Effect of parameters on squeeze cast component – A review paper

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Abstract

Squeeze casting is the mixture of the casting and forging process that can be done by applying high pressure during melt slurry solidification. For better mechanical properties squeeze casting process parameters plays important role. These parameters are squeeze pressure, melting temperature, reinforcement pre-heating temperature, reinforcement wt%, die preheating temperature, die material and pathway preheating temperature. Squeeze pressure play a wide role for determining the mechanical properties. Applied pressure timing on the solidification of molten metal can change melting point of alloys which improve the solidification rate. Squeeze pressure also refines the micro and macrostructure; it is helpful to minimize the entrap gas, shrinkage and porosities of the casts component. This paper overlooks the importance of squeeze casting of the Aluminium based Metal Matrix Composites in all aspects for better mechanical properties.

I. Introduction

A composite material is defined as a combination of two or more materials with different chemical and mechanical properties that are not soluble in one another. The matrix phase is Aluminum alloy and reinforcement phase is hard ceramic particles. The matrix phase transfers load and supports the integrity of the structure while the particle phase provides the enhanced mechanical properties of the composite. Excellent mechanical and thermal properties enable composites to be utilized in a wide range of applications, such as automotive, aerospace, oil and gas, etc. Characteristics such as a high strength-to-weight ratio, high modulus-to-weight ratio, good damage tolerance, acceptable fatigue life, and corrosion resistance are highly anticipated in these applications and many of them can be uniquely achieved through utilization of composites.

Metal matrix composite (MMC) are used in engineering applications due to its superior mechanical properties. MMC's are reinforced with particles fiber, whisker and particulate. The size of particulates used is classified as micro, nano and macro. The particulate reinforced MMC's have excellent formability compared to fiber and whisker composite. MMC's reveal outstanding wear, heat resistance and better mechanical properties. Reinforcement improves the hardness, tensile strength, low coefficient of friction and good thermal shock resistance. Now a day the MMC's are used in defense, marine, automobile and aerospace industries due to their superior properties. Fabrication technique plays an important role in distribution of reinforcement [1]. There are many fabrication routes available. The selection of right fabrication route despites the homogenous distribution of ceramic particles and dimensional tolerances. Squeeze casting route is advantageous due to less shrinkage, porosity, closer dimensional tolerances, less cycle time, good quality product, precise shape and better surface finish.

Squeeze casting is a relatively new and developing casting process. Squeeze casting is simple and economical, efficient in its use of raw material, and has excellent potential for automated operation at high rates of production. The process generates the highest mechanical properties attainable in a cast product. The micro structural refinement and integrity of squeeze cast products are desirable for many critical applications. It is suitable for high strength, high ductility, lightweight structural aluminum castings needed for advanced components [1]. A major market is the automotive market which is increasingly demanding lightweight components to improve fuel efficiency. Because squeeze casting is relatively new, much work needs to be done to better understand the fundamentals of the process. In particular, the relationships between the design, the processing parameters, and the integrity of the squeeze cast parts are still to be understood well. Squeeze Casting is a combination of the processes of forging and casting.

II. Literature Review

Almir Kazuo et al. [2] suggested that the temperature distribution in the tool might be obtained by using information about the changes in the hardness and microstructure of the steel tool. It is necessary to calibrate the hardness of the tool against the temperature and time of heating and samples of structural changes at corresponding temperatures. These methods permit measurement of temperatures to an accuracy of ± 25 0C within the heat-affected region. Miller et al [3], developed Experimental techniques using modern, digital infrared imaging and successfully applied them during this study to gather cutting tool temperature distributions from orthogonal machining operations. Abhang L.B. et al. [4], worked to measure the tool-chip interface temperature experimentally during turning of EN-31 steel alloy with tungsten carbide inserts using a tool-work thermocouple technique. Average chip-tool interface temperatures have been experimentally studied using the tool work thermocouple technique. It has been observed that increasing cutting speed, feed rate and depth of cut lead to an increase in cutting temperature. Federico M. Aneriro et al. [5], Investigated the influence of cutting parameters (cutting speed, feed rate and depth of cut) on tool temperature, tool wear, cutting forces and surface roughness when machining hardened steel with multilayer coated carbide tools. A standard K-type of thermocouple inserted near the rake face of the tool was used to measure the interface temperatures. They concluded that the temperature near the rake face increases significantly when the depth of cut changes from 0.2 to 0.4 mm. The increase in contact length between chip and rake face could be responsible, since it grows, together with uncut chip cross-section.

Lowen and Shaw et al. [6] developed analytical prediction model for the measurement of cutting temperature during machining. They concluded that the cutting temperature is the function of cutting speed and feed rate. θt = V 0.5 x t 0.3 Where, θt = Average cutting temperature V = cutting speed t = un-deformed chip- thickness or feed rate.

Stephenson [7] suggested that the temperature distribution in the tool might be obtained by using information about the changes in the hardness and microstructure of the steel tool. It is necessary to calibrate the hardness of the tool against the temperature and time of heating and samples of structural changes at corresponding temperatures. These methods permit measurement of temperatures to an accuracy of ± 25 0C within the heat-affected region.

Sullivan et al. [8] measured the machined surface temperatures with two thermocouples inserted into the work piece when machining aluminum 6082-T6. The results indicated that an increase in cutting speed resulted in a decrease in cutting forces and machined surface temperatures. This reduction in temperature was attributed to the higher metal removal rate that resulted in more heat being carried away by the chip.

S.K. Chaudhary et al. [9] predicted cutting zone temperatures by natural tool work thermocouple technique, when machining EN 24 steel work piece and HSS with 10% cobalt as the cutting tool. The results indicated that an increase in cutting speed and feed rate resulted in an increase in tool wear and cutting zone temperature increases with the increase in the cutting speed. While in the whole range of feed the temperature increases with increase in feed rate. Huda et al [10] developed a technique for measuring temperature at the interface between a cutting tool and a chip using two-color pyrometer with fused fiber coupler for the temperature measurement of the tool-chip interface in dry and wet turning. H.Ay and Yang [11], used a technique with K thermocouple to analyze temperature variations in carbide inserts in cutting various materials such as copper, cast iron aluminum 6061 and AISI 1045 steel. They observed oscillations in temperature near the cutting edge, which were more marked for ductile materials and less in the hard machining materials. These observations were attributed to the chip formation and its contact with the work material.

Kashiway and Elbestawi [12] investigated the effect of cutting temperature on the integrity of machined surface. It has been shown that cutting temperature has a major effect on the integrity on the machined surface. The undesirable surface tensile residual stresses were attributed to the temperature generated during machining. Therefore, controlling the generated tensile residual stresses relies on the understanding of the effect of different process parameters on the cutting temperature.

B. Findes, et al [13], studied the influence of cutting speed, feed rate and depth of cut on cutting pressures, cutting force and on cutting temperature, when machining AISI H11 steel treated to 50 HRC work piece material with mixed ceramic tool. The results show that depth of cut has great influence on the radial cutting pressure and on cutting force. The cutting pressure and cutting force increase with an increase in depth of cut and feed rate. It was found that increase in cutting speed increases cutting zone temperature rapidly.

W. Grzesik [14], His work related to create a FEM simulation model in order to obtain numerical solutions of the cutting forces, specific cutting energy and adequate temperatures occurring at different points through the chip/tool contact region and the coating/substrate boundary for a range of coated tool materials and defined cutting conditions. Results showing how the tool chip interfacial friction influences the temperature distribution fields as the effect of using coated tools are the main. A good agreement was achieved, especially for uncoated and three-layer coated tools, between predicted and experimental values of cutting temperatures.

W. Grzesik, M. Bartoszuk et al. [15], the aim of this study was to create a FEM simulation model in order to obtain numerical solutions of the cutting forces, specific cutting energy and adequate temperatures occurring at different points through the chip tool contact region and the coating/substrate boundary for a range of coated tool materials and defined cutting conditions.

III. Process Parameters involve in Squeeze casting

3.1 The die, die temperature and melting temperature

A most critical phase in squeeze casting is the die itself and also the design of the die as well as the selection of appropriate die material, the manufacturing method, suitable heat treatment and the preservation practice. Squeeze casting dies are showing to severe thermal and mechanical cyclic loading, which may origin thermal weariness, cracking, erosion, corrosion, and notch. The life and features of a die are greatly depends on alloy to be cast. Currently H13 tool steel is a widely used material of die but generally die steels should have better hot hardness, higher temper resistance, enough toughness and especially a higher degree of cleanliness and uniform distribution of particles.

Fig 1 characterizes the various authors' selections of melting temperature and Die preheating temperature for squeeze casting of Aluminium alloy/Composites. It may be conclude that the optimum range for melting temperature in squeeze casting process can be 600°C - 700°C, and the die temperature range can be around 250°C for better mechanical properties.

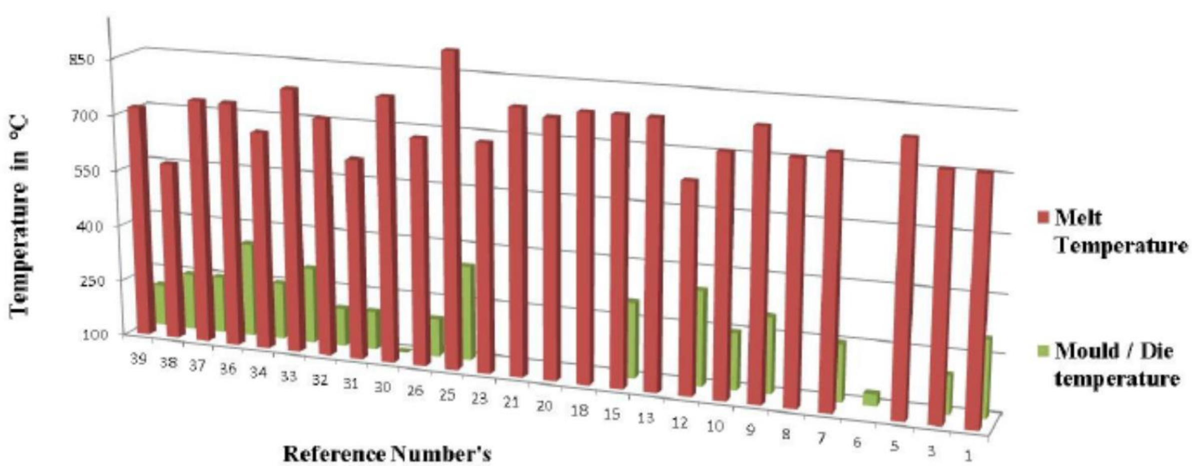

Fig.1 Melting temperature and Die temperature for Squeeze Casting [16]

When the melting temperature was lowered (680°C) the macrostructures gradually became finer, and the grains became smaller as the temperature increases in the range of 780 to 730°C grains become large.

However, further decrease of the melting temperature to 630°C results in the formation of very fine and uniform grains. For the squeeze casting of the aluminium alloy, the better melting temperature to use was either 690 or 660°C; the former would give a better property at the top of the casting while the latter, at the bottom of the casting [16].

3.2 Timing of pressure application

Although squeeze casting is observed as the pressurization of molten alloy, it may also be used for shaping semi-solids and therefore, a further classification may be predicted as: (i) before the starting of crystallization, and (ii) after the starting of crystallization, which may also be described as semi-solid pressurization.

3.3 Reinforcement particle sizes

The strength of the composites increased as the reinforcement particle size was reduced for the same quantity fraction of SiCp. The smaller particle will provide more interfacial region, which provides as the nucleation spot for grain formation. When the particle size is minor, the spacing between the particles is reduced. The smaller particles will apply more constraint on grain growth during cooling, and more constraint on plastic flow during deformation, which can also contribute to the increase in strength of component [16]. An increased filler fraction can be acquired, by mixing particles that have a proper particle size distribution, because fine particles can pack additional efficiently around better ones. Even a very higher packing fraction of more than 90% could be achieved by mixing the suitable volume fraction of different particle sizes, that differed by several orders of magnitude.

As shown in Fig 2, the collection of the refinement particle grain size (SiCp) in μm for squeeze casting of Aluminium composites was significant, from which the most favorable reinforcement particle grain size of SiCp in the range of 15–30 μm was considered for squeeze casting. This is due to the higher particle size which decrease the nucleation sites during solidification, and a weaker interfacial bond strength which develop into the crack initiation site in the composites.

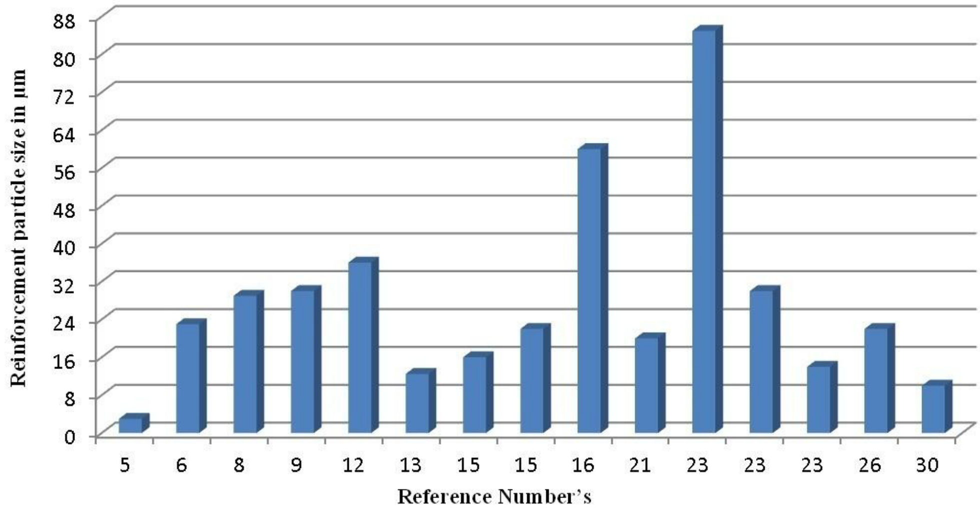

Fig.2 Reinforcement particle size for Squeeze Casting [16]

Conclusion

A large number of publications on the squeeze casting route indicate that it is still being developed successfully. The popular of publications are associated to aluminium- and magnesium-based alloys and particularly their respective metal matrix composites. The process parameters play a wider role in determining the mechanical properties of cast components. Thus it may be true to say that the main propensity of the progress of the squeeze casting process, equipment and alloys. It has been linked to the fabrication route of advanced materials, particularly in the field of Al- and Mg-based alloys, and metal matrix composites. The introduction of hard ceramic particles into the soft Al alloy improved the overall mechanical properties of composites. The density, hardness and tensile strength of composites increased on increasing the weight fractions of reinforcements.

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