison to typical the austenitic cast iron.

X-ray phase analysis confirmed occurrence austenite in so large part in studied melting - figure 7.

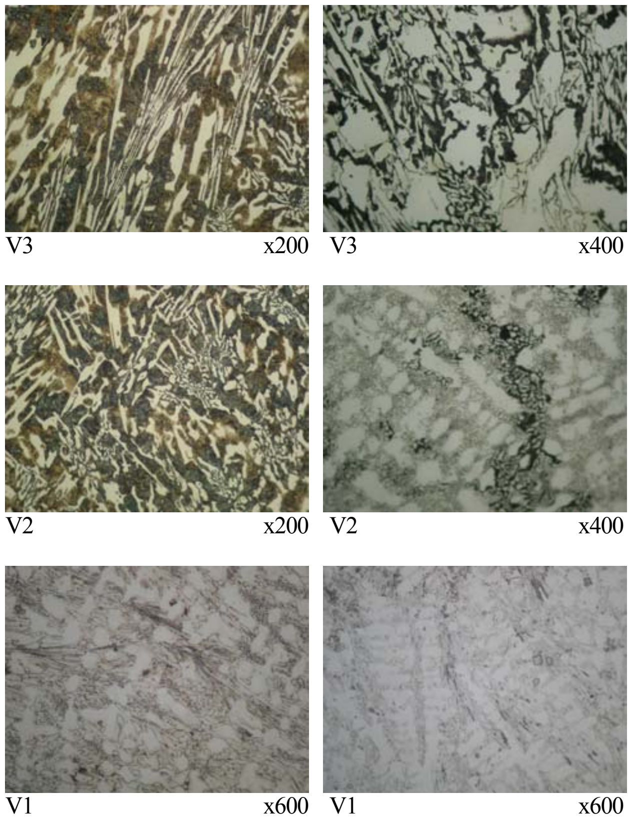
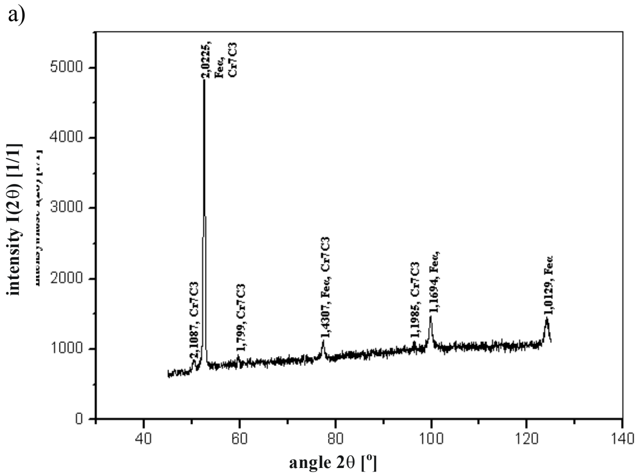


Fig. 6. In raw state of studied cast irons the structure with different solidification speed

a)



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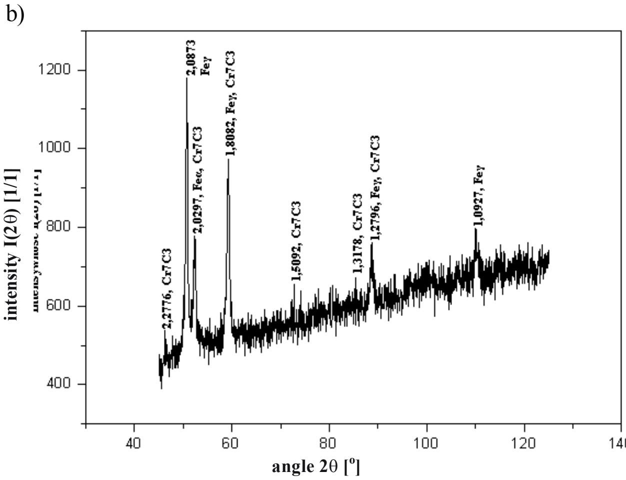

Fig. 7. The exographs of cast iron M1 in raw state with different solidification speeds: a) small V3, b) large V1

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