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ARCHIVES
of
FOUNDRY ENGINEERING

DOI: 10.24425/122499

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

ISSN (2299-2944)
Volume 18
Issue 2/2018

35 – 38

7/2

The Effect of the Heat Flux Density on Microstructure of Surface Remeltings on C355 Alloy Castings

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Received 24.07.2017; accepted in revised form 25.09.2017

Abstract

The paper presents results of a study on the effect of the flux density of heat carried away for the remelting area to substrate in the course of surface remelting with concentrated heat stream on values of structural parameters λ_{1D} and λ_{2D} of α(Al) phase dendrites in C355 alloy. The remeltings were made with the use of GTAW method, at arc current intensity I = 200 A and concentrated heat stream scanning speed v_s = 200, 400, 600, and 800 mm/min. The used protective gas was argon supplied at rate of 20 l/min. It has been found that the increase of the rate of scanning with concentrated heat stream results in a change of the remelting-substrate separation surface shape consisting in reduction of the remelting width and depth. This increases the value of the flux density of heat transmitted from the remelting area to substrate which in turn acts in favor of reduction of structural parameters λ_{1D} and λ_{2D} characterizing α(Al) phase dendrites in C355 alloy.

Keywords: C355 alloy, Remelting with concentrated heat stream, Microstructure

1. Introduction

One criterion used in many practical cases when a material is selected for cast machine parts, is the value of ratio of the strength to specific gravity of alloy. This is of special importance in case of strongly loaded and responsible parts for automotive industry in which, besides from high values of strength parameters, the value of specific gravity is expected to be as low as possible. Materials characterizing by high values of strength to specific gravity include aluminum-silicon alloys (silumins).

Silumins are characterized with good casting properties, satisfactory mechanical strength parameters, good weldability and resistance to corrosion, and acceptable resistance to abrasive wear.

Chemical composition and microstructure are decisive for service properties of silumins. Microstructure of hypoeutectic silumin comprises precipitates of α (Al) and β(Si) phases as well as intermetallic phases.

Among basic tools available to the process engineer for the purpose of modelling microstructure of alloys, including also silumins, the most commonly used is controlling the casting cooling rate [1, 2].

One method of forming fine-grain microstructure consists in providing conditions for rapid crystallization which occur after remelting surface of a casting with concentrated heat stream generated by e.g. laser beam or electric arc plasma. In a number of papers it was demonstrated that as a result of application of the process, a microstructure guaranteeing high service properties of castings is obtained [3–5].

The goal of the study presented in this paper was to demonstrate the effect of the remelting-substrate separation surface formed in the course of scanning surface of C355 alloy casting with concentrated heat stream on microstructure of surface remeltings formed under conditions characteristic for rapid crystallization.

2. Research methodology

The process of local casting surface remelting with concentrated heat stream was realized with the use of the gas tungsten arc welding (GTAW) method. The remeltings were made on C355 alloy castings with dimensions 250 mm × 50 mm × 15 mm. Chemical composition of C355 alloy is presented in Table 1. The casting were made in a casting die.

Table 1.
Chemical composition of C355 alloy

Element content, wt%						
Si	Cu	Fe	Mg	Mn	Ti	Al
4.56	1.25	0.12	0.50	0.02	0.14	to balance

To determine the quantity of heat intercepted by remeltings, the calorimetric method was used described in patent document [6]. Four remeltings were made at different values of the speed of scanning with concentrated heat stream (v_s = 200, 400, 600, and 800 mm/min) at constant arc current intensity value $I = 200$ A. The used protective gas was argon supplied at rate of 20 l/min. Remeltings were performed with tungsten electrode with diameter of 4 mm.

The flux density q of the heat carried away to substrate via the remelting–parent metal separation surface was determined according to formula

$$q = \frac{Q_{cal}}{l_{pl} \cdot l \cdot t} \qquad (1)$$

where Q_{cal} is the quantity of heat intercepted by the heated specimen; l_{pl} — length of penetration line; l — length of remelting; and t — remelting formation time.

Geometry of the problem is explained in schematic view of Figure 1. Experiments consisted in making remeltings with length l = 200 mm. Lengths of the remelting penetration line were assessed on metallographic sections cut in plane perpendicular to longitudinal axis of remeltings.

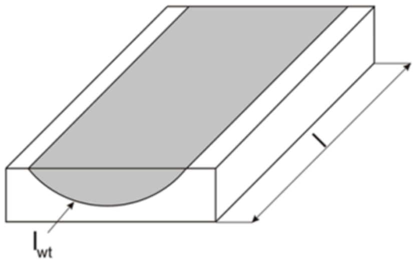

Fig. 1. A schematic view defining length parameters used in Eq. (1) to calculate the flux density of heat carried away via the remelting-substrate separation surface

The same metallographic sections were used to assess values of structural parameters λ_{1D} (distance between main axes of α(Al) phase dendrites) and λ_{2D} (distance between axes of second-order branches of α(Al) phase dendrites). The measurements were taken by means of Neophot 2 metallographic optical microscope equipped with MultiScan advanced image acquisition and analysis system. Values of structural parameters λ_{1D} and λ_{2D} were determined by means of the secants method on 50 randomly selected images of microstructure, at half-depth of remeltings, under a magnification of 800×.

3. Results of the research

The obtained results indicate that with increasing speed of scanning with concentrated heat stream, widths and depths of remeltings decrease. This is a result of shorter time for which heat is intercepted by the surface scanned with concentrated heat stream and thus reduced value of heat intercepted by the remelting. As a result, the remelting-substrate separation surface area decreases reducing thus the width of substrate in the zone adjacent to remelting which is heated up be means of the heat conduction mechanism (HAZ) and, in combination with the quantity of heat used to form the remelting, will affect the value of the flux of heat carried away to neighboring regions of substrate.

Figure 2 shows results of experiment carried out to determine the effect of the speed of scanning with concentrated heat stream on the flux density of heat carried away via the remelting-substrate separation surface.

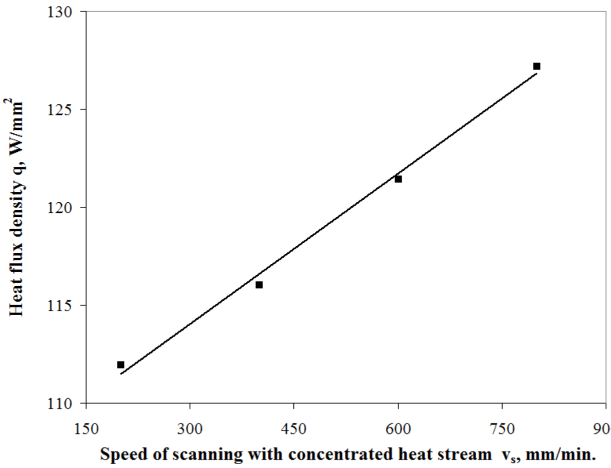

Fig. 2. The effect of speed of scanning a C355 alloy casting surface with concentrated heat stream on the value of flux density of heat carried away from the remelting area to the substrate

Figure 3 presents result of examination of the effect of the speed of scanning with concentrated heat stream on width and depth of remeltings on castings of C355 alloy.

The obtained results show that with increasing speed of scanning the specimen with concentrated heat stream, the value of the flux density of heat conducted from the remelting area to the substrate increases. This can be attributed to higher intensity of heat flow through less intensively heated areas adjacent to remeltings made at higher value of speed of scanning with concentrated heat stream.

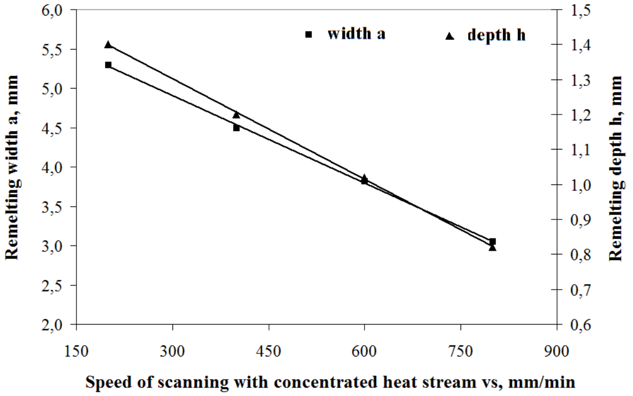

Fig. 3. The effect of the speed of scanning with concentrated heat stream on width and depth of remeltings on castings of C355 alloy

Images of microstructure of the substrate material and microstructure of remeltings observed at their half-depth are presented in Figures 4-6.

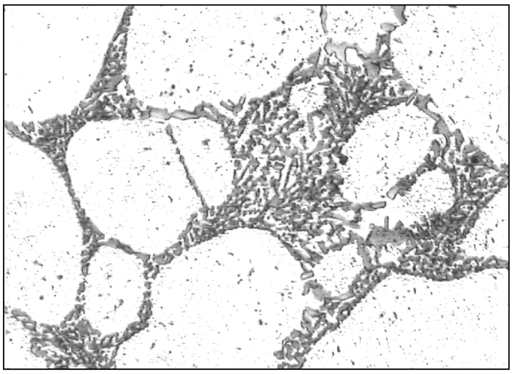

Fig. 4. An example microstructure of C355 alloy in as-cast condition. Magnification 800×

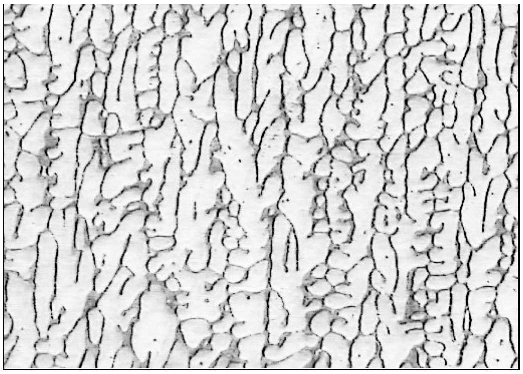

Fig. 5. An example microstructure of the remelted area on surface of a C355 alloy casting made at the speed of scanning with concentrated heat stream $v_s = 200$ mm/min and current $I = 200$ A. Magnification 800×

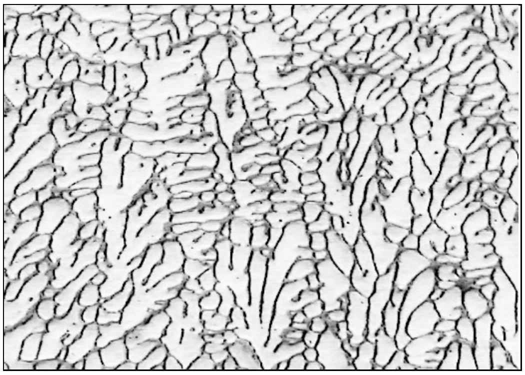

Fig. 6. An example microstructure of the remelted area on surface of a C355 alloy casting made at the speed of scanning with concentrated heat stream $v_s = 800$ mm/min and current $I = 200$ A. Magnification 800×

The obtained results indicate that together with increasing values of flux density of the heat flowing from the remelting area to the parent material, values of structural parameters λ_{1D} and λ_{2D} characterizing the microstructure decrease. The microstructure is subject to refinement.

The effect of the flux density of heat carried away in the course of the process of forming remeltings via the remelting-substrate separation surface on values of structural parameters λ_{1D} and λ_{2D} of microstructure of remeltings made on surface of C355 alloy castings are presented in Figures 7 and 8.

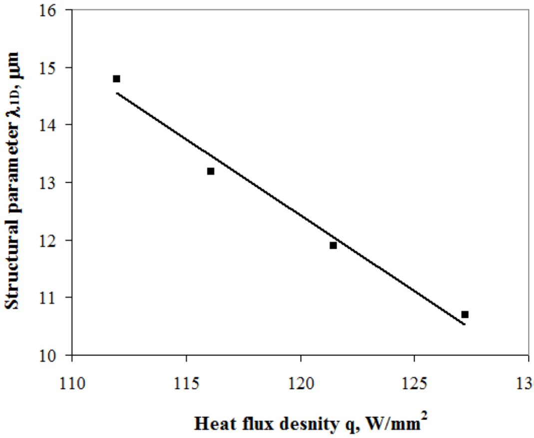

Fig. 7. The effect of the flux density of heat carried away in the remelting forming process via the remelting-substrate separation surface on value of structural parameter λ_{1D} of microstructure of remeltings made on surface of C355 alloy castings

The relationship between structural parameters λ_{1D} and λ_{2D} of microstructure characterizing remelting areas on C355 alloy castings and the heat flux q of heat carried away via the remelting-substrate separation surface in the process of remelting formation can be expressed as

$$\lambda_{1D} = 43.999 - 0.263q \qquad R^2 = 0.98 \tag{2}$$

$$\lambda_{2D} = 12.903 - 0.064q \qquad R^2 = 0.99 \tag{3}$$

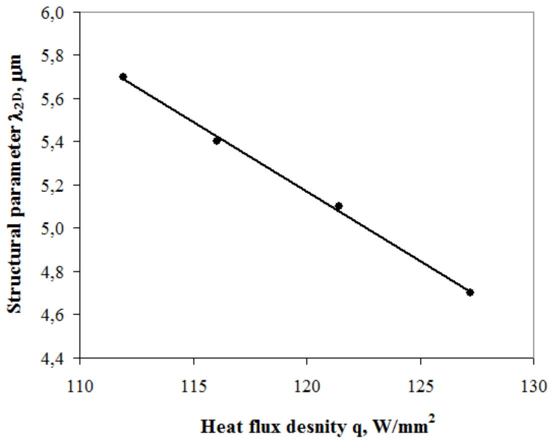

Fig. 8. The effect of the flux density of heat carried away in the remelting forming process via the remelting-substrate separation surface on value of structural parameter λ_{2D} of microstructure of remeltings made on surface of C355 alloy castings

4. Conclusions

The obtained results indicate that together with increasing speed of scanning with concentrated heat stream, both widths and depths of remeltings decrease which results in reduction of the remelting-substrate separation surface area and increased value of the flux density of heat carried away to the substrate from remelted areas.

The increase of value of the flux density of heat conducted from the remelting area to the parent metal results in refinement of C355 alloy microstructure manifesting in reduction of value of structural parameter λ_{1D} which, according to [7], is sensitive to the solidification time, and λ_{2D}, which in turn, according to [8], depends strongly on temperature gradient. According to results published in [3] and [4], this will result in increased tensile strength and increased fatigue strength of C355 alloy.

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