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Inoculation of Austenite Primary Grains in Cast Iron

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Abstract

The modification is a widespread method of improving the strength properties of cast iron. The impact in terms of increasing amounts of eutectic grains has been thoroughly studied while the issue of the impact on the mechanical properties of primary austenite grains has not been studied in depth yet. The paper presents the study of both aspects. The methodology was to conduct the melting cast iron with flake graphite, then modifying the alloy by two sets of modifiers: the commercial modifier, and a mixture of iron powder with a commercial inoculant. The DAAS test was carried out to identify the primary austenite grains. The degree of supercooling was determined and the UTS test was performed as well. Additionally carried out the metallographic specimen allowing for counting grains. It can be concluded that the introduction of the iron powder significantly improved the number of austenite primary grains which resulted in an increase in tensile strength UTS.

Keywords: Crystallization process,Grey cast iron, Primary austenite grains, Inoculation, Tensile strength

1. Introduction

Inoculation is a metallurgical treatment applied by foundries to improve the mechanical properties of cast iron. The improvement of mechanical properties of cast iron by modifying is related to the physico-chemical state of the liquid metal due to the incorporation into the liquid metal shortly before the casting the small quantities of modifying substances which increase the number of embryos to heterogeneous crystallization.

Effects of this treatment[1-4] are:

– increasing the number of eutectic grains,
– decreasing undercooling degree during eutectic crystallization,
– pearlitic matrix with varied degree of dispersion,
– interdendritic graphite disappears in favour of the graphite of a uniform distribution,
– increasing in tensile strength,
– increasing the number and degree of branching of dendrites of austenite.

For technical reasons related to difficulties in obtaining adequate test samples often overlooked effect of the influence of primary austenite grains, which also have a large effect on the strength properties of the casting made. Way to the primary austenite grains structure was revealed is a Direct Austempering After Solidification (DAAS) method[5-7],which as a result of isothermal quenching allows for the disclosure of the structure and the number of primary austenite grains. The strength properties are also affected by the sulfur content in the alloy which is both high and low levels deteriorates mechanical properties of cast iron [8,9].

2. Methodology

Two melts of cast iron with flake graphite was prepared in an electric induction furnace with 15kg capacity crucible. Metal charge consisted of Sorel pig-iron, scrap steel, high-purity silicon, ferro-manganese and sulfur. In both cases liquid metal was overheated to 1490°C for 300 seconds and then cooling the temperature to 1460°C. After that in first melt (A)commercial inoculants was introduced to liquid metal, waited180 seconds and in temperature of 1410°C flooded to form obtain a castings of rollers (Fig 1a,b). In second melt (B) procedure was similar but it was introduced also iron powder before commercial. The chemical composition of cast iron (A and B) is shown in Table 1.

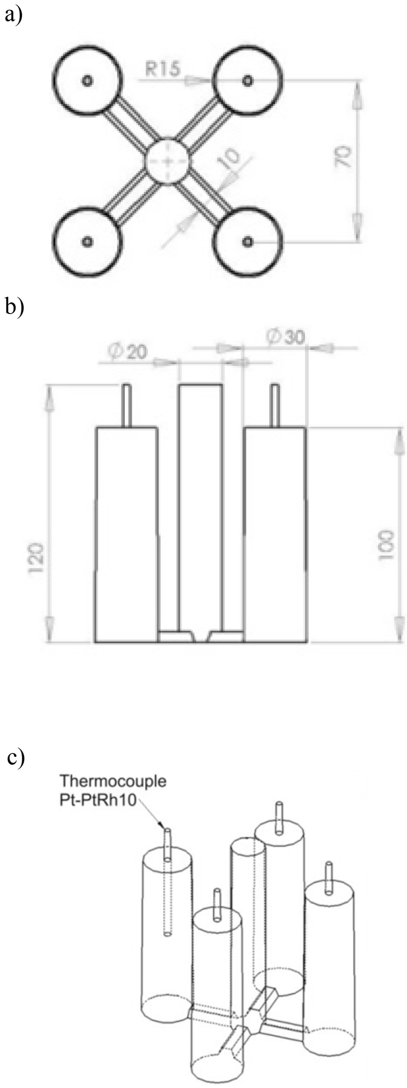

Fig. 1. Casts of rollers – a,b), thermocouple connection – c)

Table 1.
Test samples of cast iron

Melt No.	C wt.%	Si wt.%	Mn wt.%	S wt.%	S_c
A	2,92	1,91	0,36	0,013	0,79
B	2,94	1,80	0,39	0,012	0,79

where: S_c=C/(4,26-0,3Si-0,36P)
A - Base cast iron, with addition of Fe-Si inoculants
B - Base cast iron, with addition of iron powder and Fe-Si inoculant

During casting crystallization cooling curves were measured by type S (PtRh10-Pt) thermocouple placed in the center in one roller in each form (Fig 1c). When reached 950°C, cast was shaken out from mold and placed in a furnace for 30 minutes. After that castings were pulled from the furnace and placed in molten salt for isothermal quenching at a temperature of 360°C - DAAS method. Then, it was made test specimens for metallographic and UTS examinations.

3. Results an discussions

Microstructure of the test specimens was presented in Fig. 2. In all the investigated samples is shown dendritic structure and graphite D and E type. Fig.2and 3 shows received structure of primary austenite in samples after inoculations. Boundaries dendrites detection was made by scanning microscopy tools (EBSP), mapping and *Met-Ilo* program created on Silesian University of Technology (Poland). In Fig. 4 presented cooling and first derivative curves. To determine the maximum degree of undercooling ΔT for the primary austenite Equation 1:

$$T_\gamma = 1636 - 113(C - 0{,}25Si + 0{,}25P) \quad (1)$$

designated by [10] was used and defined experimentally T_γ by cooling curves (Fig. 4).

Undercooling, UTS tests and number of austenite primary grains was presented in Table 2.

Table 2.
Samples specifications of cast iron

Melt No.	Sulphur content, wt.%	UTS, MPa	Number of primary grains N_{P1}, 1/cm^2	Number of primary grains N_{P2}, 1/cm^2	Undercooling ΔT, K
A	0,013	217	9,76	15,82	14,7
B	0,013	315	7,78	20,34	11,3

N_{P1}– in cross-section, N_{P2}–in center of sample

The grains has been counted as follows. N_{P1}- number of grains in the cross section of the sample (30mm diameter test area). N_{P2}- number of grains in the center of the sample (15mm diameter test area) was determined that UTS specimen had this type of research area. In the second case to counts a number of grain used a modified *Jeffries–Saltykow* method, where in counted under the same conditions full and cut grain. UTS results obtained on the B were significantly higher than A. At the same time differences in shape of primary austenite grain from coaxial in A to elongated in B was observed.

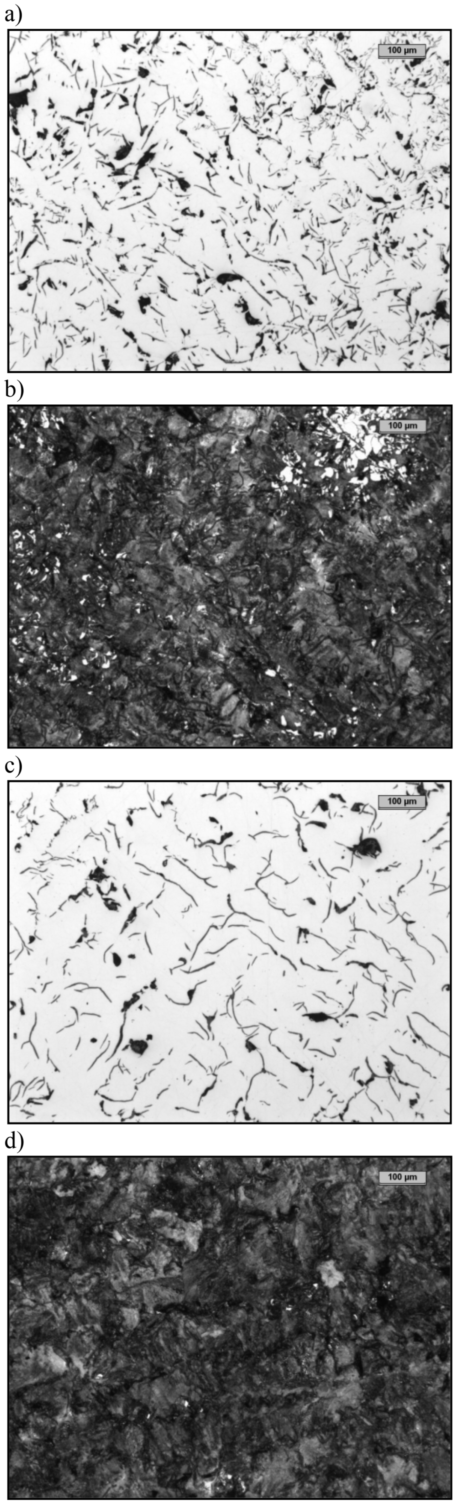

Fig. 2. Microstructures of cast iron from melts: no. A – (a,b) and no. B– (c,d), etched Nital

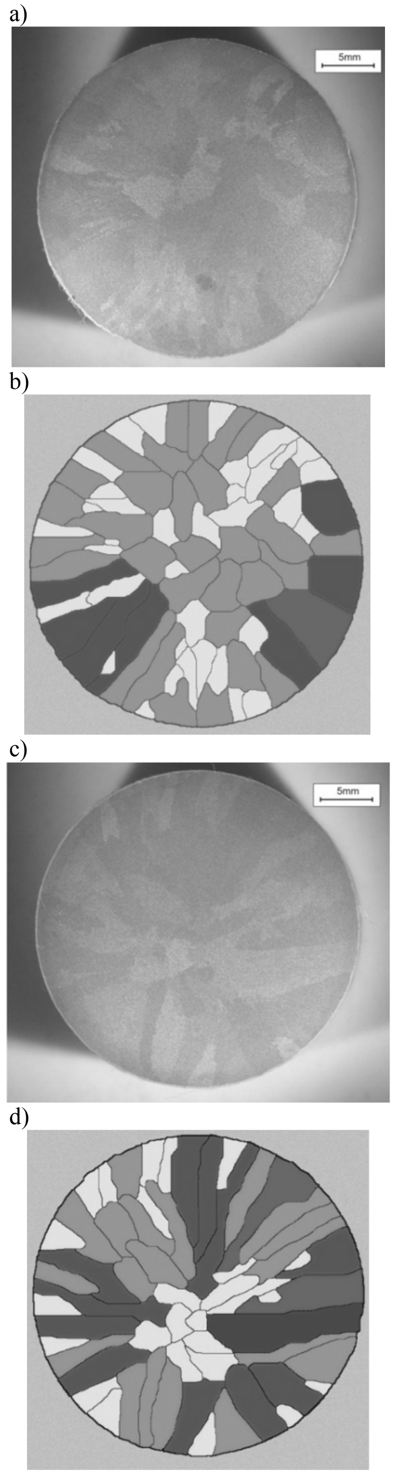

Fig. 3. Sample: melt no. A – (a), result of primary austenite grains detection– (b); melt no. B – (c), result of primary austenite grains detection– (d)

a)

b)

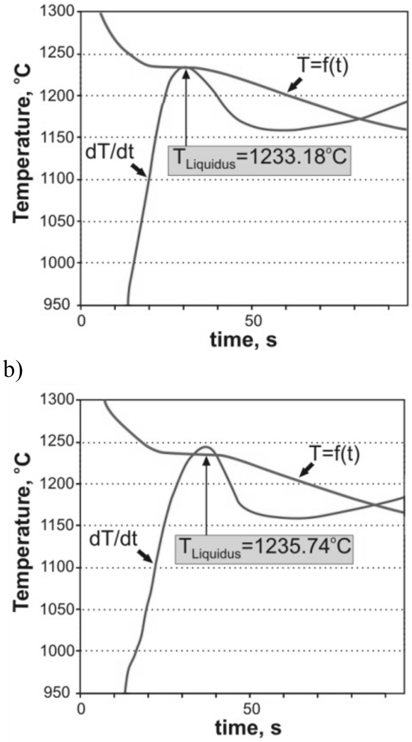

Fig. 4. Temperature change during crystallization and crystallization:melt no. A – b), melt no. B – c)

4. Conclusions

The addition of iron powder to the modifier resulted in a significant improvement of mechanical properties. The difference in UTS depending on the inoculation method is significant and is 98 MPa greater in the case of the use of iron powder with commercial innoculant, in melt (B) with respect to the melt (A). In both cases, the sulfur content of the alloy do not exceed 0.02% mas. Moreover, the degree of supercooling ΔT reduced and the amount of primary austenite grains increases. Summary of the results of research strength (UTS) with the calculated primary grain allowed to conclude that in order to obtain meaningful results from these two studies should be measured from the same research area, which is from the same place and on the same diameter.

The research will be continued using ductile iron produced at the Company Odlewnie Polskie S.A.

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