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Effects of applied pressure on microstructure and mechanical properties of squeeze cast ductile iron

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ABSTRACT

In this study, the effects of applied pressure during solidification on the microstructure and mechanical properties of cylindrical shaped ductile iron castings were investigated. Magnesium treated cast iron melts were solidified under atmospheric pressure as well as 25, 50 and 75 MPa external pressures. Microstructure features of the castings were characterized using image analysis, optical microscopy, scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) techniques. Tensile properties, toughness and hardness of the castings were also measured. The results showed that average graphite nodule size, free graphite content and ferrite content of the castings decreased and pearlite and eutectic cementite contents increased as the applied pressure was raised from 0 to 75 Mpa. Graphite nodule count was first increased by raising the applied pressure up to 50 MPa and then decreased. The highest graphite nodule count was obtained at 50 MPa applied pressure. The microstructural changes were associated with the improved cooling rate and the expected changes in the corresponding phase diagram of the alloy under pressure. The ultimate tensile strength (UTS), yield point strength (0.2% offset) and fracture toughness of the castings were improved when the applied pressure was raised from 0 to 50 MPa. Further increase of the applied pressure resulted in slight decrease of these properties due to the formation of more cementite phase in structures as well as reduced graphite nodule count. Hardness of the castings continuously increased with increasing the applied pressure.

1. Introduction

Ductile iron is the most superior member of the cast iron family with interesting combination of mechanical properties both in the as-cast and heat treated conditions. Although development of advanced light and high performance materials such as metal matrix composites once thought to limit ductile iron production, extensive studies over the years to further improve ductile iron properties and to develop new casting practices and strategies have resulted in slimmer designs which has enabled ductile iron to remain in the competition as a central structural material.

One of the techniques used in recent years for production of advanced materials with enhanced mechanical properties is squeeze casting process. The method, sometimes known as liquid forging [1], is a hybrid casting process which combines casting and forging advantages together. Ghomashchi and Vikhrov [2] have reviewed squeeze casting process and stated that squeeze casting products can have superior mechanical properties compared to their conventionally cast counterparts due to sounder inner structure, higher density, finer grain size and more homogenous microstructure. These characteristics are attributed to four factors including: (i) improved heat-transfer between the mold and the casting resulting in higher cooling rates during solidification, (ii) change in the liquidus temperature of the alloy and modification of the corresponding phase diagram, (iii) opportunity for creation of large sudden undercoolings in the melt as a result of (ii), and (iv) reduction of gas and shrinkage porosities formed under pressure in the castings [2].

Recently, some authors have investigated effect of squeeze casting parameters on the microstructure and mechanical properties of aluminum alloys [3,4] and magnesium alloys [7] as well as their composites [5,6,8]. Maleki et al. [3] have investigated effects of squeeze casting parameters such as applied pressure, melt and die temperatures on the macrostructure, density and hardness of LM13 alloy. They also have studied effects of the same squeeze casting parameters on the microstructure of LM13 alloy [4]. They showed that the density of the samples decreased with application of a 20 MPa external pressure but increased steadily for higher applied pressure up to about 106 MPa. As they reported, increasing the applied pressure resulted in smaller primary α phase grain size and reduced secondary dendrite arm spacing (SDAS) and therefore improved hardness. It also modified the eutectic silicon particles [4]. A decrease in the melt or die temperature rendered similar effects on the macrostructure and hardness of the samples [3,4].

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