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ARCHIVES
of
FOUNDRY ENGINEERING
DOI: 10.2478/v10266-012-0114-x

ISSN (2299-2944)
Volume 12
Issue 4/2012

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

101 – 104

The Effect of Ductile Cast Iron Matrix on Zinc Coating During Hot Dip Galvanising of Castings

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Received 29.06.2012; accepted in revised form 03.09.2012

Abstract

The growth kinetics of the zinc coating formed on the surface of casting made from ductile iron grade EN-GJS-500-3 was investigated. To produce homogenous metal matrix in test samples, the normalising and ferritising annealing was carried out. Studies showed a heterogeneous structure of cast iron with varying content of the phases formed. This was followed by hot dip galvanising treatment at 450°C to capture the growth kinetics of the zinc coating (the time of the treatment ranged from 60 to 600 seconds). Nonlinear estimation of the determined growth kinetics of the alloyed layer of a zinc coating was made and an equation of the zinc coating growth was derived. Based on the results of the investigations it was concluded that thickness of the zinc coating formed on the surface of casting with a 100% pearlitic matrix makes 55% of the thickness of coating formed on the surface in 100% ferritic.

Keywords: Hot dip galvanizing, Ductile iron, Growth kinetics of zinc coating, Metallic matrix

1. Introduction

Hot dip galvanising is one of the commonly used modern methods of protection against corrosion of iron and its alloys [1-11]. This method allows producing a permanent and effective protection that can last up to several dozen years. The cast iron is more and more frequently used for the production of industrial fittings, and thus it is more and more often evaluated in terms of the corrosion resistance it can offer [1-3]. The generally prevailing opinion that only the surface-decarburised cast iron is fit for hot dip galvanising is no longer justified. The galvanising plants dealing with castings of this type must face the fact that in the majority of cases these will be castings made of ductile iron (and vermicular cast iron) which, for reasons of both economic and ecological nature, is replacing the malleable iron castings [12,13]. At the same time, technical literature lacks the description of broad and comprehensive researches on various reactions that take place during hot dip galvanising of ductile iron, especially as regards the type of the cast iron metallic matrix.

2. Experimental procedure

The aim of the study was to test what effect the type of ductile iron metallic matrix can have on the growth kinetics of zinc coating during the hot dip galvanising treatment. To achieve this goal, a 30x100x100mm plate was cast in a standard bentonite sand mould using ductile iron of EN-GJS-500-3 grade with the chemical composition shown in Table 1. As a next step, 10x10x10mm specimens for hot dip galvanising test were prepared and subjected next to a heat treatment.

Table 1.
Chemical analysis of ductile cast iron melts (wt. pct.)

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

Hot dip galvanising was conducted on a laboratory stand in the Department of Cast Alloys and Composites Engineering, University of Science and Technology in Cracow (Fig. 1); the test temperature was 450°C and the test time ranged from 60 to 600 seconds.

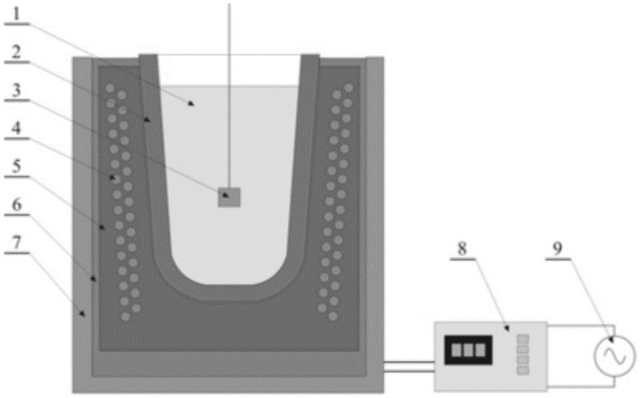

Fig. 1. The laboratory stand for hot dip galvanizing of iron castings: 1-zinc bath, 2- crucible pot, 3 – steel rod with specimen, 4 – heating elements, 5 – chamotte lining, 6- insulating material, 7– steel shell, 8 - automatic control system of furnace temperature, 9 – voltage source

3. Heat treatment of specimens

Since cast iron is characterised by a gradient structure, the heat treatment process covered normalising annealing (Fig. 2) and ferritising annealing (Fig. 3). The aim of the treatment was to obtain a homogeneous structure and four groups of specimens characterised by different type of the metallic matrix. Figures 4 and 5 show the microstructure of specimens characterised by varying percent content of ferrite and pearlite. These specimens were next subjected to a chemical treatment following the specification given in [5].

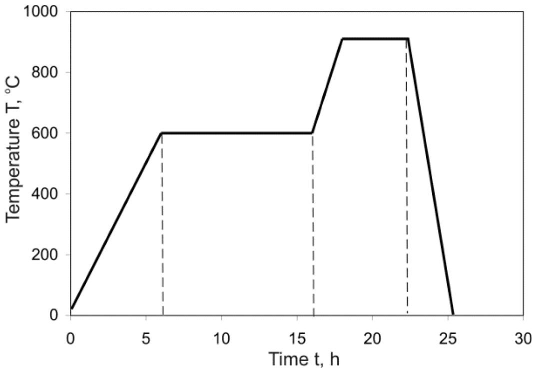

Fig. 2. The scheme normalizing annealing

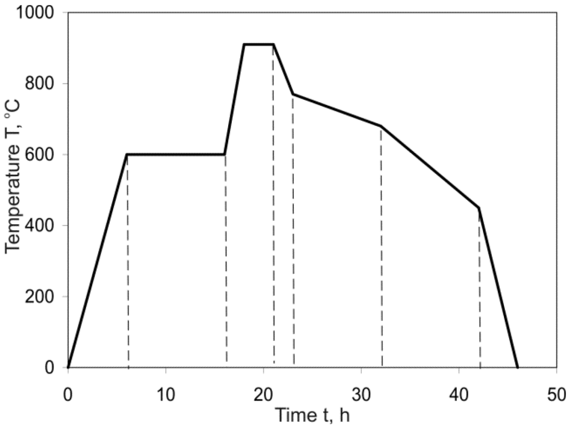

Fig. 3. The scheme ferritising annealing

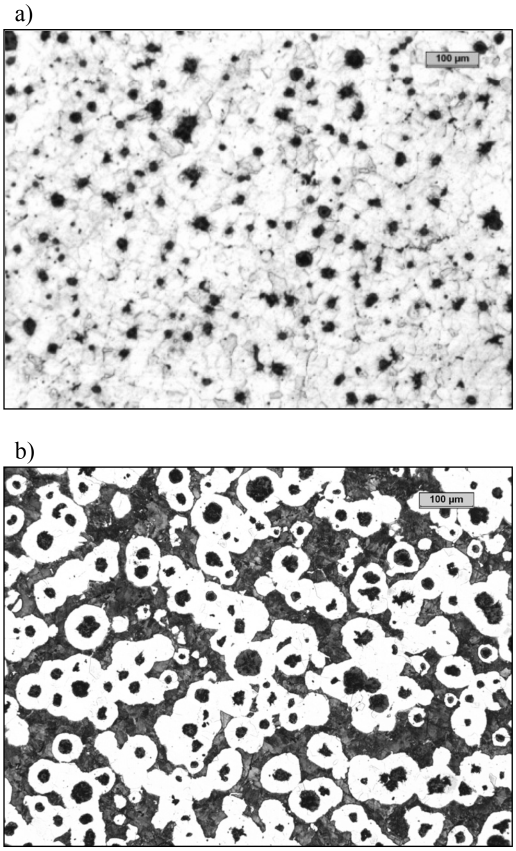

Fig. 4. Microstructure of the test specimen after heat treatment of various metal matrix with: 0% participation of perlite (F100%P0%) – a), 35% participation of perlite (F65%P35%) – b),

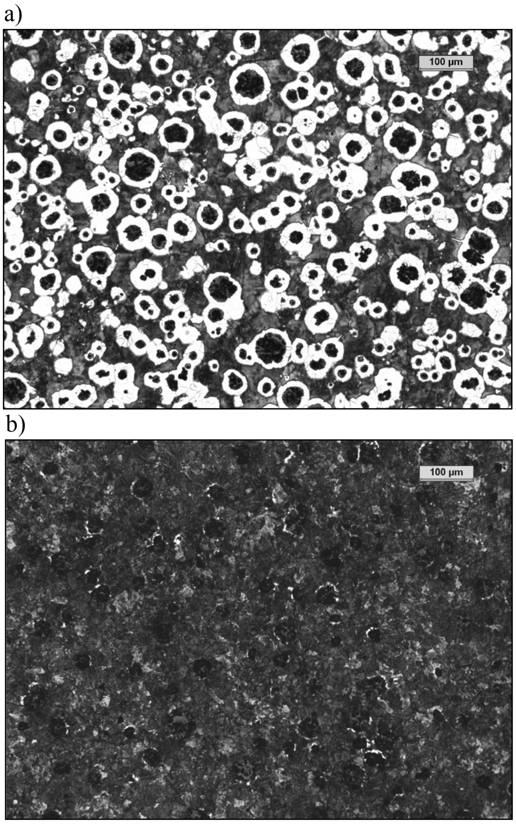

Fig. 5. Microstructure of the test specimen after heat treatment of various metal matrix with: 55% participation of perlite (F45%P55%)– a), 100% participation of perlite (F0%P100%) – b)

4. Results and discussion

Examples of the resulting structure of the zinc coating are shown in Figures 6 and 7.

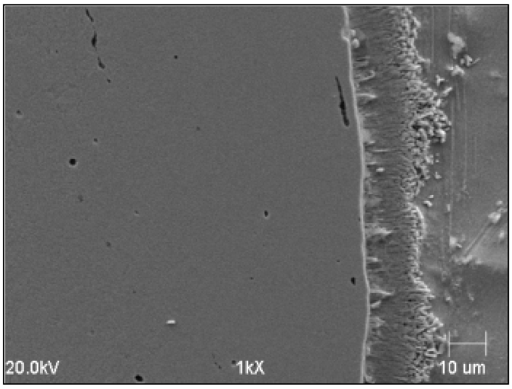

Fig. 6. The zinc coating formed on the cast iron surface of of various metal matrix with: 100% ferrite after 60 sek.

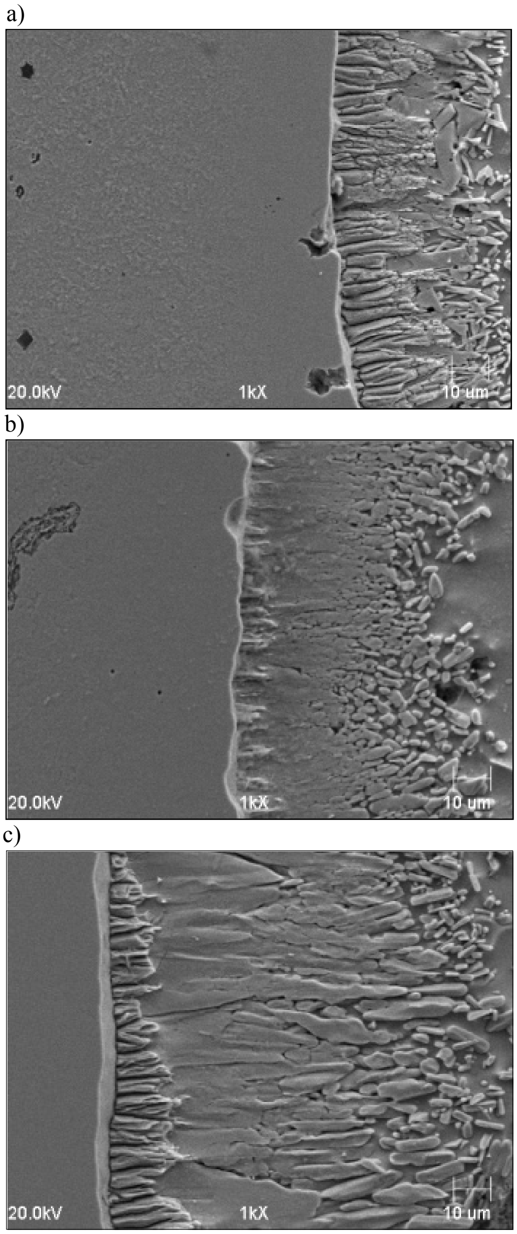

Fig. 7. The zinc coating formed on the cast iron surface of of various metal matrix with: 100% ferrite after 300 sek – a), 100% perlite after 60 sek.– b), 100% ferrite after 300 sek. – c)

Based on the results of the measurements of the zinc coating thickness formed on the surface of different types of cast iron, the growth kinetics was determined, as shown in Figure 8, and relevant equations (1) ÷ (4) were derived.

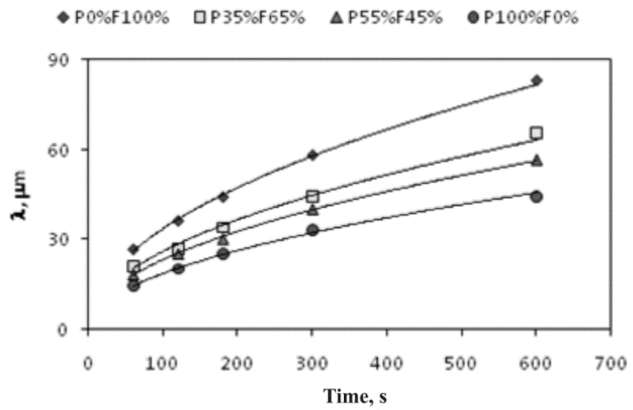

Fig. 8. The calculated and measured value of the zinc coating growth kinetics of ductile iron specimen with different metallic matrix

Using the calculated value of the zinc coating growth kinetics, a nonlinear estimation was made and, as a result of this operation, an equation for the zinc coating growth was obtained, where the zinc coating is considered a sum of sublayers of the δ phase and ζ phase (the η phase was not included in the studies, but it can be assumed that the thickness of the η(Zn) phase makes 30% of the total zinc coating thickness.

For the metallic matrix of a P0% F100% type in ductile iron:

$$\lambda = 3{,}338 \cdot t^{0{,}50} \tag{1}$$

For the metallic matrix of a P35% F65% type in ductile iron:

$$\lambda = 2{,}580 \cdot t^{0{,}50} \tag{2}$$

For the metallic matrix of a P55% F45% type in ductile iron:

$$\lambda = 2{,}291 \cdot t^{0{,}50} \tag{3}$$

For the metallic matrix of a P100% F0% type in ductile iron:

$$\lambda = 1{,}849 \cdot t^{0{,}50} \tag{4}$$

Comparing the derived zinc coating growth equations for a 100% pearlitic matrix and 100% ferritic matrix, relationship (5) can be derived.

$$\lambda_{P100\%F0\%} / \lambda_{P0\%F100\%} = 0{,}55 \tag{5}$$

5. Conclusions

Studies have shown that thickness of the zinc coating depends on the type of ductile iron matrix. Pearlite content in the metal matrix produces zinc coating of much smaller thickness. Hot dip galvanising of items made from the cast iron with matrix in 100% pearlitic reduces thickness of the zinc coating by up to 55%, compared with the thickness of the coating produced on the surface of cast iron with matrix composed in 100% of ferrite. The developed relationships are used to determine the duration of hot dip galvanising treatment at 450°C, which enables controlling the process of the zinc coating overgrowth.

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