Squeeze Casting-Influence of Squeeze pressures on Das and other related properties

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Abstract

Squeeze casting is a hybrid process combining the advantage of both casting and forging. It is established that squeezed casting technique improves the properties of the castings. Dendritic arm spacing has profound influence on all the mechanical properties of material like hardness, tensile strength, ductility and toughness. Dendritic arm spacing is the distance between the adjoining arms of dendrites. In this study, Al-Si-Cu alloy (LM4) has been considered and cast at various squeeze pressures. Toughness test, hardenness test, ultimate tensile strength test and DAS values were conducted on the obtained castings. It was noted that mechanical properties increase or decrease corresponding to DAS values.

Keywords: Squeeze casting, hybrid process, dendritic arm spacing, tensile strength, squeeze pressures.

Introduction

Squeeze casting fits in the general category of casting as a manufacturing process (Khanna, 1996; Heine et al., 1996). Casting has been around for approximately 6000 years, so squeeze casting is a relatively new development; being introduced along with other pressurized casting techniques during the mid 1800’s. The squeeze casting process uses an accurately measured or metered quantity of molten metal which is poured into a heated mould via a launder. The mould is closed to produce an internal cavity in the shape of the required component. Molten metal is forced or displaced into the available space of the die cavity. As with most casting processes, using a permanent pattern, the mould is coated with a suitable release agent and for squeeze casting it is usually in the form of a graphite coating. Pressure continues to be applied to the molten metal until it has solidified and forms the required component. The press is then withdrawn and the component is ejected. Squeeze casting is most suited to the production of light alloy components in large production quantities. Retractable and disposable cores can be used to create complex internal features.

Squeeze casting process originated in Soviet Union and it was subsequently developed in United States, Europe and Japan. The service life of a cast component is determined by the micro-structural distribution throughout the casting, especially in those regions that are critically stressed. In the drive toward light weight vehicle production, the description and prediction of the microstructure in shape castings has become important. This is because the microstructure length scales are required in the mechanical property models used for design optimization. The use of predictive property models are critical due to the need to replace heavy ferrous parts with aluminum alloy castings and the limited experience base in the use and long term performance of aluminum alloy castings (Midson and Brisson, 1997; Liu et al., 2011). The development of the solidification microstructure in aluminum alloys is well documented in the literature (Taylor, 1995; Rao, 1998; Brabazon et al., 2002). On cooling, Al-rich dendrites first precipitate from the melt. A eutectic constituent, comprising of Al-rich and silicon phases, then grows between the aluminum rich dendrite networks. The morphology of the silicon phase is either rod-like or plate like depending on whether the melt has treated with modifiers such as sodium or strontium. An aluminum grain consists of six primary dendrite arms. Primary dendrite arm contains of a number of secondary dendrite arms that are almost perpendicular to the primary dendrite arm. The silicon phase is distributed randomly in the eutectic, in order to describe the morphology of the primary aluminum-rich phase; we need the primary dendrite size (spacing), d1, and secondary dendrite arm spacing, d2 and dendrite cell spacing. The dendrite cell spacing is defined as the average length intersecting dendrites using random lines. Dendrite cell spacing is a useful parameter as it can be conveniently measured by image analysis techniques.

Fig. 1. Typical metal dendrite.
Dendrite arm spacing: Basically the temperature of the molten metal falls, a point is reached where the metal starts to solidify. At this point, the atoms change from a disordered or amorphous state to an ordered or crystalline state. Once the nucleus of the crystal forms, it provides a solid/liquid interface where crystallization can be produced. As the crystal grows on these nuclei, it tends to develop spikes and changes into a 'tree-like' shape called dendrite (Greek dendron = a tree). Figure 1 shows a typical metal dendrite.

The dendritic crystal grows until the spaces between the branches fill up. Growth of the dendrite ceases when the branches of one dendrite meet those of an adjacent dendrite and eventually the entire liquid solidifies. At this point, there is a little trace of dendrite structure left and it is only possible to see the grains into which the dendrites have grown. The dendrite arm spacing, which is the average intercept of a random line intersecting dendrites, is a useful parameter for image analysis. This is because in many cases the primary dendrite size and secondary dendrite arm spacing are not easily measured. The basic microstructural feature for the Al-rich primary phase consists of randomly distributed secondary arms.

LM4 Aluminium alloy: This alloy conforms with British standards 1490 LM4 and is similar to the obsolete specifications BS.L79 and D.T.D 424A. Castings may be in the cast (M) of fully heat treated (TF) conditions.

Casting characteristics fluidity: Of a moderately high order intermediate between Al-Si and Al-Cu alloys.

Pressure tightness: Suitable for leak tight castings.

Hot tearing: Its resistance to hot tearing is superior to that of most Al base casting alloys except the Al-Si type.

Typical pouring temperature (720°C): The actual temperatures employed may range considerably above or below this value and will depend upon the particular for each casting.

Application and general notes: Suitable for most general engineering purposes including crankcase, junction boxes, gear boxes, clutch case, switch gear covers, instruments cases, tool handles and where moderate mechanical properties are desirable. Its casting characteristics permit it to be used for the production of moderately thin forms and also for castings required to be pressure tight. In the heat treat state, it may be used for castings required to maintain a relatively high static loading. LM4 is equally suitable for the production of sand and permanent mould castings. It can be die cast but the higher silicon alloys such as LM2 and LM24 are generally to be preferred.

Against these backdrops, this study was aimed with the following objectives:
- Design and fabrication of an experimental setup to carry out the squeeze casting process.
- To cast a product by squeeze casting method.
- To analyze the influence of squeeze pressure on DAS and other related properties.

Materials and methods

Fabrication of die: The material used for the fabrication of die is high carbon high chromium steel. The purpose of the die is to produce the required shape of casting.

Fabrication of punch: The material used for the fabrication of the punch is high carbon high chromium steel. Here, the purpose of the punch is to apply the required pressure for casting the material.

Fabrication of ejector: The purpose of ejector is to eject the component after from the die by applying very minimum amount of load.

Fabrication of fixture: The purpose of the fixture is to hold the die firmly under various pressures.

Experimental setup: A metallic mould made of die steel is firmly seated over the fixture (Fig. 2). The die and the punch are fixed in the universal testing machine and are bolted properly. Here, the punch is fixed to upper arm of universal testing machine and die is bolted to the fixture by mean of pressure pads. Ejector is positioned correctly on the die, so that the casted component can be removed very easily.

Experimental work: Taking usual precautions, LM 4 alloy has been melted in a crucible furnace and degassed. The temperature of the molten metal has been maintained at 800°C before pouring into the die. The die has been preheated to 250°C, a die coat applied and the pressure is applied as soon as the metered quantity of molten metal is poured into the die. The pressure is maintained constant until all the metal in the die solidifies. This has been repeated for various values of pressure ranging from 0-120 N/mm in steps.
Preparation of specimen: The small pieces of casts are taken from the each mother cast for preparation of specimen to analyzing a DAS value. These specimens are prepared by the following step:
1. Grinding the specimen
2. Mechanical polishing
3. Chemical etching.

Results and discussion
Figure 3 shows the influence of squeeze pressure on DAS value. It is seen that in the unmodified condition, the squeeze pressure has a strong influence on the DAS value i.e., the decrease drastically from 17.05 microns, to 10.45 microns, when the pressure varies from 0 to 112 N/mm². Squeeze pressure has a direct influence on toughness of the material. It is seen from Fig. 4 that hardness of the material goes on increasing as the squeeze pressure increases. Squeeze pressure has a direct influence on tensile strength of the material. It is seen from Fig. 5, tensile strength of the material goes on increasing as the squeeze pressure increases. Squeeze pressure has a direct influence on toughness of the material. It is seen from Fig. 6 that the toughness of the material goes on increasing as the squeeze pressure increases.

Conclusion
The more useful and one of the important alloys known as LM4 Aluminium alloy has been analyzed by various aspects through its microstructure with the help of DAS values. The dendritic arm spacing values were determined for various pressures and this causes the changes in the properties like tensile strength, hardness and toughness. From the study, it can be concluded that the properties of the material are influenced by DAS which is mainly decided by the squeeze pressure.

References