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Squeeze Casting of Aluminium Metal Matrix Composites- An Overview

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Abstract

Squeeze casting is the combination of the casting and forging processes that can be done with help of high pressure when it is applied during melt solidification. Applying pressure on the solidification of molten metal could change melting point of alloys which enhances the solidification rate. Moreover it refines the micro and macrostructure; it is helpful to minimize the gas and shrinkage porosities of the castings. This paper stresses the importance of squeeze casting of the Aluminium Metal Matrix Composites in all aspects: squeeze pressure, casting (melt)/ preform preheat/ die temperature, solidification rate, reinforcement particle sizes, porosity and mechanical properties.

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Keywords: Squeeze casting; Aluminium metal matrix composite; mechanical properties.

1. Introduction

Composite materials are gaining wide spread acceptance, due to their characteristic behavior and high strength-to-weight ratio. Of these Aluminium metal matrix composites are finding increased applications, because of their improved mechanical and tribological properties. The fabrication techniques of MMC's play a major role in the improvement of the mechanical and tribological properties [27, 28]. Among the available casting techniques, squeeze casting has the following major advantages: (i) the parts produced are without gas porosity or shrinkage porosity; (ii) feeders or risers are not required, and therefore no metal wastage occurs; (iii) alloy fluidity (castability) is not critical in squeeze casting, as both common casting alloys and wrought alloys can be squeeze cast to finished

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shape with the aid of pressure, and (iv) squeeze castings can have mechanical properties as good as wrought products of the same composition [20]. Squeeze casting is an attractive processing method for producing Aluminium MMC's as they exhibit better mechanical properties due to the presence of fewer common defects such as porosity and shrinking cavities, and the elimination of segregation of the reinforcement [5, 17]. Squeeze casting employs low die filling velocity, with minimum turbulence and high-applied pressure, to produce good quality products [40]. There are two different forms of squeeze casting, i.e., direct SC and indirect SC. In the direct squeeze casting process, the pressure is applied on the entire surface of the liquid metal during solidification by a punch, which produces castings of full density. In the indirect squeeze casting process, the metal is injected into the die cavity by a small diameter piston [24]. In the casting of metal matrix composites, the dispersion of the reinforcement particles within the matrix plays an important role in achieving the desired properties in the material [6]. The wettability of the reinforcement particles in molten metal is improved by applying high pressures during casting [15].

1.1 *Squeeze Pressure:*

In squeeze casting, the applied pressure improves the wettability and the bonding force between the Al alloy/SiCp [15, 26]. The applied pressure has an undercooling effect which, together with the loss of heat through the dies, favours rapid solidification. The high pressure also discourages the nucleation of gas bubbles [29]. The high pressure further reduces the size of the gas bubbles, but may be absorbed into the solution and disappear in a bubble free casting. Applied pressure on primary α phase can decrease the grain size and secondary dendrite arm spacing (SDAS). The pressure is applied to gain the largest melt undercooling, so that the nucleation rate can be increased exponentially when the melt temperature in the die was lower than the liquidus temperature. When the higher cooling rate and large undercooling effect are applied on melt there would be expected refinement change in structure of the squeeze cast samples. There are two core constituents in the microstructure of squeeze cast sample. At first, it has α phase identified as light dendritic areas; next the darker areas shown in micrographs due to the effect of a eutectic matrix of the α phase and silicon particles. Following Fig.1 shows of the main two constituents in the microstructure of each sample include a primary α (Al rich) phase seen as light dendritic areas, and a eutectic matrix of the α phase and silicon particles seen as darker areas in the micrographs. Closer views of the eutectic regions of the samples are shown in Fig.1, where the changes in the morphology of the eutectic silicon particles on increasing the applied pressure can be easily recognized [3]. Due to the undercooling, the contact time between the reinforced particles and the molten aluminum was shortened, and this decreased the possibility of interfacial reactions [5]. For both the Al alloy and the composites, a squeeze pressure of the order of 100 MPa is found to be sufficient to get the microstructural refinement, to reduce these porosities, and obtain a complete contact between the metal and the die surface.

Table1. Summary of author's conclusion on optimum selection of squeeze pressure

SI. NO	Material-Alloy/Composite	Reinforcement Particle Size	Optimum Pressure (Mpa)	Time Duration (Sec)	Reference Number's
1	LM 6		140 MPa		14
2	LM 13		100 MPa		3
3	LM 13		100 MPa		31
4	LM 25		100 Mpa	60 Sec	32
5	5083 Al		100 Mpa		33
6	Al–Zn–Mg–Cu alloy		160 Mpa	120 Sec	34
7	SiC/Gr/Al, Alloy: 2024 Al	SiC : 3μm &40% Gr : 3%, 5%, 7% & (1,6,10,20,70 μm)	100 MPa	180 Sec	5
8	Al 2124 alloy & Al 2124-10%SiC_p	SiC :23μm	100 MPa	120 Sec	6
9	Al_2O_3/A356	Al_2O_3	100 MPa	180 Sec	30
10	a) Al-15%SiC_p b) A 356/SiC_p	SiC_p	100 MPa	30 Sec	26