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Influence of Over-Cooling the Nodular Cast Iron to the Graphite Form in the Surface Layer

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Abstract

A cast iron is gradient material. This means that depending on the cooling rate it is possible, at the same chemical composition and the physicochemical state of molten metal, to obtain material with a different structure. The connection between the wall thickness of the casting and the speed of its cooling expresses the casting module. Along with the module escalation a cooling rate of the casting is reducing what can cause changes of the microstructure and the increased tendency to the crystallization of distorted graphite forms. Inspections of experimental castings from nodular cast iron with different modules were conducted to the graphite form.

Keywords: Nodular cast iron, Casting module, Graphite form

1. Introduction

The anomaly of the structure in the form of lamellar graphite in the surface layer of the nodular iron casting constitutes subject of many deliberations. Current authors examinations, placed in publications [1-4], were focused on making experimental iron castings with nodular graphite in no-bake moulds with furfuryl resin (in so-called furan mould) and sour hardeners on the basis of sulphur compounds. Hardeners contained a different amount and proportion of sulphonic acids and sulphuric acid in water solutions. Also reclamation sand about the different sulfur content was used as a warp. A research purpose was to determine the influence of the sulfur diffusion from moulding sand to the casting surface for distorted graphite forms existence. Analysis of these examinations showed the sulphur impact for forming lamellar graphite in the surface layer of the nodular iron casting. The influence of over-cooling the cast iron constitutes the another element in these considerations. The essential condition of receiving nodular graphite is strong over-cooling the liquid cast iron [6]. The cast iron treatment with magnesium or cerium affects the sulphur and oxygen activity reduction, reaching the level lower than the essential value to graphite nucleation. A such cast iron presents a great tendency to over-cooling during the crystallization [7]. However a cast iron is gradient material. Depending on the cooling rate it is possible, at the same chemical composition and the physicochemical state of molten metal, to obtain material with a different structure. The greater cooling rate the higher tendency of the cast iron to over-cooling what causes the formation of interdendritic graphite, and in a consequence

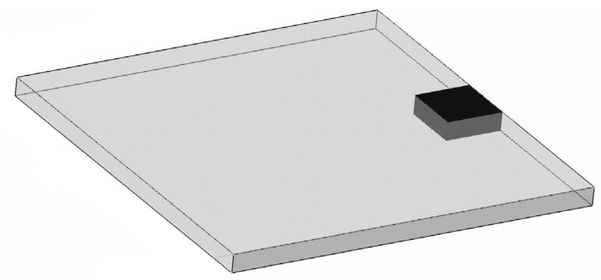
solidification of the cast iron in the metastable system. Also an increase of the number of eutectic grains is watched, which sizes are reducing [6].
Following factors affect the cooling rate: the shape and dimensions of the casting, thermophysical properties of metal, the pouring temperature, the structure and dimensions of the mould, thermophysical properties of moulding material, coefficient of the heat accumulation, the mould temperature. The connection between the wall thickness of the casting and the speed of its cooling expresses the casting module. Along with the module escalation a cooling rate of the casting is reducing what can cause changes of the microstructure and the increased tendency to the crystallization of distorted graphite forms [6].
In sand moulds the cooling rate of the casting is changeable. With the time this speed is reducing. The humidity, the permeability, the grain size of sand warp or the density degree influence also the casting structure. The higher values of these parameters the faster cooling of the sand mould. Increasing cooling rates, as a result of increasing the coefficient of the heat accumulation of the mould, is being observed at replacing the sand mould with the graphite mould or the permanent mould [6].

2. Own investigations

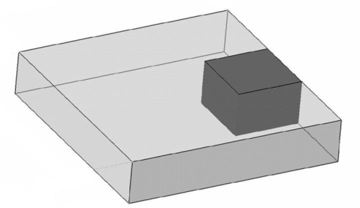
The aim of researches was to determine the module influence of the nodular iron casting on its microstructure and the impact of cooling rates in the surface layer for distorted graphite forms existence.

2.1. Examination methodology

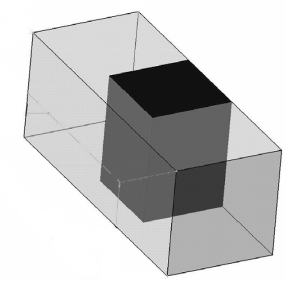
No-bake sand with the phenolic resin hardened with esters, called process alphaset, was used in examinations. This sand is free from sulphur and nitrogen and phosphorus compounds. In this process alkaline phenol-formaldehyde resin of resol type is applied, containing under 1% of the free phenol and below 0.1% of the free formaldehyde. The moulding sand composition constituted quartz sand Grudzeń Las about the main fraction 0.20/0.32/0.40 and the average grain size 0.31mm in the amount of 100 parts per weight, the phenolic resin Sinotherm in the amount of 1.1 parts per weight and the hardener being a mixture of esters in the amount of 0.33 parts per weight. The design of experimental castings was taken into according to a module of this casting.
Experimental castings were made in the mould with given sand composition and poured with the nodular graphite iron EN-GJS 500-7.



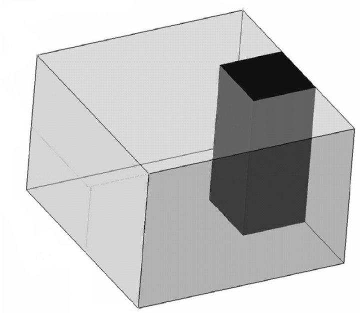
Sample 1: casting dimensions 200x200x10 mm, Mo=0,45cm



Sample 2: casting dimensions 100x100x20 mm, Mo=0,625cm



Sample 3: casting dimensions 100x40x40 mm, Mo=1,10cm



Sample 4: casting dimensions 100x100x60 mm, Mo=1,40cm

Fig. 1. Experimental castings with the marked place of taking samples to examinations

Table 1.
Chemical composition of the experimental casting sample

element content,%	C*	Si	Mn	P	S*
Sample 3	3,36	2,65	0,17	0,13	0,006
	Cr	Ni	Cu	Mg	
	0,03	0,07	0,01	0,08	
Foundry Master spectrometer	* Leco CS46				

2.2. Examination results

Samples were immersed in conducting bakelite, they were grinding and polishing. Then samples were being etched with 3% nital to reveal differences of the structure between the surface layer and the casting interior. Structure examinations were being conducted with using the light microscope Axio Imager MAT.M1m Carl Zeiss and the scanning electron microscope Hitachi S-3500N. Moreover, with the analyser EDS NORAN 986B-1SPS a research of the elements content in chosen areas was conducted.

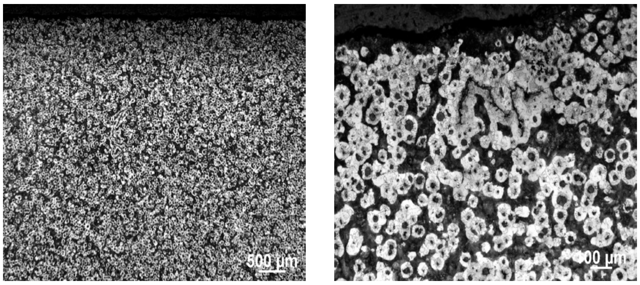


Fig. 2. Light photograph of the microstructure Sample 1 at different magnification

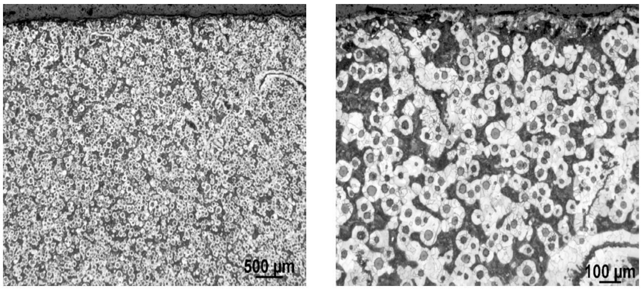


Fig. 3. Light photograph of the microstructure Sample 2 at different magnification

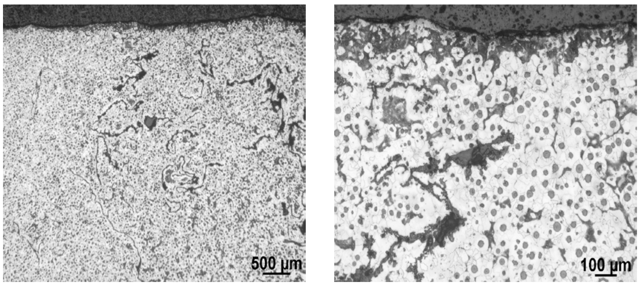


Fig. 4. Light photograph of the microstructure Sample 3 at different magnification

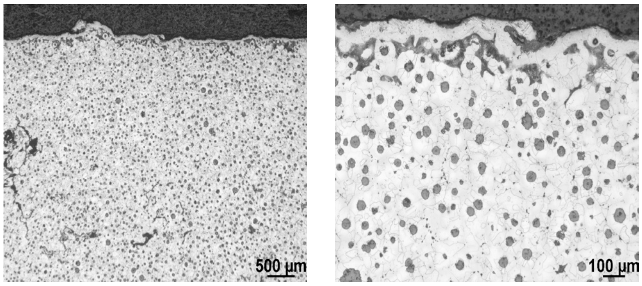


Fig. 5. Light photograph of the microstructure Sample 4 at different magnification

In the structure of experimental castings, especially in Sample 3, but also in Sample 4, extended constituents appeared which were subjected of a detailed analysis. Below results were placed.

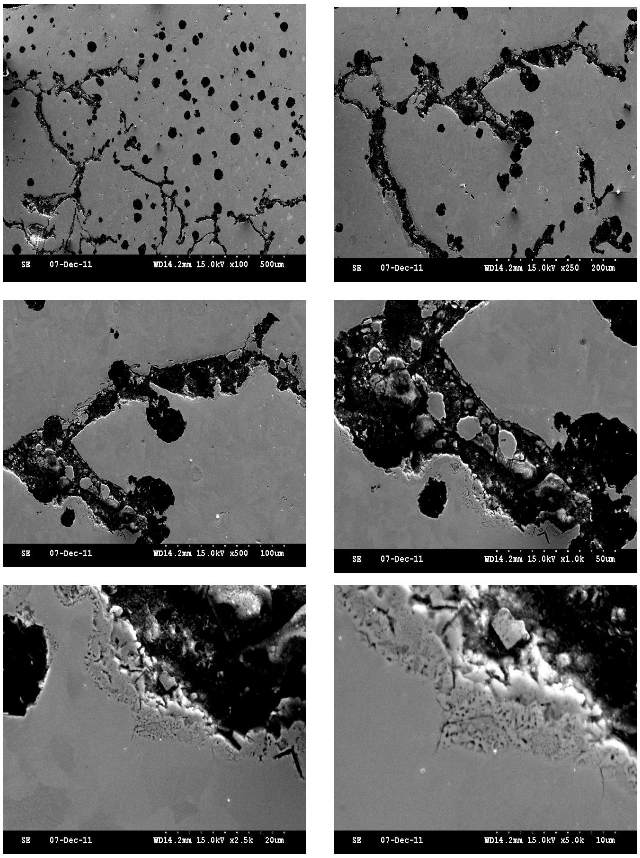


Fig. 6. Scanning photographs of the casting Sample 3, constituents in the structure at different magnification

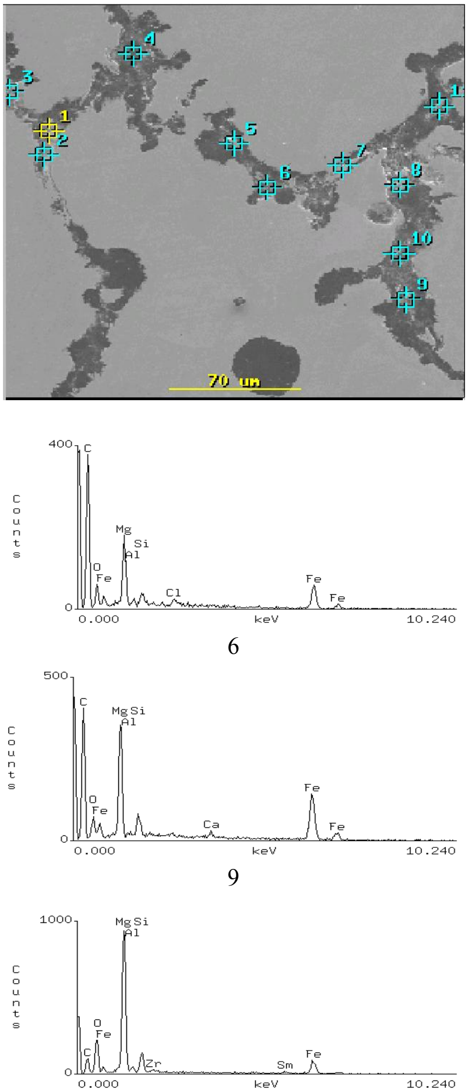


Fig. 7. Scanning photograph of the constituent in the structure of the casting Sample 4 with marked points, in which EDS analysis was performed. Below chosen spectrograms

3. Conclusions

Conducted examinations showed changes of the microstructure in the surface layer of experimental castings. An influence of the casting module was observed on the kind of metallic matrix. Castings Sample 1 and Sample 2 contains ferrite and pearlite in the matrix, however castings Sample 3 and Sample 4 have actually only ferrite in the matrix. The higher casting module the lower pearlite participation in the matrix. In the structure of experimental castings, especially in Sample 3, but also in Sample 4, extended constituents appeared. Analysis of their chemical composition mainly showed the presence of silicon, coal and iron, as well as oxygen, magnesium and aluminium. Scanning photographs in Figure 6 are presenting the great diversity of these constituents and the small eutectic is visible on edges.

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