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THE INFLUENCE OF DIFFERENT COATINGS ON THE GRAPHITE DEGENERATION IN THE SUPERFICIAL LAYER OF IRON CASTINGS

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ABSTRACT

The main objective of this experimenal reserch is to investigate new possibilities for reducing the graphite degeneration phenomenon in the superficial layer of iron castings.

For the experiment, a spheroidal graphite cast iron was poured in standard Quik-Cup moulds covered with various types of coatings. The sources of sulfur and oxygen used for coatings were based on FeS_2 and Fe_2O_3, respectively. After applying the coatings with sulfur or oxygen sources on the inner surface of the cups and after drying them, coatings based on iron powder and carbon containing powder respectively, were applied to block sulfur or oxygen access from the mould to the liquid iron. The coatings effect was evaluated by measuring the thickness of graphite degenerated surface layer and also by graphite nodularity and graphite shape factors deplating in the surface layer of the cast samples. The experimental results show a protective effect of the coating based on iron powder against the sulfur source while the coating based on carbon containing powder exerts a protective effect against the oxygen source.

KEYWORDS: coatings, graphite degeneration, superficial layer, sulphur, oxygen, iron powder, carbon containing powder

1. Introduction

The appearance of degenerated graphite layer phenomenon was observed with the first compacted graphite castings. A superficial layer in ductile iron castings can display a mixture of different graphite morphologies, from lamellar, compacted and spheroidal with various degrees of compactness up to a clear transition in the structure to fully spheroidal graphite [1, 2].

In ductile and compacted graphite irons, solidified with thin wall, the formation of an abnormal structure in the surface layer and its detrimental effect on mechanical properties has been documented over the years [3-9].

Various coating materials have been tested [10-12] to determine whether they can prevent deterioration in the surface structure. The severity of the abnormal surface layer has been significantly reduced, by employing CaO or MgO coatings due to a desulphurization reaction [11, 12].

To investigate new possibilities for reducing the graphite degeneration phenomenon in the superficial layer of the iron castings, the present work is especially focused on the evaluation of the influence of different coatings on the graphite degeneration in the superficial layer of the iron castings.

In this respect, a spheroidal graphite cast iron is developed. After the Mg treatment and CaBaFeSi inoculation, the iron melt was poured into standard Quik-Cup molds covered with various types of coatings. The metalographic samples were drawn for structure analysis.

2. Experimental procedure

The base iron was prepared by induction melting using a 150 kg acid coated induction furnace, at 1000 Hz frequency. As charge material 100% high purity pig iron was used while for iron melt chemical correction, high purity FeSi (90 wt.% Si) was added.

The thermal regim of iron melts processing was as follows: superheating temperature – T_s=1565 ^oC; Mg-treatment temperature - T_m=1530 ^oC; pouring temperature - T_p=1350 ^oC. The tehnical schedule of the experimental research program is presented in Fig. 1. FeSiCaMgRE (8 wt.% Mg) alloy as nodulizer was used (2 wt.% addition) while, for inoculation, CaBaFeSi75 (0.5 wt.% addition). The inoculated Mg-treated iron was poured in standard Quik-Cup resine molds [13] covered with various types of coatings. The materials used in this experimental program for creating the coatings are presented in Table 1. For metallographic analysis the cup samples were drawn [13]. The thickness of the surface layer was evaluated according to the schematic Fig. 2.a. with 100 µm between measurements on the unetched samples end 2% Nital etched samples.

The measured thickness of the surface layer is the average of all measurements. The structure in the healthy sample section was analized according to the schematic in Fig. 2.b. along 3 analysis directions, the distance between points in the same direction is the 0.66 mm. The average level of the structure parameters was calculated. Graphite nodularity was made in accordance with ISO 945 norm [14] after a previous metallographic preparation [13]. The main graphite shape factors analyzed are: circularity, sphericity, convexity and elongation [1].

Graphite morphology analysis was made by using a professional automat image analyzer using both the standard cast iron modulus and particle analysis software.

3. Results and discussions

The chemical composition of inoculated iron shows a level of Mg_{res} which suggests obtaining a ductile cast iron. The iron has a hypereutectic position - Table 2.

3.1. Effects on the surface layer thickness

On the etched samples were clearly obtained higher values of the average thickness of the degenerated graphite layer compared to the unetched samples. These differences are due to the difficulty in assessing the transition layer on the unetched samples and high sensitivity of metal matrix on this transition layer.

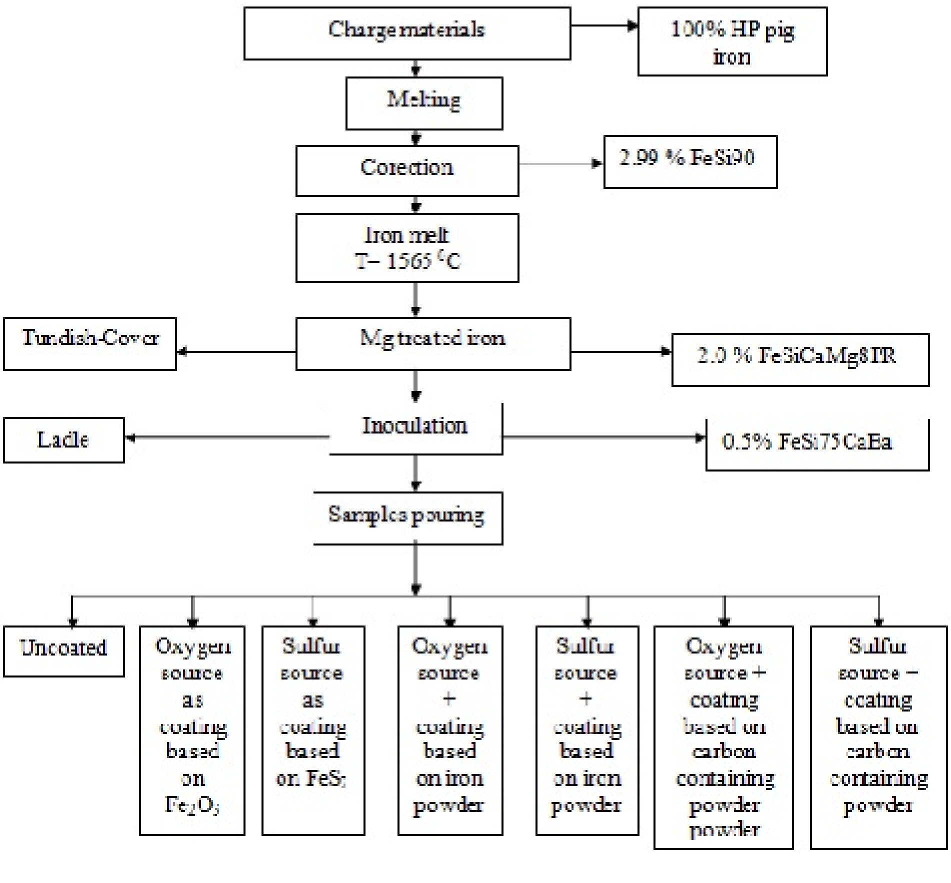
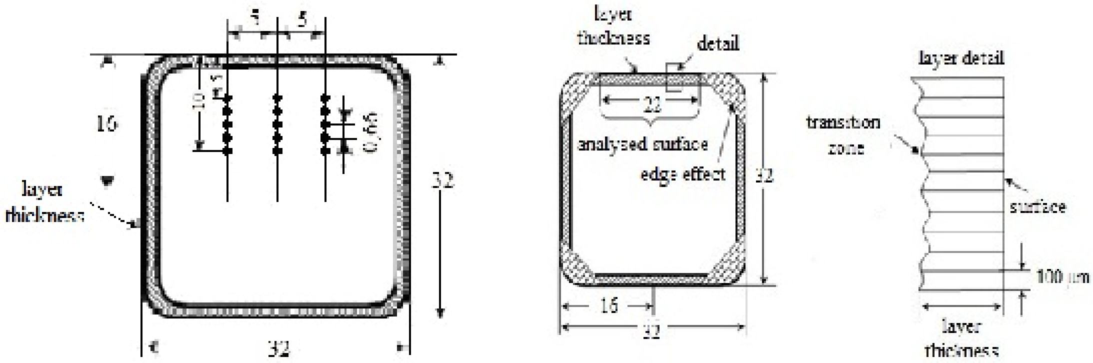


Fig. 1. *Technical schedule of the experimental program*

Table 1. *Dye coating materials*

Materials used for creating coatings	Binder
0.6 g FeS_2	- 4 g polystyrene - 10 ml toluene
0.6 g Fe_2O_3	
1.12 g iron powder	
1g carbon containing powder	



a) b)

Fig. 2. *The analysis procedure to evaluate the surface layer thickness (a) and the structure parameters in the healthy sample section (b)*

Table 2. *Chemical composition of obtained iron*

Chemical composition, [wt.%]*						CE**
C	Si	Mn	P	S	Mg	
3.65	3.15	0	0.013	0.004	0.049	4.6

*Others : Cr: 0.08, Mo: 0.05, Ni: 0.072, Al: 0.002, Cu: 0.02, V: 0.016, W: 0.004
**CE = C + 0.3·(Si + P) - 0.03·Mn + 0.4·S

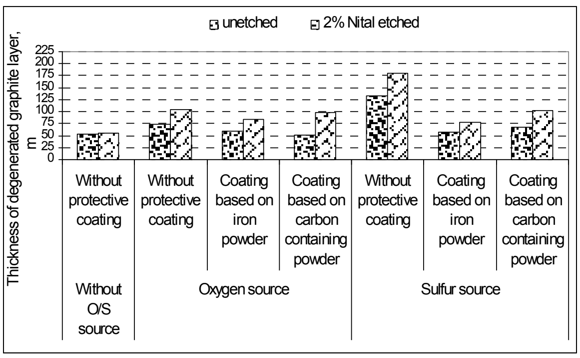


Fig. 3. *Influence of coatings on the surface layer thickness*

Samples protected with coating based on the iron powder or carbon containing powder showed lower values of the graphite degenerated superficial layer thickness compared to the unprotected (reference) samples (Fe_2O_3 or FeS_2 coated).

The largest thickness of the degenerated graphite layer was recorded for the unprotected (FeS_2 coated) sample which again highlights the strong influence of sulfur on graphite degeneration.

Coating based on iron powder shows a protective effect against the sulfur source while the coating based on the carbon containing powder shows a protective effect against the oxygen source (Fig. 3, Table 4).

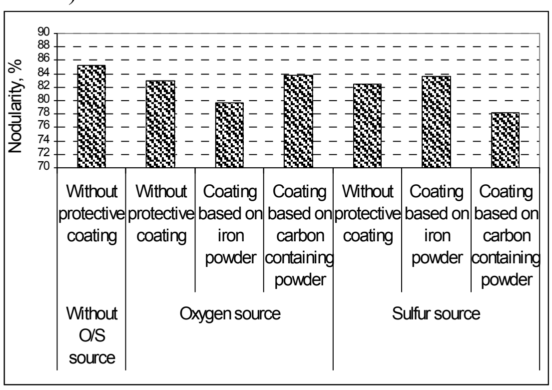
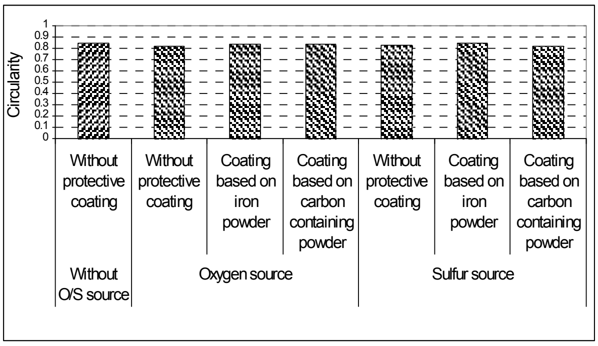
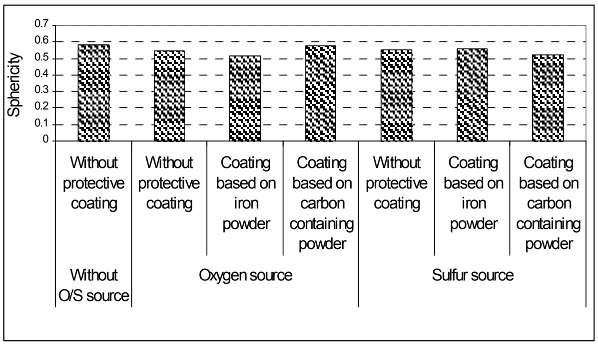


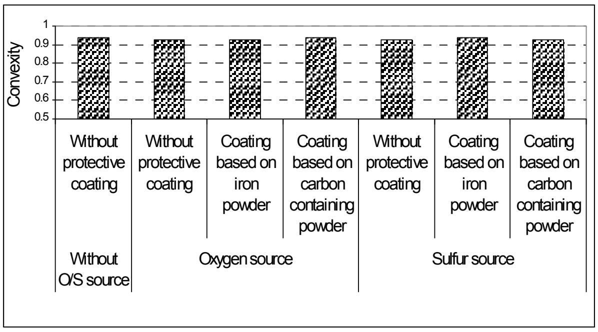
Fig. 4. *Graphite nodularity in healthy sample section under the influence of coatings*



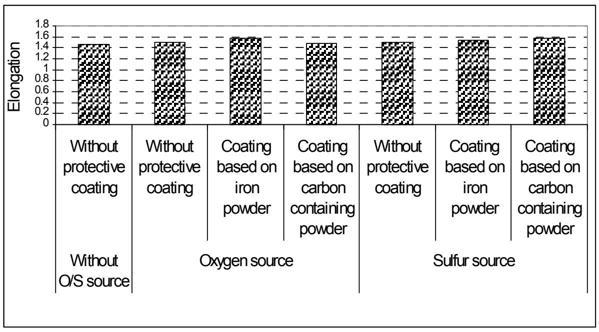
(a)



(b)



(c)



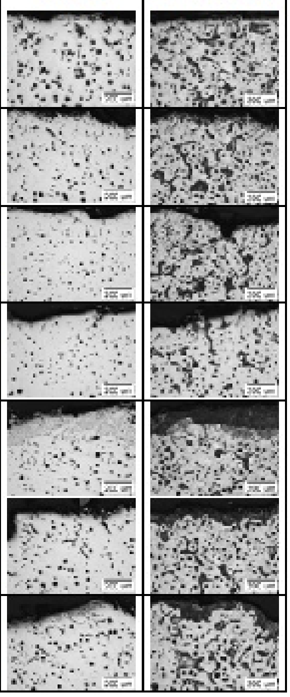
(d)

Fig. 5. *Graphite shape factors in healthy sample section under the influence of coatings: a - circularity, b - sphericity, c - convexity, d - elongation*

3.2. Effects on graphite morphology

Table 3. *Thickness layer evolution underthe influence of coatings*

Oxygen/ Sulfur source	Coating protection type	Sample state: Unetched	Sample state: 2% Nital etched
Without oxygen/ sulfur source	Without protective coating		
Oxygen source	Without protective coating		
	Coating based on iron powder		
	Coating based on carbon containing powder		
Sulfur source	Without protective coating		
	Coating based on iron powder		
	Coating based on carbon containing powder		



Graphite morphology was also affected by the experimented coatings in the healthy section of the samples. The influence of the O/S containing coatings without or with protective coatings on the graphite morphology (nodularity/graphite shape factors) is presented in Fig. 4 and Fig. 5.

As it can be seen in Fig. 4 and Fig. 5 result, coating based on iron powder has a protective action against the sulfur source (FeS_2), but does not exhibit the same effect against the oxygen source (Fe_2O_3) while the coating based on carbon containing powder has a reverse effect.

The effects on graphite morphology are in good connection with that on the graphite degenerated surface layer thickness. A higher thickness of degenerated surface layer means a lower graphite compactness (nodularity/shape factors) in the healthy section of the sample.

The explanation of these effects could be found if the different reactivities of the carbon towards oxygen and sulphur and the higher activity of oxigen towords the base iron components (C, Si Mn etc.) by comparing them to sulphur are taken into account.

The protective effect of the iron powder based coating could be explained by the decreasing of sulphur diffusion capacity on the sample – mould interface because of a lower sulphur gradient determined by the iron powder presence (sulphur diffusion effect).

4. Conclusion

(1) The experiment pointed out the much stronger degenarative effect of sulphur by comparing it to oxygen, objectified both through the size (thickness) of graphite degenerated superficial layer and graphite compactness decreasing in the sample volume.

(2) The coating of the sulphur source with iron powder coat has been shown to have a protective effect by lowering or eliminating the superficialy degenaration layer but it has been ineffective towards the oxygen source.

(3) The use of a carbon containing coat had an opposite effect compared to iron powder based coating that is, it had a protective effect towards de oxygen source but it was ineffective towards the sulphur source. The explanation of these effects consists in the different reactivity of S/O towards the main components of base iron and the different action of the two coats (iron powder and carbon containing powder) on the iron sample – mold interface.

Acknowledgement

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