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The change of temperature gradient in solidification of hypereutectic chromium cast iron casting

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Abstract

In article the analysis of temperature gradient of solidification in section of hypereutectic chromium cast iron model casting was introduced. On this example was presented the method (DTGA – derivative and thermal gradient analysis), which was worked out in Department of Foundry Silesian University of Technology enabling the record of indispensable data to execution of analysis the temperature gradient and its derivative after time on section of model casting. It multichanneled apparatus to registration of data was used Crystaldigraph - PC.

Keywords: DTGA method, Thermal gradient, Thermal gradient rate, Chromium cast iron

1. Introduction

Continuous development of methods of thermal analysis and derivative (DTA) in Department of Foundry Silesian University of Technology in Gliwice is connected with development in electronics and computer science and in peculiarity the next generations of apparatus Crystaldigraph.
The DTA be associated with scientific casting centre of Gliwice, long ago mainly with person of Professor Stanislaw Jura [1,2] and at present with his learners. Department of Foundry in Gliwice between different field of scientific interests - investigative in area of study and description of crystallization process of casting alloys realizes be base at on more and more modern investigative apparatus, unreeling the next versions of thermal analysis and derivative method (GDTA [6,7], DTA-K 3 [3,4]).

Author of presented work uses and improves the DTA method still mainly to investigation of crystallization processes of chromium cast irons, however the achievement, particularly in range of applied investigative DTA-K3 method from success can to be used for different materials casting. It near study of DTA-K3 method was turned the attention on use of the technique of physical modelling of castings about larger solidification modules, which has the essential practical meaning for many alloys, in this the chromium cast iron, because it is very often applied on heavy-walled castings. The physical modeling approximate to industrial conditions how the most makes possible the more exact analysis of the setting processes in mould of real cast.
The basic premise to applying the DTA-K3 method is the dependence of crystallization parameters from rate of cooling, what the author confirmed in his investigations of chromium cast iron for characteristic solidification temperatures [5]. In investigations [8] authors show that the also global value of warmth of crystallization undergoes in dependence of the change of rate cooling. To be visible so that the conditions of cooling in

mould have essential influence on crystallization parameters and necessary it seems that the knowledge of individual parameters of solidification in function of cooling rate is indicated how the most, particularly for experts deal with numeric simulations of cooling processes of the castings.
The investigative method in present article was introduced the enabling analysis of the temperature gradient and its derivative after time (temperature gradient rate). It method was named DTGA (derivative and thermal gragient analysis). It modified tester to study of method was used ϕ100 from method DTA-K3.

2. ϕ100 tester to analysis of temperature gradient

In construction of tester the worked out to investigation of temperature gradient in cooling of model casting ϕ100 the constructional foundations of testers well-known from DTA-K3 method [4]. The results of computer simulation of ϕ100 tester on figure 1 was shown. From analysis of results of simulation to be visible that the arrangement of isotherms in model casting makes possible such distribution of thermocouple to assure on direction of flow of stream warmth the registration of temperature from model casting to model mould in time of cooling casting. Profitable the way of putting thermocouple (in this construction of tester is also thermocouple be led out from tester to course of isotherms in model cast simultaneously). Such arrangement considerably less influences on disorder of measurement of temperature.

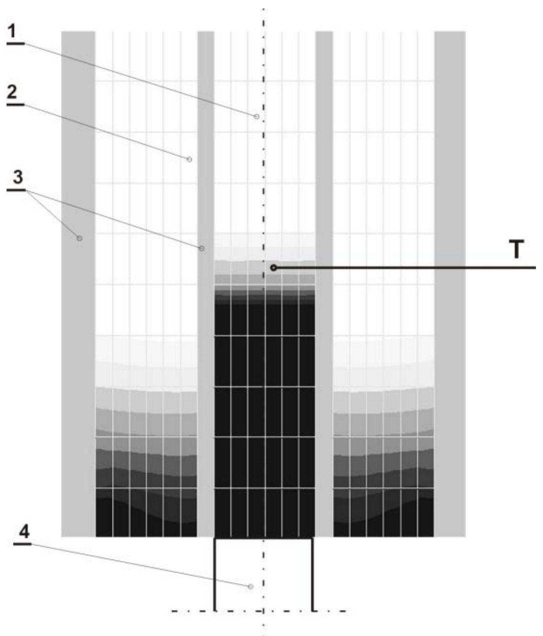

Fig. 1. Simulation of cooling ϕ100 tester
1 - model casting, 2 - thermal insulator, 3 - isolating material, 4 - model mould (steel), T - method of distribution of thermocouple in tester

On figure 2 is presented the construction of the tester applied in DTGA method together with method of distribution of next thermocouple. It even distances were accepted (10 mm) between next level of thermocouple.

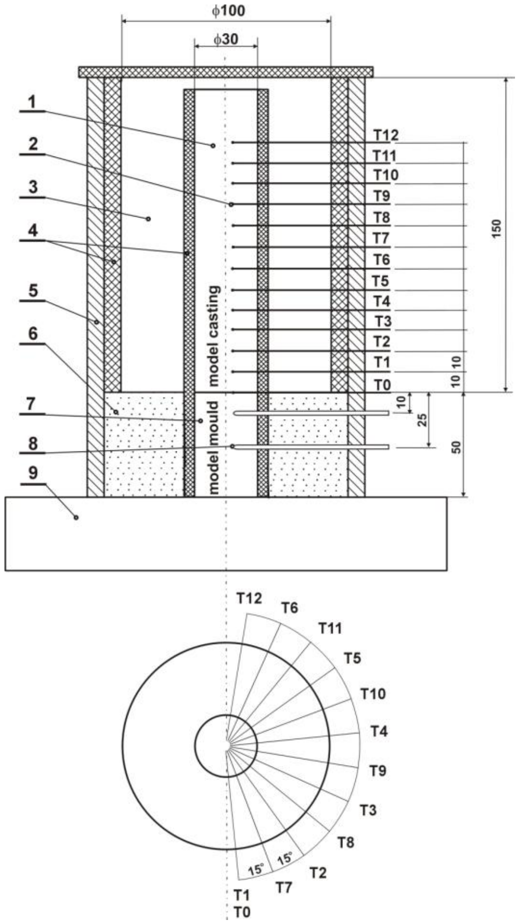

Fig. 2. Construction of ϕ100 tester and method of distributions of thermocouple
1 - model casting, 2 - PtRh10-Pt thermocouple, 3 - thermal insulator, 4 - material isolating SIBRAL 300, 5 - steel casing, 6 – mould material (the quartz sand), 7 - model mould (steel), 8 - NiCr-Ni thermocouple, 9 – bottom plate
T0 - PtRh10-Pt thermocouple which placed on border of model casting - model mould,
T1÷ T12 - PtRh10-Pt thermocouples in shields quartz disposed in model casting

Quantity and distribution of thermocouple so well-chosen to fully possible the realization the measurement of temperature on road the flow of warmth from casting model (from thermal centre of casting) to model mould in time of cooling the tester. The lack of possibility unambiguous delimitation in dependence the position of thermal centre model casting from studied alloy, mould material, technological parameters and different factors caused the use of excessive quantity of thermocouple. Really the delimitation for set parameters of experiment the position of

thermal centre model casting on basis of analysis of registered curves of cooling is possible.
In next chapter of article on example of hypereutectic chromium cast iron was introduced the analysis the DTGA in solidification casting. Short qualitative analysis of metallographic structure also was passed studied casting iron, which is the result of chemical composition and thermal process cooling parameters of casting iron described with use of temperature gradient and its derivative after time.

3. Hypereutectic chromium cast iron DTGA

To investigations was used the hypereutectic chromium cast iron about following weight part of basic elements: C = 3,80 %; Cr = 23%. Melting experimental was conducted remelting method in crucible inductive furnace about indifferent lining and capacity 20 kg. Traditional charge materials were applied - steel scrap-iron, pig-iron, low and high carbon ferrochromium. The tapping temperature of liquid cast iron to ladle pouring carried out 1480 ^{o}C. After ϕ100 tester was flood curves of cooling in 13 points (see fig.2.) of model casting was recorded. The registration was led to moment of temperature in measuring points below 500 ^{o}C. Time this carried out over 3 hours. The registered cooling curves on figure 3 were showed. After course of cooling curves was it been possible to infer that the thermal centre of model casting is in vicinity of thermocouple T10.

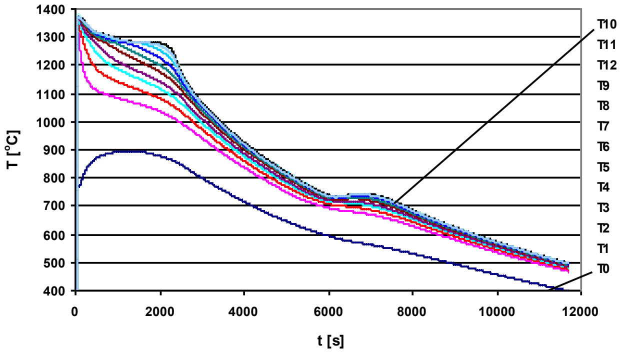

Fig. 3. Registered cooling curves in model casting

Acquaintance of cooling curves is the point of exit to delimitation the temperature gradient. The average value of temperature gradient between measuring points, for example. 2 and 3 to count in following way:

$$G2-3=\frac{T3-T2}{d2-3} \qquad [\mathrm{K/cm}] \qquad (1)$$

where:
T2, T3 - temperature in point 2 and 3 in ^{o}C
d2-3 - distance between measuring level points 2 and 3 in cm (in applied tester distance between next measuring level points carries out 1 cm)

On figure 4 is presented only the temperatures gradient of model casting executed from hypereutectic chromium cast iron section in range of solidification of this casting. The temperature gradient (G0-1) for the area laid in bordering on from model mould it achieves the maximum value about 550 K/cm, however in area of the thermal centre of model casting achieves the maximum value about 18 K/cm.

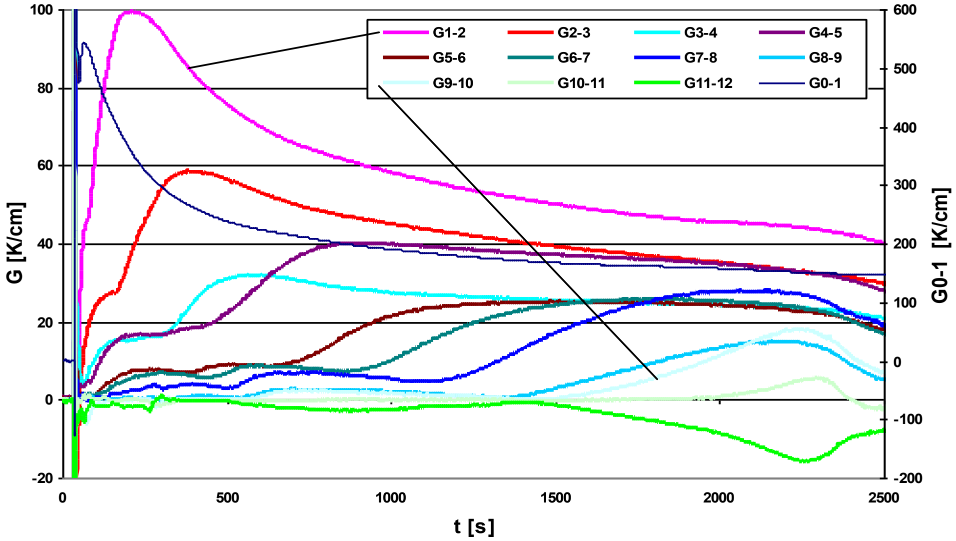

Fig. 4. Appointed temperature gradient in solidification range of studied chromium cast iron

4. DTGA curves and structure of hypereutectic chromium cast iron

Kinetics of changes of temperature gradient can also deliver many interesting information about solidification process of casting. In formation of the primary structure of casting the significant part has the rate of the setting thermal processes. In simple the speed of temperature gradient is possible to mark counting first derivative the temperature gradient curve after time. The course of DTGA curves on figure 5 was showed for two extreme cases. (1-2) then the curves for area of casting in vicinity of model mould. (9-10) then the curves for area of casting in vicinity of thermal centre.

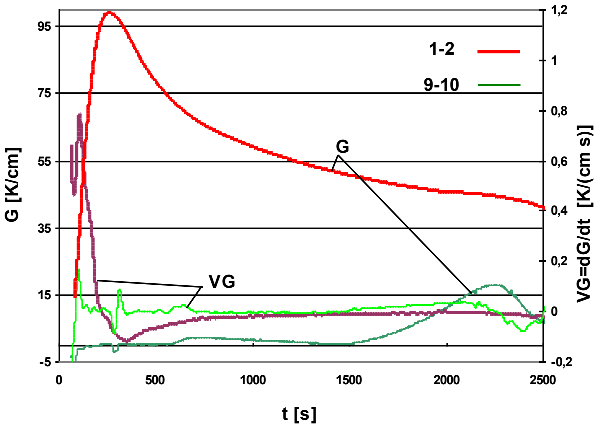

Fig. 5. DTGA curves in chosen areas of model casting in solidification range

What has this the shift on structure? Author conducted preliminary metallographic investigations. On figure 6 was introduced the picture of model casting as well as show the places of be paying on delivery and sign to metallographic investigations samples. It definite structure in this way was attributed answering its temperature gradient (G) and rate of temeperature gradient (VG) curves.

Conducted qualitative metallographic investigations show, that value temperatures gradient and its rate have influence on refinement of structure. Quantitative investigations should this prove unquestionably.

On figure 7 are presented structures from area, which was placed in near of mould (microsection 1-2 in distance 15 mm, microsection 2-3 in distance 25 mm from model mould - cuts were executed to axis of model casting perpendicularly). They are the typical structures for hypereutectic chromium cast iron. Structure consists from primary carbides of chrome of type M_7C_3 (hexagonal bright sections) on background eutectic carbides. The regular hexagonal sections of primary carbides testify about one-way accompanying the warmth during solidification (warmth parallel movement to axis of model casting).

On figure 8 are presented structures from area, which was placed in near of thermal centre casting area (microsection 9-10 in distance 95 mm and microsection 10-11 in distance 105 mm from model mould - cuts were executed to axis of model casting perpendicularly). The phase composition of structures is similar to talked over above. Of the principle differences concern the geometry. Primary crystallizing in this area carbides have diverse orientation, which testifies about lack one direction of accompanying during crystallization warmth. Accompanying from this area warmth is also slow about what distinctly temperature gradient curves and its speed testify (fig. 5). Conditions such favour the crystallization of large primary carbides as well as eutectic coarse-grained.

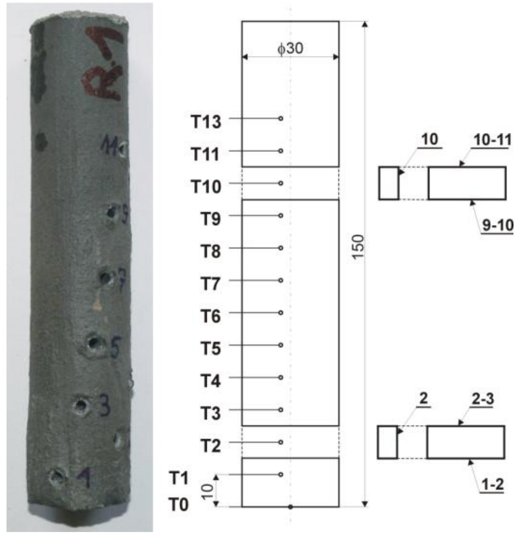

Fig. 6. Drawing and marking of samples to metallographic investigations from model casting

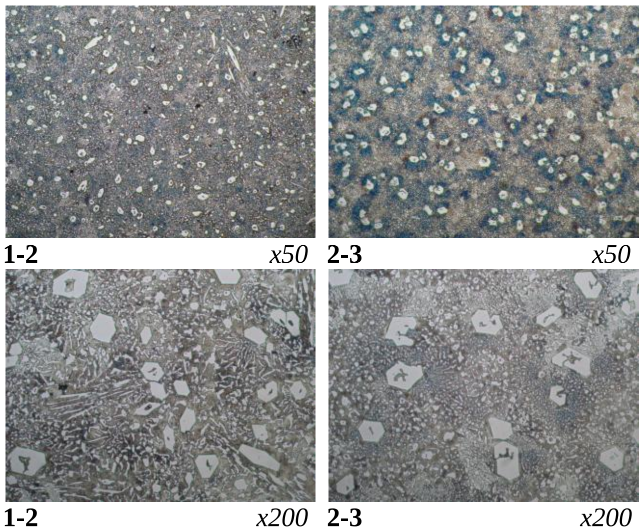

Fig. 7. Metallographic structures of studied chromium cast iron on sections1-2 and 2-3 (etching Nital)

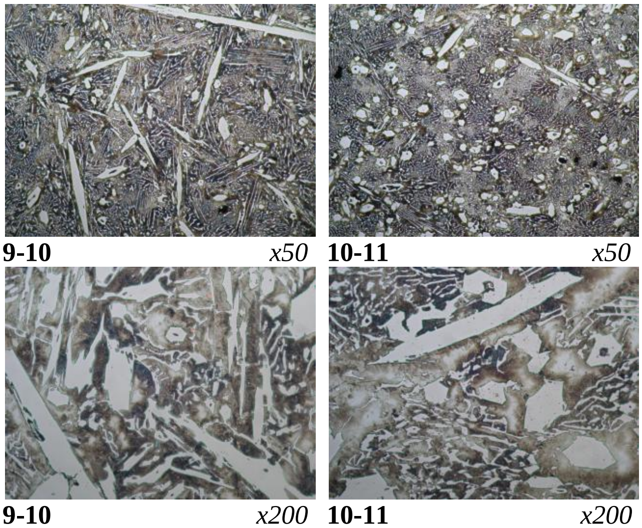

Fig. 8. Metallographic structures of studied chromium cast iron on sections 9-10 and 10-11 (etching Nital)

On figure 8 are presented structures from area, which was observed on executed to axis of model casting with parallel cuts sections. On section 2 step out long emissions primary carbides, which they crystallized according direction of warmth flow to model form. On section 10 does not step out already the privileged direction of carbides arrangement. Painting of this structure is similar to observed structures on microsections 9-10 and 10-11.

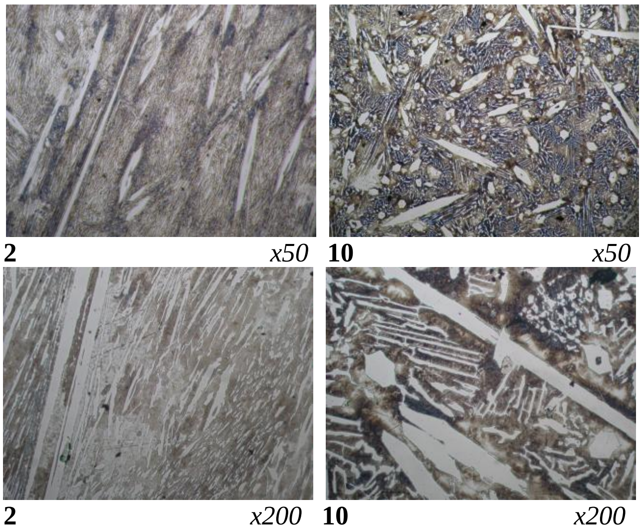

Fig. 9. Metallographic structures of studied chromium cast iron on sections 2 and 10 (etching Nital)

For disclosed structures in studied area which placed in distance 15÷25 mm from model form the maximum temperature gradient changed oneself in range 60÷100 K/cm, however for area in neighbourhoods the thermal centre casting gradient changed oneself in range 5÷18 K/cm. The set of graphs on figure 10 was introduced the DTA and DTGA for area of model casting which longest solidify.

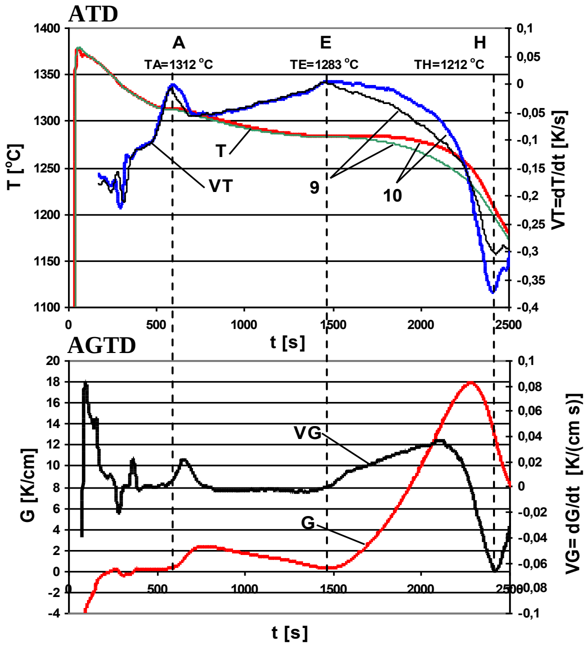

Fig. 10. DTA and DTGA graphs of hypereutectic chromium cast iron in ϕ100 tester

Acknowledgements

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References

[1] Gawroński J., Szajnar J., Jura Z., Studnicki A.: Professor Stanisław Jura creator of theory and industry applications of diagnostic and wear of metals and alloys. Archive of Founding. Special edition, no 16, 2004 (in Polish).

[2] Jura S.: Essence of method DTA. Modern methods of opinion of quality alloys. PAN-Katowice, Foundry Instytute of Silesian University of Technology, 1985 (in Polish).

[3] Studnicki A.: The investigation of crystallization process of wear resistance casting materials. Archive of Founding, vol.2, No.4, 2002. (in Polish).

[4] Studnicki: Experimental modeling of cast cooling in foundry mould. Archive of Founding, no. 14, 2004, p.476 (in Polish).

[5] Studnicki A., M. Przybył, Bartocha D.: The investigation of sensibility of chromium cast iron on speed cooling of casting - the analysis of parameters of crystallization and structure cast iron, Review of Founding, v.55, no. 4, 2005, p. 232 (in Polish).

[6] Cholewa M.: Innovations in founding, Part I, Foundry Instytute in Krakow, 2007, s. 169 (in Polish).
[7] Cholewa M., Suchoń J., Kondracki M.: The examples of application of thermal gradient analysis and derivative ((ATDG). Archives of Foundry Engineering, vol. 9, Issue 4 2009.
[8] Mikołajczak P., Ignaszak Z.: Influence of changeability of potential warmth solidification in function of temperature on results of simulation solidification of castings. Archive of Technology of Machines and Automation, Committee of Building of Machines PAN, vol. 25, no 1, Poznań 2006.