Solidification Microstructure and Properties of Gray Cast Iron Made by Lost Foam Casting with Vibration

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Abstract: The effects of sample wall thickness, vibration frequency and amplitude on graphite morphology, primary austenite and properties of gray cast iron (GCI) made by lost foam casting (LFC) with vibration were studied. The results show that when the thickness of the sample is relatively thin (20 mm), type B and type C graphite are formed in the GCI, but no type B and type C graphite are observed in the sample thickness of 40 and 60 mm. The results of GCIwith a thickness of 70 mm made by LFC with mechanical vibration show that when the vibration frequency is 35 Hz and the amplitude is 2 mm, the flake graphite length of the GCIis small, the austenitic dendrite arms are thick and evenly distributed, and an effective network skeleton is formed in the GCIwith large tensile strength and elongation. This can be attributed to the effect of vibration on heat and mass transfer during solidification of GCImelt.

Keywords: Solidification; Vibration; Gray cast iron; Microstructure; Property; Lost foam casting

1 Introduction

Lost foam casting (LFC) is a near-net forming method, known as "the new casting technology in the 21st century" and "green engineering in casting", is widely used in the production of complex GCIcastings, such as cylinder block, cylinder head and so on. However, the dry sand molding is used in the LFC, and the pouring temperature is 30~50 ℃ higher than that of the traditional casting, resulting in the solidified structure of the iron base alloy castings is coarse and the mechanical properties are low, which is very unfavorable to the service life of the castings. For this reason, refining the microstructure and improving the performance of the alloy castings made by LFC are particularly key to improving the service life of the castings, among which mechanical vibration can refine the alloy microstructure and improve the alloy properties without adding additional equipment. Therefore, in this paper, mechanical vibration is applied to GCIin the LFC, and the effects of sample wall thickness, vibration frequency and amplitude on graphite morphology, primary austenite and properties of GCIin the LFC are studied to lay a foundation for improving the structure and properties of GCImade by the LFC.

2 Experimental procedure

Scrap steel, pig iron, ferromanganese, carburant and 75 ferrosilicon was used as raw materials for preparing HT 100 iron liquid. Melting equipment was a one-ton medium-frequency induction furnace. The scrap steel, pig iron and carburant were firstly added into the furnace. When the temperature increased to 1,500 °C, the scrap steel, ferromanganese and ferrosilicon were added into the furnace to adjust the component of the molten metal. Finally, the melt was modified with 75 ferrosilicon and then poured into the sand box. The Y-type specimen of GCI was produced and their dimensions are shown in Figure 1. During pouring, vibration solidification parameters are shown in Table 1. The cube specimen for the density measurement was cut using wire cutting and its dimensions were 10.4 mm x 10.4 mm x 10.4 mm. It was then polished to the dimensions of 10 mm x 10 mm x 10 mm using 100, 400 and 800 grit abrasive papers in sequence and the surface was cleaned using ultrasonic cleaning in alcohol. Then the cube mass was measured using a balance, and the density of the GCI was calculated. The average density value was obtained from three specimens for each specified condition. The flake graphite of the GCI before corrosion and the morphology of the primary austenite after corrosion were observed by an optical microscope (OM), and the length of the flake graphite was measured by the optical microscope software system. The etching solution was 4% nitric acid and alcohol solution, and Alkaline sodium caustic acid solution. The Brinell hardness of the GCI was measured by a HBE-3000A-type Brinell hardness tester with a load of 1,000 kgf and a loading time of 15 s. The average value of the Brinell hardness was taken from three measurements. The mechanical properties of the casting were tested by a SHIMADZU AG-IC universal testing machine. The tensile test was carried out at room temperature at the tensile speed of 1 $mm\cdot min^{-1}$. Then, the fracture morphology was observed by Quanta 200 environmental scanning electron microscopy (ESEM). Finally, the temperature field of the columnar zone during solidification of the GCI fabricated by the LFC with vibration frequency of 0 and 35 Hz was measured by a thermocouple with a diameter of 0.3 mm. The thermocouple wire was welded and embedded into the ceramic tube, and embedded in the foam pattern. The embedded depth of the thermocouple wire was 12.5 mm.

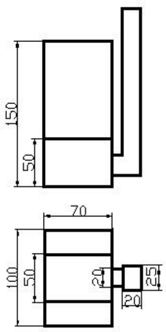

Figure 1. The size of EPS shape

Table 1. Vibration solidification parameters

Amplitude/ mm		3		
Frequency/ Hz	0	35	50	100
Frequency/ Hz		35		
Amplitude/ mm	0.75	2	3	4

3 Result and discussion

1.Effect of vibration frequency on microstructure

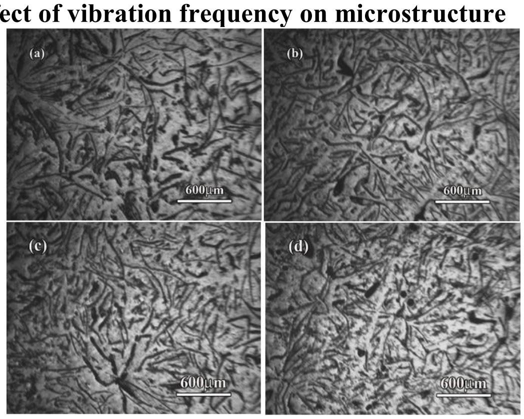

Figure 2. Effect of vibration frequency on primary austenite of GCI: (a) 0 Hz, (b) 35 Hz, (c) 50 Hz, (d) 100 Hz

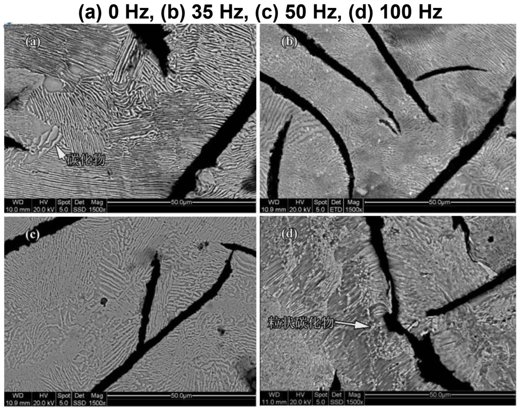

Figure 3. Effect of vibration frequency on matrix structure of GCI: (a) 0 Hz, (b) 35 Hz, (c) 50 Hz, (d) 100 Hz

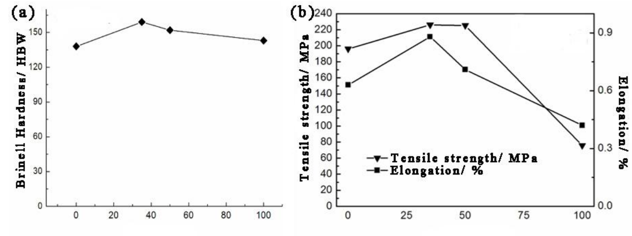

Figure 4. Effect of vibration frequency on mechanical properties of GCI: (a) Brinell Hardness, (b) Mechanical property

2.Effect of amplitude on matrix structure of GCI

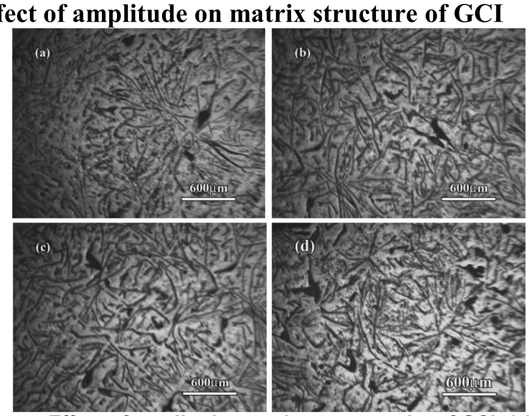

Figure 5. Effect of amplitude on primary austenite of GCI: (a) 0.75 mm, (b) 2 mm, (c) 3 mm, (d) 4 mm

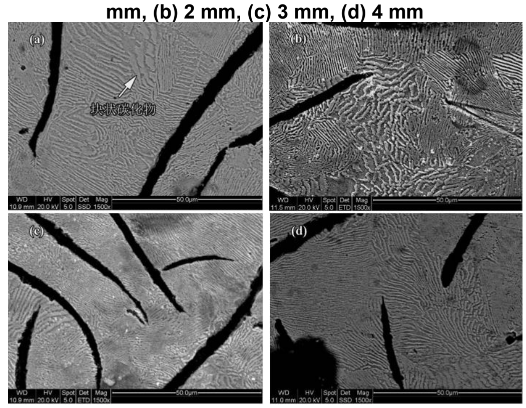

Figure 6. Effect of amplitude on matrix structure of GCI: (a) 0.75 mm, (b) 2 mm, (c) 3 mm, (d) 4 mm

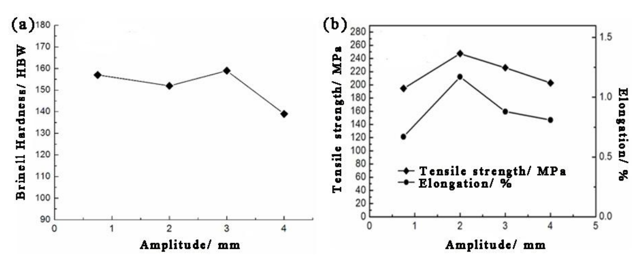

Figure 7. Effect of amplitude on mechanical properties of GCI: (a) 0.75 mm, (b) 2 mm, (c) 3 mm, (d) 4 mm