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Nodular cast iron and casting monitoring

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Abstract

In this paper quality monitoring of nodular cast iron and casting made of it is presented. A control system of initial liquid cast iron to spheroidization, after spheroidization and inoculation with using of TDA method was shown. An application of an ultrasonic method to assessment of the graphite form and the metal matrix microstructure of castings was investigated.

Keywords: Non-destructive testing; Nodular cast iron; TDA method; Ultrasounds; Graphite; Microstructure

1. Introduction

Production of high quality nodular cast iron castings requires monitoring of the liquid initial cast iron to spheroidization, after spheroidization and inoculation and castings control. Thermal derivate analysis (TDA) is one of method to control of the liquid cast iron quality [1]. The ultrasonic method guarantee fast, non-destructive control and the graphite form and the metal matrix microstructure assessment [2-4]. These methods of production control of nodular cast iron castings are using often and often in foundries, especially using "Inmold" technology.

The aim of this work was to show control system of the liquid cast iron using TDA and ultrasonic methods.

2. Work methodology

To TDA method the Cristalldigraph apparatus was used. To castings control with ultrasonic method the defectoscope GE USM 35 was used. Studies were made by use of the GE MSEB 2 ultrasonic depth finder.

Longitudinal wave velocity was calculated using the following equation [3]:

$$V = \sqrt{\frac{E}{\rho}\left[\frac{(1-\nu)}{(1+\nu)(1-2\nu)}\right]} \tag{1}$$

where:
E – modulus of elasticity, for cast iron: 10 000 ÷ 18 000 [MPa]
ρ - mass density, for cast iron: 6,8 ÷ 7,4 [g/cm^3]
υ - Poisson's ratio, for cast iron: 0,2 ÷ 0,3

Graphite form index was calculated using the following equation:

$$W_{KG} = \frac{O_K}{O_G} \tag{2}$$

where:
O_K – circumference of a circle
O_G – circumference of graphite

For condition: $F_K = F_G$ (3)

where:
F_K – circle area
F_G – graphite area
W_{KG} graphite form index is described as following:
W_{KG} = 0,80 ÷ 1,00 – nodular graphite
W_{KG} = 0,65 ÷ 0,79 – vermicular graphite
W_{KG} < 0,65 – flake graphite.

3. Results

In figure 1 system of the liquid cast iron quality monitoring using TDA method is presented.

It encloses the control of the liquid cast iron: initial, after spheroidization and inoculation. Each of these cast irons is characterized by another TDA curves. They are shown in figure 2. Results from it, that the initial cast iron after spheroidization (grey cast iron, 1 curve) is characterized by the highest temperature of eutectic crystallization i.e. 1155°C. After spheroidization with magnesium, temperature of eutectic crystallization is the lowest and amounts to 1120°C and after inoculation - 1145°C (nodular cast iron). This cast iron is characterized by the greatest intensity of the eutectic crystallization. In the cast iron after spheroidization (white cast iron) there is the lowest intensity of the eutectic crystallization. S, T and W points show the nodular graphite presence in the cast iron. There are essential differences on TDA curves during austenite $\rightarrow$ ferrite transformation too. For the cast iron after spheroidization there is the highest temperature of austenite eutectoid transformation, about 800°C. The initial and nodular cast iron are characterized by the similar temperature of eutectic transformation - 743°C. However, there are essential differences for the thermal effect from austenite transformation and its intensity. Characteristic values of TDA curves are using to work out statistic relationships between these values and the chemical composition of cast iron and its mechanical properties. These relationships are the base of algorithm of computer programme to quality cast iron monitoring.

In case of the cast iron spheroidization with "Inmold" technology, the chemical composition and especially sulfur concentration in the initial cast iron is controlled. Later control concerns only finished castings, where the graphite form, the metal matrix microstructure, and R_m, $R_{p0,2}$, A_5, HB and in case of need KC mechanical properties are checked.

Using of ultrasounds is one of method to the graphite form and the metal matrix microstructure assessment. Ultrasonic wave velocity depends on the graphite form and the metal matrix microstructure.

In figure 3 the change of the ultrasonic wave versus the graphite form index W_{KG} and in figure 4 – for nodular graphite versus the metal matrix microstructure are presented.
In these figures the theoretical and real velocity are shown. From figure 3 results, that approaching nodular form by the graphite ($W_{KG} \rightarrow 1$) causes increase of V velocity of ultrasonic wave. The change of the metal matrix microstructure from ferritic, pearlitic-ferritic to pearlitic witch carbides causes increase of the ultrasonic wave velocity. The change of the metal matrix microstructure to martensitic-pearlitic, martensitic-austenitic and martensitic with carbides decreases the velocity of ultrasonic wave. The results show, that application of ultrasonic method to castings control enables the graphite form and the metal matrix microstructure assessment. Later research will be conducted for mechanical properties assessment.

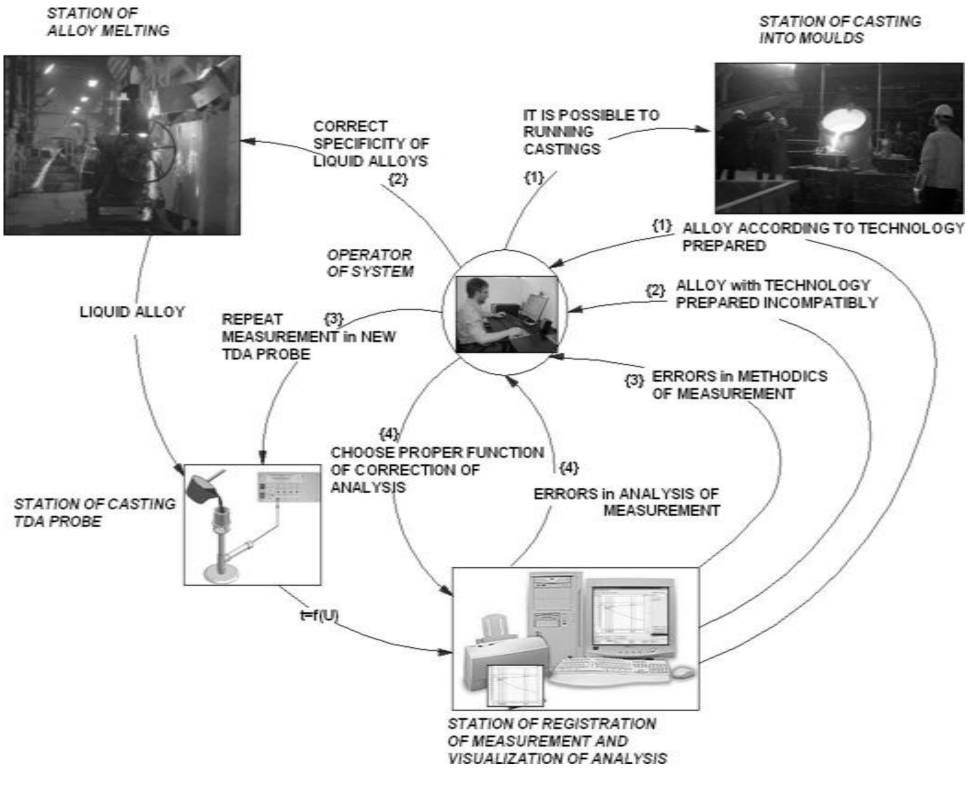

Fig. 1. Monitoring system of liquid cast iron quality

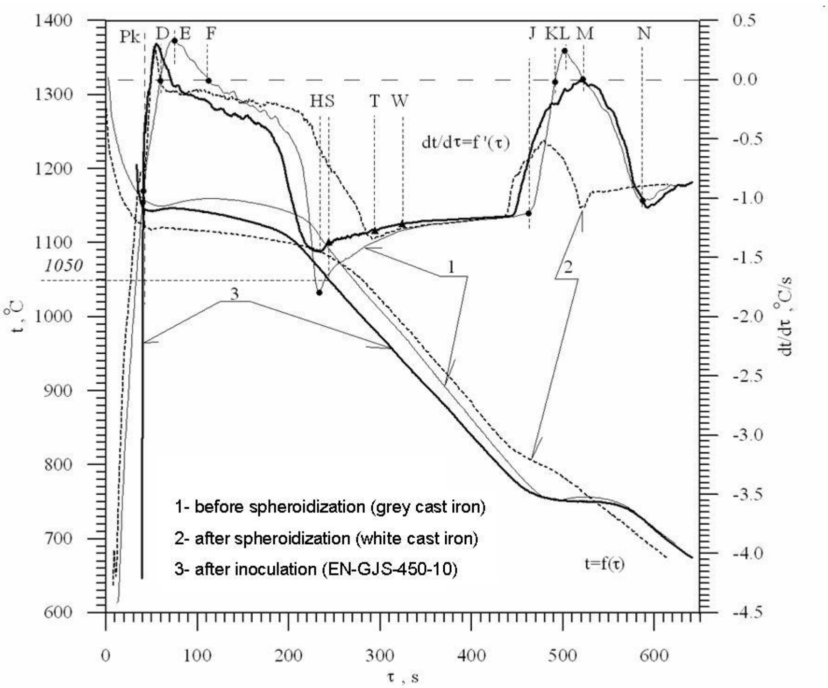

Fig. 2. TDA curves of cast iron: initial to spheroidization, after spheroidization and inoculatio

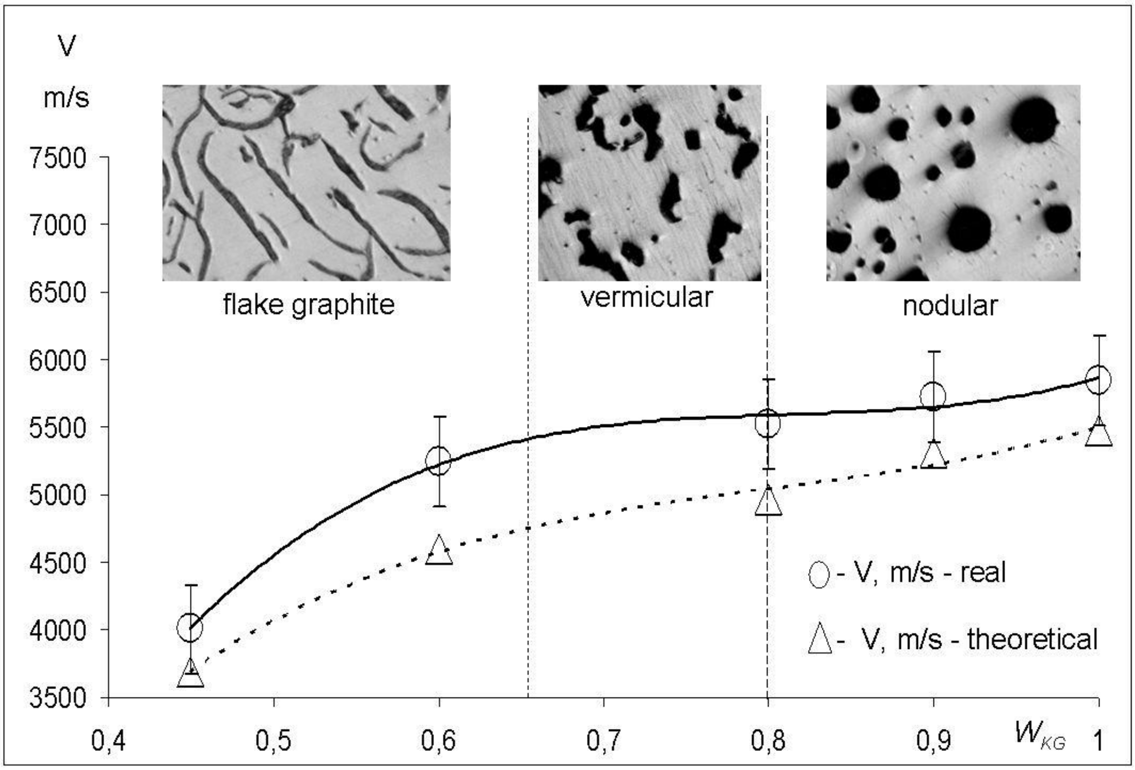

Fig. 3. Ultrasonic wave velocity Vversus the graphite form W_{KG}

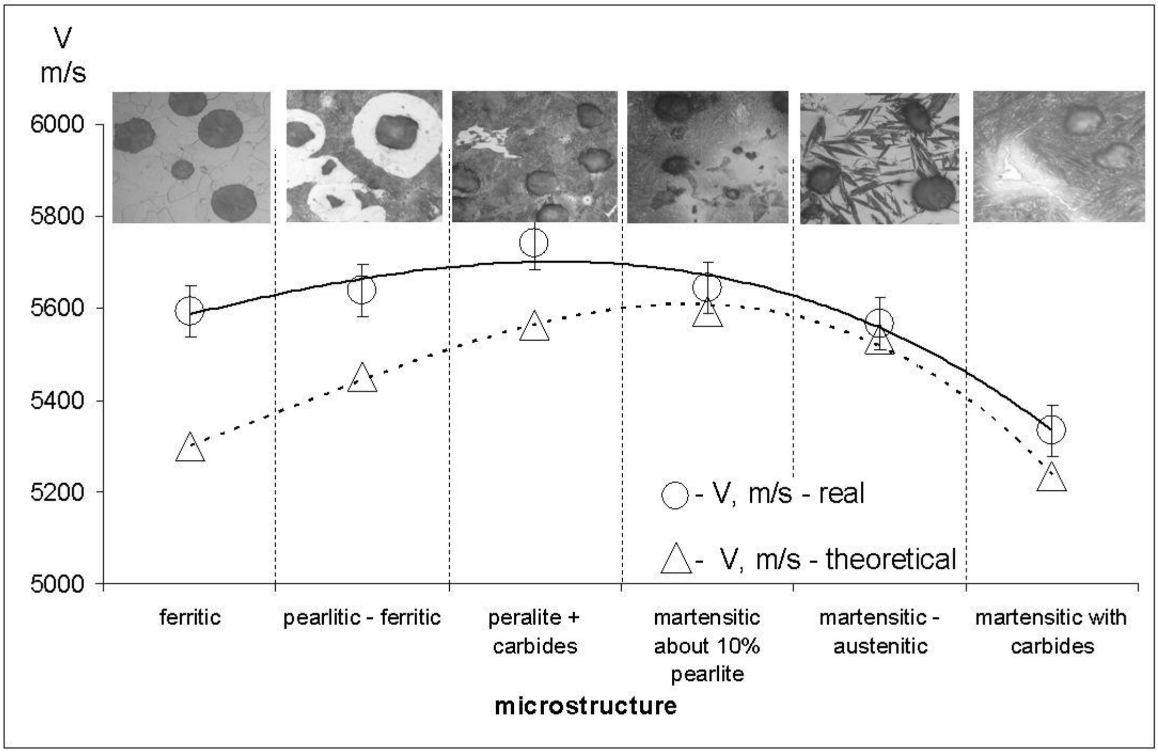

Fig. 4. Ultrasonic wave velocity V versus the metal matrix microstructure

3. Conclusions

The results have indicated the following:

- quality monitoring of liquid cast iron and casting guarantee production of high-quality nodular cast iron castings,
- the liquid cast iron control: initial, after spheroidization and inoculation should be carried out with use of the computer programme using TDA method,
- the castings control with ultrasonic method enables the graphite form and the metal matrix microstructure assessment.

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