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THE EFFECTS OF THE METAL TEMPERATURE AND WALL THICKNESS ON FLAKE GRAPHITE LAYER IN DUCTILE IRON

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This article addresses the effect of mold filling and wall thickness on the flake graphite layer in ductile iron. The research was conducted for castings with different wall thickness (3-8 mm) and using molding sand with furan resin. A thermal analysis has been performed along the length of the castings to determine the initial temperature of the metal in the mold cavity and the contact time of the liquid metal with the mold. Results demonstrated the strong influence of the temperature decrease of the metal in the mold cavity on the occurrence and the thickness of the flake graphite in the surface layer in ductile iron.

Key words: Foundry,ductile iron, temperature, graphite degeneration, microstructure

INTRODUCTION

The production of castings of ductile iron, in loose self-hardening moulding sands with furan resin hardened by paratoluenosulphonic acid, carries a danger of forming defected casting microstructure, which most often occurs in its surface layer [1 - 9]. This unfavourable effect is caused by surface-active elements like oxygen or sulphur contained in a hardener of resin binders, which enters the surface layer causing flake graphite formation in the surface layer of castings. In a such cases the surface layer with flake graphite can cause stress raising in the casting, similar to a notch, so all useful properties are reduced, especially the fatigue limit and impact resistance. The flake graphite in the surface layer is the most critical for thin wall castings (≤ 5 mm), where it could become more than 10 % of the total section. It affects also castings of thicker walls, due to the long solidification time providing an extended metal/mould interaction time [10, 11].

In this present paper, an analysis is shown of the effect of the wall thickness and the initial temperature of the metal in the mold cavity on the formation of the flake graphite in the surface layer of ductile iron castings.

EXPERIMENTAL

The experimental melts were performed in an induction furnace. The furnace charge consisted of the following materials: Sorelmetal, silicon of technical purity, Fe-Mn and steel scrap. After the heating of the metal to a temperature of 1 490 ^{o}C, the bath was held for 2 minutes and then spheroidising and innoculation by the bell method was carried out. For the spheroidisation treatment the foundry alloy Fe-Si-Mg (6 % by mass Mg) was used, while for the inoculation the Foundrysil modifier was used in the amount of 0,5 mass %.

The pouring temperature was app. 1 400 °C. In order to determine the effect of the pouring temperature (represented by the initial temperature of the metal in the mold cavity), plate shaped castings with 3 × 50 × 1 000 mm, 5 × 50 × 1 000 mm and 8 × 50 × 1 000 mm were cast. The temperature of the metal in the mould cavity was determined by thermoelements (Pt-PtRh10 with 0,2 mm in thickness) wires in regular 10 cm distances, connected to the digital data acquisition system (AGILENT 34970 A.) Molding sands were prepared with furan-urea Kaltharz U404 resin and 100T3 hardener. The following molding sand composition was applied: matrix (reclaim of high-silica sand) – 98,5 mass %, furfuryl resin – 1,0 mass % of the sand batch, and hardener (paratoluenesulphonic acid) — 0,5 mass % of the sand batch [12 - 14]. Ductile iron of the following chemical composition was obtained: 3,56 – 3,65 C mass %; 2,65 - 2,75 Si mass %; 0,29 – 0,40 Mn mass %; 0,03 P mass %; 0,010 S mass %; 0,046 – 0,50 Mg mass %. The view of the plate shaped casting is presented in Figure 1.

Metallographic investigations were carried out by means of the optical microscope Leica MEF-4M connected to a computer equipped with image analysis software Leica QWin (v. 3.5.0). In addition, the near

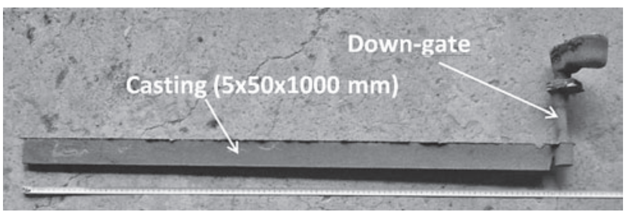

Figure 1 Plate-shaped casting with dimensions 5 × 50 × 1 000 mm

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surface microstructures were examined by a JEOL JSM-7 100F scanning electron microscope (SEM) operated at 20 kV. The characterization of the graphite and matrix microstructure was performed on cross-sections at different distances from the entrance to the casting.

RESULTS AND DISCUSSION

Figures 2 - 4 shows the microstructure of ductile iron in the surface layer in plate shaped castings.

The relationship between the thickness of the flake graphite layer located at the metal-mould contact and the distance from the beginning of the plate inlet is graphically presented in Figure 5. The thickness of the flake graphite layer in ductile iron decreases with distance from the beginning of a plate inlet. At a distance of 40 cm from the beginning of the plate shaped casting flake graphite is not present in the surface layer of a casting with wall thickness of 3 mm. It is worth noting that, in castings with wall thickness of 5 and 8 mm thicknesses of flake graphite layer is much higher, and disappears after reaching 70 and 90 cm, respectively from the casting inlet. This demonstrates a significant influence of the wall thickness on the occurrence and the thickness of flake graphite in the surface layer. The smaller the wall thickness of the casting, the higher the temperature drop of the flowing metal stream filling the mold cavity.

The temperature of the melt decreases approximately linearly with the distance from the entrance to the mold cavity. From the figure 6, it follows that there is a high temperature drop during mold filling that strongly depends on wall thickness. For casting with higher wall thickness decrease of the temperature during mold filling is lower. The consequence of this is a higher temperature and a longer contact time of the liquid metal with the mold as compared to a casting with smaller wall thickness. A flowing metal stream through the mold cavity heats it up. As a consequence, the conditions of heat ex-

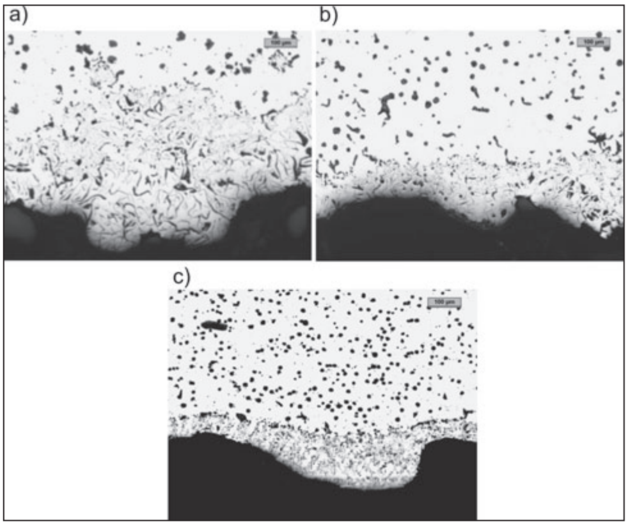

Figure 2 Microstructure of ductile iron in plate shaped castings with different wall thickness (a, b, c - plates with 8, 5 and 3 mm wall thickness, respectively) and 1 cm distances from the beginning of the plate

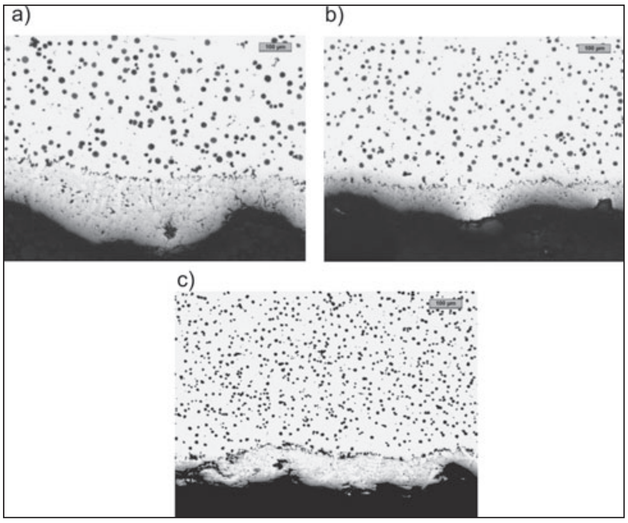

Figure 3 Microstructure of ductile iron in plate shaped castings with different wall thickness (a, b, c - plates with 8, 5 and 3 mm wall thickness, respectively) and 30 cm distances from the beginning of the plate

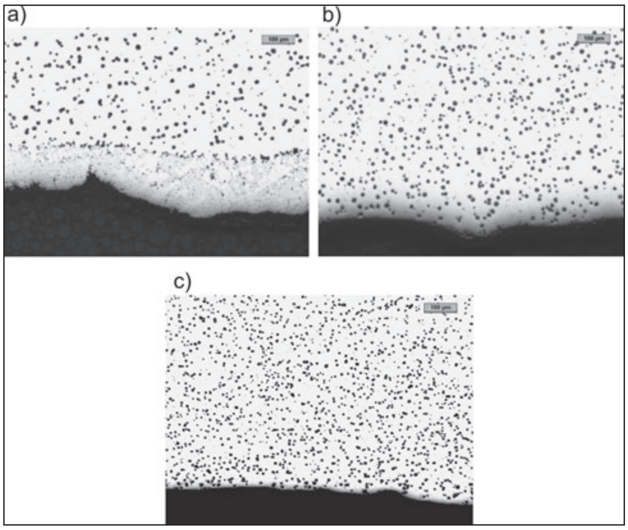

Figure 4 Microstructure of ductile iron in plate shaped castings with different wall thickness (a, b, c - plates with 8, 5 and 3 mm wall thickness, respectively) and 70 cm distances from the beginning of the plate

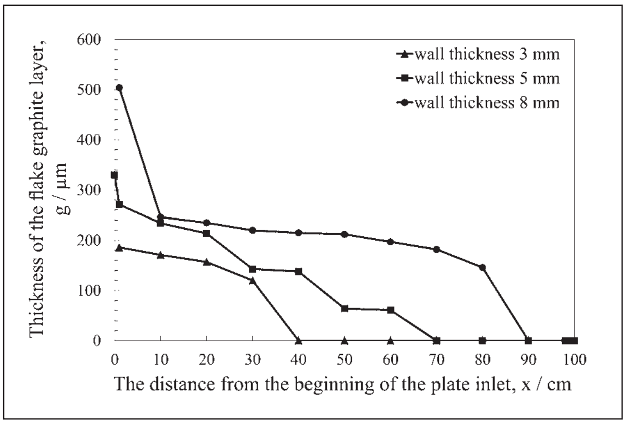

Figure 5 Thickness of the flake graphite layer (g) as a function of the distance from the beginning of the plate inlet (x)

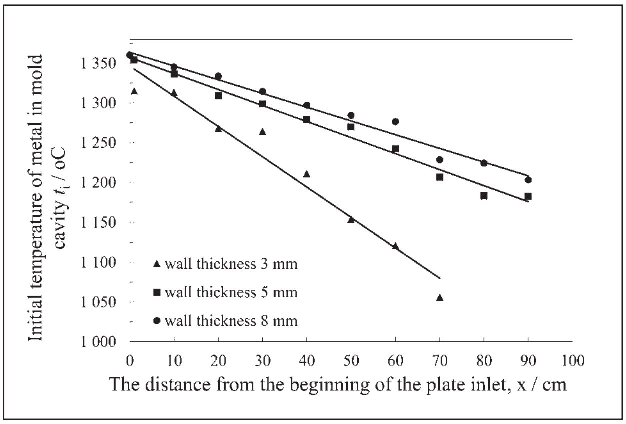

Figure 6 Initial temperature of metal in mold cavity (t_i) during metal filling for castings with different wall thicknesses

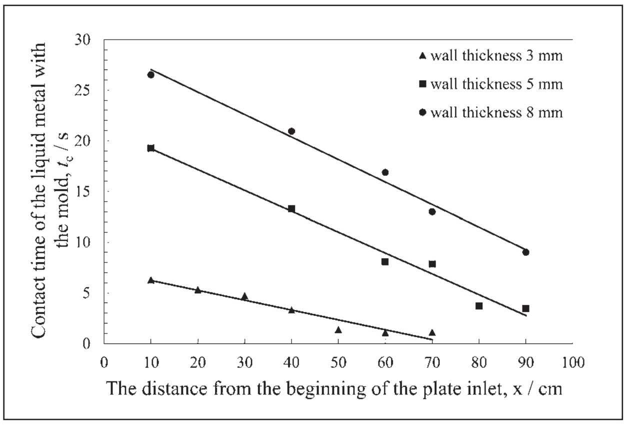

Figure 7 Contact time of the liquid metal with the mold (t_c) as a function of distance from the entrance to the mold cavity (x) for castings with different wall thickness

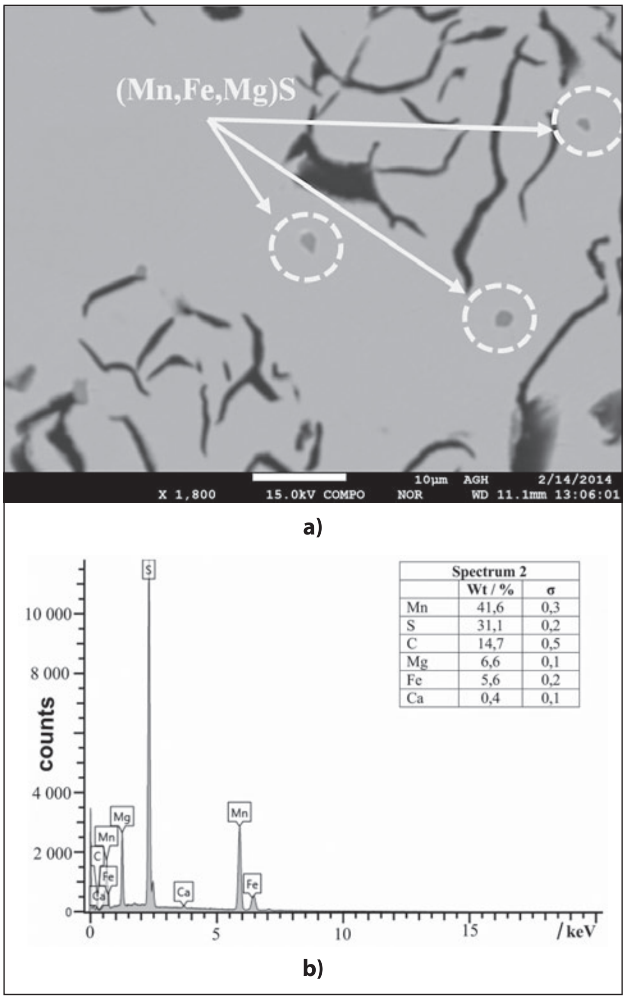

Figure 8 SEM microstructure (a) and EDS spectrum (b) of complex sulfides (Mn,Fe,Mg)S

change along the flowing path change. With increasing distance from the entrance to the mold cavity there is a shorter contact time of liquid metal with the mold, which results in decreasing temperature and velocity profiles. Figure 7 shows the effect of wall thickness and the distance from the entrance to the mold cavity on the contact time (t_c) of the liquid metal with the mold ($t_c = t_{min}$-t_i, where: t_{min} – time of reaching maximum undercooling at the beginning of eutectic solidification, t_i – time of initial temperature of metal in mold cavity).

From Figure 7 results that the longest contact time of the liquid metal with the mold is for a casting with wall thickness of 8 mm and decreases approximately linearly with the distance from the entrance to the mold cavity. Thickness of the flake graphite zone depends mainly on despheroidizing elements (especially sulphur) content in the molding sand and on the magnesium to sulphur ratio in the cast iron. Research has shown that for a given wall thickness of the casting thickness of the flake graphite layer in the surface of the casting depends on the initial temperature of the metal in the mold cavity and on its contact time with the casting mold.

The flake graphite in the near surface layer of ductile iron occurs due to the magnesium (spheroidizing element) concentration decreases. From EDS analysis (Figure 8) results, that this occurs by interaction of sulfur with magnesium, and also with among others with manganese and iron through the creation of complex sulphides in the surface layer.

EDS studies indicate that the number of such sulphides decreases as distance from the casting surface increases. This decrease depends on the diffusion of sulphur from the molding sand into metal.

Summing up, it can be stated that the higher the concentration of sulphur in the molding sand, the higher initial temperature of metal in the mold cavity and the longer contact time of liquid metal with molding sand, the higher thickness of the flake graphite layer in the surface of casting.

CONCLUSIONS

The thickness of the flake graphite layer depends on the initial temperature of the metal in mold cavity and on the contact time of the mold with the liquid metal. In the case of casting a wall thickness of 3 mm, flake graphite in the surface layer does rise up to a distance of 40 cm. This corresponds to the minimal initial temperature of the metal in the mold of 1 206 °C and the minimum contact time of about 3.5 seconds of the liquid metal with a mold. In the case of casting with a wall thickness of 8 mm flake graphite in the surface layer does arise up to a distance of 90 cm. This corresponds to the minimal initial temperature of 1 203 °C and the minimum contact time of about 9 seconds of the liquid metal with a mold. It is worth noting that the above mentioned temperatures for which there is a disappearance of flake graphite in a surface layer for casting with different wall thicknesses are similar.

The flake graphite in the near surface layer of ductile iron occurs due to magnesium (a spheroidizing element) and its concentration decreases. It results from the interaction of sulfur with magnesium, and also with among others, manganese and iron through the creation of complex sulphides (Mn, Fe, Mg)S in the surface layer.

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REFERENCES

[1] D. M. Stefanescu, S. Wills, J. Massone, International Journal of Metalcasting, Fall (2008), 7-28.
[2] J. W. Torrance, D.M., AFS Transactions, no 112 (2004), 757-772.
[3] D. M. Stefanescu, F.R. Juretzko, AFS Transactions, 2007, 1-4.
[4] S. Boonmee, D. Stefanescu, International Journal of Metalcasting/Spring (2013), 15-26.
[5] S. Boojumee, D. Gyesi D., D. M. Stefanescu, Giesserei -Praxis 64 (2010) 3-4, 182-191.
[6] M. Kawalec, M. Górny, Archives of Foundry Engineering, 12 (2012) 4, 95-100.
[7] L. Tomek, K. Rusin, International Foundry Research, 62 (2010) 3, 16-25
[8] I. Riposan, M. Chisamera, S. Stan, China Foundry, 7 (2010) 2, 163-170.
[9] N. Ivan, M. Chisamera, I. Riposan, International Journal of Cast Metals Research, 26 (2013), 138-142.
[10] M. Górny, Journal of Iron and Steel Research International, 19 (2012), 52-59.
[11] M. Brzeziński, Archives of Metallurgy and Materials, 55 (2010) 3, 763-770.
[12] J. Dańko, R. Dańko, M. Holtzer, Metalurgija, 42 (2003) 3, 173-177.
[13] R. Dańko, Metalurgija, 50 (2011) 2, 93-96.
[14] M. Łucarz, Metalurgija, 47 (2008) 1, 43-45.

Note: The responsible translator for English language: "ANGOS" Translation Office, Poland, Kraków