TSINGHUA SCIENCE AND TECHNOLOGY
ISSN 1007-0214 06/20 pp147-151
Volume 13, Number 2, April 2008

Effect of Slope Plate Variable and Reheating on the Semi-Solid Structure of Ductile Cast Iron

M. Nili-Ahmadabadi**, F. Pahlevani, P. Babaghorbani

School of Metallurgy and Materials Engineering, University of Tehran, Tehran 11155-4563, Iran

Abstract: Semi-solid metal casting and forming is a promising production method for a wide range of metal alloys. In spite of many applications for semi-solid processed light alloys, few works have reported on the semi-solid processing of iron and steel. In this research, an inclined plate was used to change the dendritic structure of iron to globular. The effects of the length and slope of the plate on the casting structure were examined. The results show that the process effectively changes the dendritic structure to globular. A sloped plate angle of 7.5° and length of 560 mm with a cooling rate of 67 K • s^{-1} gave the optimum graphite nodularity and solid particle globularity. The results also show that the sloped plate more easily prevents inoculant fading since the total time processing is rather short. In addition the semi-solid ductile cast iron prepared using the inclined plate method was reheated to examine the effect of reheating conditions on the microstructure and coarsening kinetics of the alloy. The solid fractions at different reheating temperatures and holding times were used to find the optimum reheating temperature range.

Key words: ductile cast iron; semi-solid; reheating; thixo-forming

Introduction

Semi-solid processing involves alloys with non-dendrite microstructures that contain spherical solid particles in the liquid matrix[1,2]. The process was invented in 1971 and developed industrially in 1996 to meet the automotive industry's needs for durable, safe, and low density parts formed by pressure die casting[3,4]. Most initial research has focused on alloys with low melting points, with several recent studies with alloys having higher melting points[5-8].

In comparison with die casting and other traditional casting methods, this method has better mechanical properties and reduces the porosity due to the reduced volume reduction and the more homogeneous filling of the mould[9]. Mechanical properties of these products can be equivalent to properties of forged products with the ability to form more complicated shapes.

The dendritic structure and the microporosity are intrinsic to solidification of ductile irons. Therefore, semi-solid processing seems to be the proper solution to improve the ductile iron structure and the mechanical properties. In addition, semi-solid processing of ductile iron may more easily produce near net shape and thin section parts.

Semi-solid processing is generally divided into three main steps[10] of feedstock manufacturing, reheating, and forming. Various methods, such as strain-induced metal activation, isothermal treatment, and casting using a sloped plate, are used to produce feedstock for thixo-forming[11-13].

The sloped plate method is a new method for applying shear stress to produce semi-solid castings with globular structures. In this method, molten metal with a suitable superheat is cast into the mould after flowing

Received: 2007-06-10
** To whom correspondence should be addressed.
E-mail: nili@ut.ac.ir

down a sloped plate. Solid nucleation occurs because of the heat transfer between the melt and the sloped plate. The nucleated particles then detach from the surface as a result of the shear stress and melt flow. The particles are then distributed into the melt. In the sloped plate method, the parameters such as the superheat, sloped plate length, mould materials, slope, and the sloped plate's materials all affect the final microstructure.

Reheating is used to provide a semi-solid state with an accurately controlled solid fraction and fine spherical particles uniformly dispersed in the liquid matrix prior to forming. The driving force is the reduction of the interfacial energy between the solid and liquid phases in a diffusion-controlled process[14]. The temperature and holding time are two key factors controlling the microstructure during reheating[15-19]. The reheating temperature controls the solid fraction in the slag. The fine uniform globular microstructure is achieved by minimizing the temperature difference between the center and the surface of the work piece[20].

This paper studies the effect of reheating of the ductile iron ingot prepared using a sloped plate on the final microstructure as a function of the various casting and reheating conditions.

1 Experimental Procedure

Cast iron with the chemical composition shown in Table 1 was prepared in a medium frequency induction furnace with a 20-kg clay-graphite crucible. The sandwich method spheroidization process was performed by the addition of 2.5% Fe-Si-Mg and 0.4% Fe-Si as post inoculants.

Table 1 The cast iron chemical composition (%)

C	Si	S	P	Mn	Ti	Mg	Fe
3.60	2.68	0.007	0.017	0.89	0.01	0.04	Balance

A 600 mm×150 mm×10 mm copper plate was used to study the effect of the sloped plate technique on the structure of the semi-solid ductile irons. The plate was coated with boron nitride to prevent adhesion between the alloy and the plate. The melt at about 1260˚C was cast on the plate, arranged to provide for different lengths and angles. The melt was then quenched in a water and steel mould 90 mm in diameter and 160 mm in height.

For the reheating, samples were cut from alloys prepared using the optimum processing conditions (contact length and slope of the inclined plate). The samples were reheated in a resistance furnace with a controlled atmosphere. The reheating temperatures ranged from 1140 to 1165℃ for 3 to 20 min holding time.

A Nikon optical microscope equipped with a Buehler Omnimet image analyzer was used to study the volume fraction and morphology of the solid particles from both processes.

2 Results

2.1 Semi-solid casting

By increasing the plate angle of a constant length plate, the applied stress increases as the duration of the applied stress and the solid fraction decrease. Therefore, for a constant plate length the solid globularity should be a function of the sloped plate angle. Figures 1-3 show the morphologies for various plate angles of semi-solid melts for a fixed plate length (L=560 mm) after 10 min reheating.

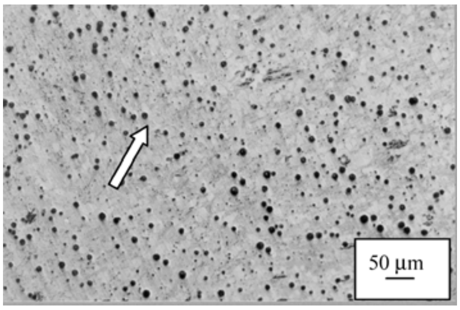

Fig. 1 Microstructure of specimen prepared with a sloped plate angle of 20˚. The arrow shows a solid particle.

Figure 1 shows that with a plate angle of 20˚, the dendritic structure is changed into a structure of mixed spheoidal and irregular shaped solid particles that are heterogeneously distributed. The results with this slope angle imply that the applied stress is enough to change the dendritic structure but that the stress application time is not enough to achieve a homogenously distributed globular structure. For a small plate angle (5˚), Fig. 2 shows that the solid particle distribution is quite homogeneous, but the particles exhibit a range of irregular shapes.

Figure 3 illustrates that for a plate angle of 7.5˚, the solid particles are uniformly distributed with uniform