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The Effect of the Number of Eutectic Grains on Coating Growth During Hot Dip Galvanising of Ductile Iron Castings

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Abstract

Studies were conducted on a zinc coating produced on the surface of ductile iron grade EN-GJS-500-7 to determine the eutectic grain effect. For this purpose, castings with a wall thickness of 5 to 30 mm were made and the resulting structure was examined. To obtain a homogeneous metal matrix, samples were subjected to a ferritising annealing treatment. To enlarge the reaction surface, the top layer was removed from casting by machining. Then hot dip galvanising treatment was performed at 450°C to capture the kinetics of growth of the zinc coating (in the period from 60 to 600 seconds). Analysing the test results it was found that within the same time of hot dip galvanising, the differences in the resulting zinc coating thickness on samples taken from castings with different wall cross-sections were small but could, particularly for shorter times of treatment, reduce the continuity of the alloyed layer of the zinc coating.

Keywords: Casting quality management, Zinc coating, Ductile iron, Eutectic grains

1. Introduction

Hot dip galvanising is one of the most commonly applied methods for protection of iron-carbon alloys against corrosion. This regards both effectiveness and duration of protection (even several dozen years). Currently, cast iron is used more and more often in the production of industrial valves, and therefore adequate protection of this material against corrosion and prolonged service life become increasingly important [1-11]. An opinion often prevailing that only the surface of decarburised cast iron is suitable for hot dip galvanising gradually loses its significance because in galvanising plants involved in zinc coating of castings of this type, the majority of items are now elements cast from ductile iron. At the same time, technical literature lacks any extensive and comprehensive studies of the reactions that occur during the hot dip galvanising of ductile iron castings, to know what impact the precipitates of spheroidal graphite may have on the protective zinc coating in terms of both its quality and the presence of surface defects. It should also be remembered that the size and the number of the spheroidal graphite precipitates will vary depending on the distance from the casting wall, resulting in increased diameter of the graphite spheroids inside the casting, that is, in the area which can be exposed by machining (the removal of risers) and react with liquid zinc during the hot dip galvanising process.

2. Methodology

The aim of the conducted studies was to examine what impact the precipitates of spheroidal graphite in ductile iron may have on the kinetics of growth of the zinc coating during hot dip galvanising process. For this purpose, plates with dimensions of 5x100x100mm, 10x100x100mm, 20x100x100mm and

30x100x100mm were cast in moulds prepared from the traditional bentonite-bonded sand poured with ductile iron of grade EN-GJS-500-7 with the chemical composition as shown in Table. 1 From these castings, samples were prepared and the resulting structure was examined. Castings were subjected to a heat treatment, and test samples of 5x10x10mm and 10x10x10mm dimensions were prepared for the subsequent hot dip galvanising.

Table 1.
Chemical composition of the tested cast iron.

Cast iron	C	Si	Mn	P	S
EN-GJS-500-7	3,58	2,40	0,42	0,021	0,009

Hot dip galvanising treatment (450°C/ 60 to 600 seconds) was carried out in a laboratory of Department of Engineering of Cast Alloys and Composites [12].

3. Evaluation of ductile iron structure

To investigate the potential factors that could affect thickness of the growing alloyed layer, detailed microstructural studies were carried out on sample plates cast from the ductile iron grade EN-GJS-500-7 with a wall thickness of 5mm, 10mm, 15mm, 20mm, and 30mm (Fig. 1).

a) b)

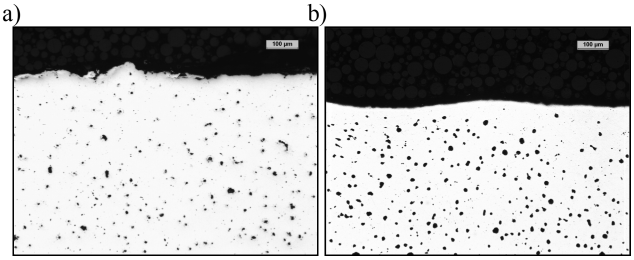

Fig. 1. Distribution of graphite precipitates in the edge of ductile iron samples - (a, b)

Studies covered analysis of the volume fraction of graphite precipitates and metal matrix phases, taking into account significant differences between the structure of the surface layer and the inside part of a test sample. It is easy to note that in the subsurface layer (casting skin), the amount of the visible precipitates of graphite is limited and their diameter increases on approaching the casting centre. Figure 2 shows photographs of microstructures used in the quantitative evaluation of metal matrix in the samples tested. The research shows that castings made from the ductile iron grade EN-GJS-500-7, poured in bentonite sand moulds, have the casting skin with a much higher content of pearlite than the metal matrix near the casting centre. This means that in the initial period of the raw casting surface metallisation, liquid zinc reacts with the metal matrix composed mainly of pearlite.

a) b)

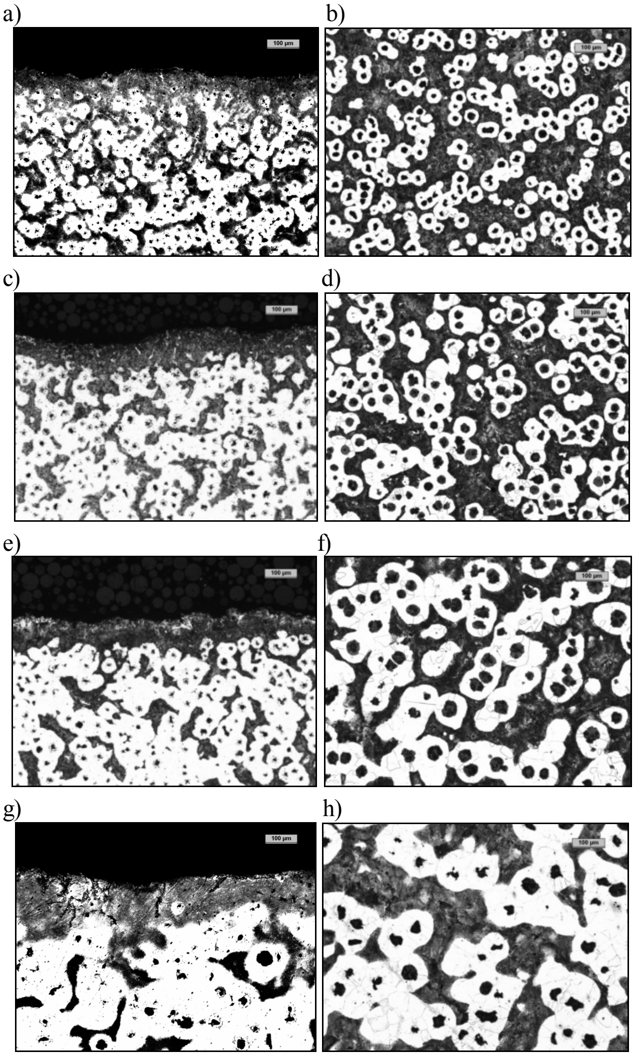

Fig. 2. Microstructure observed in the EN-GJS-500-7 grade cast iron samples with the wall thickness of 5mm – a, b), 10mm – c, d), 20mm – e, f) and 30mm – g, h)

As a next step, the number of eutectic grains (nodule count) in the structure of ductile iron samples (Fig. 3) was examined in areas distant by 0.5 to 2 mm from the casting edge. The examined areas were characterised by the number of graphite precipitates decreasing with the increasing distance from the sample edge. Thus it can be concluded that with the use of mechanical surface treatment, the number of graphite precipitates will vary, depending on a distance from the casting edge. However, it has to be remembered that on approaching the casting centre, the precipitates will be characterised by a larger diameter.

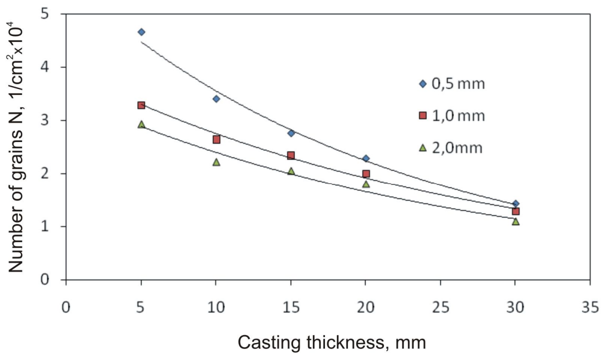

Fig. 3. The relationship between the number of graphite precipitates and casting wall thickness (in the place where the sample was cut out) in function of the measuring distance from the edge of ductile iron sample

It should also be noted that in the region from 100μm to the sample edge (casting skin), both quantity and size of the spheroidal graphite precipitates are significantly reduced.

4. Graphite effect on zinc coating

To see how the number of eutectic grains (the graphite nodule count) as a component of the cast iron phase structure can affect the formation of zinc coating, appropriate test samples were prepared. Because of the gradient character of the cast iron structure shown in Figure 2, much higher content of pearlite in the casting skin - in particular, it was decided to carry out a heat treatment and obtain the metal matrix ferritic in 100% on the whole casting wall cross-section, which is schematically shown in Figure 4.

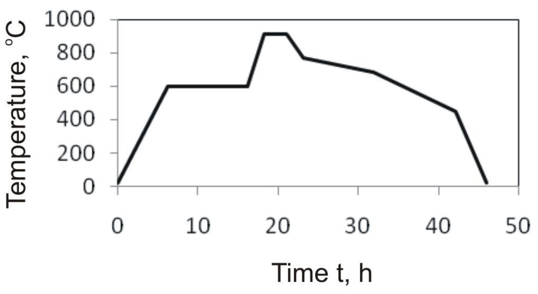

Fig. 4. Schematic representation of the ferritising annealing

As a result of the ferritising annealing (Fig. 3), test samples were obtained from castings with the wall thickness of 5mm, 10mm, 20mm and 30mm, characterised by a homogeneous metal matrix as shown in Figure 5. The samples were next subjected to a chemical surface treatment according to the description presented in [12].

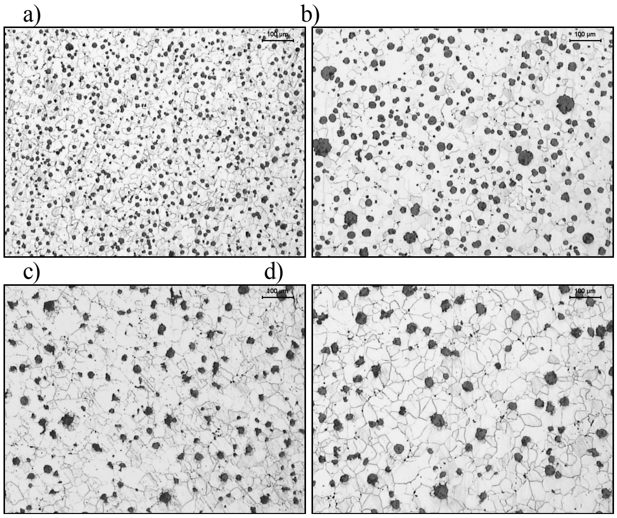

Fig. 5. Microstructure of test samples with different wall thicknesses, i.e.: 5mm - a), 10mm - b), 20mm - c) 30mm - d) made from the ductile iron after ferritising annealing

5. Results and discussion

Examples of the obtained zinc coating structure depending on the type of metal matrix produced in a ductile iron casting and on the galvanising treatment time are shown in Figure 6.

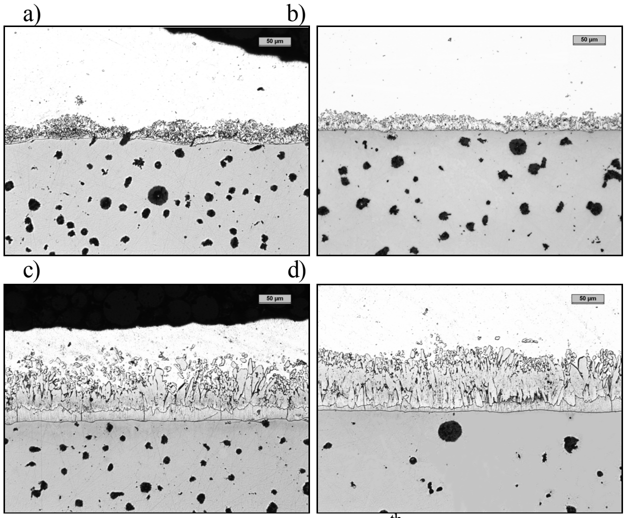

Fig. 6. Zinc coating formed in the 60^{th} second of the hot dip galvanising process on the surface of samples with the wall thickness of: 5mm - a), 30mm - b) and in the 600^{th} second of the galvanising process for the wall thickness of: 5mm - c) and 30 mm - d); ductile iron of ferritic metal matrix (machined surface)

To enhance the impact of graphite precipitates, the sample surface was examined after earlier removal of the top layer to expose the graphite precipitates. Based on the measurements of the zinc coating thickness formed on different cast iron surfaces, the kinetics of the coating growth was determined, as shown in Fig. 7.

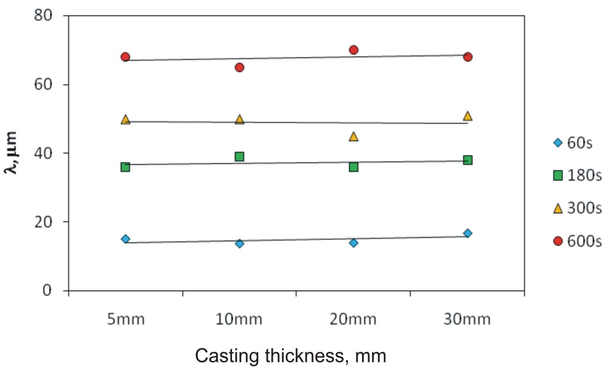

Fig. 7. The kinetics of growth of the alloyed layer on the surface of ductile iron sample with varied metal matrix

6. Conclusions

Widely prevailing opinion that only the surface-decarburised cast iron is suitable for the production of protective coating by hot dip galvanising is the result of attempts to galvanise the cast iron with flake graphite. Galvanising this type of cast iron is problematic indeed, because of the large surface development in graphite flakes and their interpenetration. Surface decarburising eliminates this problem, but due to the increasing cost of production of malleable cast iron, industrial fittings cast from ductile iron have been widely used. Despite the lack of surface decarburisation, this grade of cast iron does not pose so big problems during the process of hot dip galvanising. Because of its sensitivity to the cooling rate, iron castings can have different content of phases in the metal matrix and different size of the graphite precipitates. The results presented in Figure 3 show that in the hot dip galvanised castings with a wall thickness of up to 15mm, the differences in the number of grains in an area distant by 0.5 to 2 mm from the casting surface are very large. On the other hand, in castings with a wall thickness of 30 mm, no major differences have been observed in the number of grains in the surface layer. The results of hot dip galvanising at 450°C (so-called low-temperature process) obtained on samples of cast iron with different size of the graphite spheroids allow concluding that graphite in the form of spheroids has no significant effect on thickness of the formed alloyed layer. In all the tested samples, this parameter mainly depended on the time of the galvanising treatment. Only in the shortest time (60s) of the treatment, local discontinuities in the alloyed layer of the zinc coating were observed but in no way their presence deteriorated the adhesion and the quality of the outer layer (η).

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