Squeeze Casting Fabrication Process Importance for MMC Fabrication- A Review

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***Abstract:*-Squeeze casting is a under pressure solidification route whose beginning in Russia dates back over a hundred years. Squeeze casting gives the properties of casting as well as forging. The process has recently been commercialized in Japan for automotive wheels," and considerable development appears to have been made in the United States towards squeeze-cast diesel engine pistons. This paper reviews recent progress in developing and applying squeeze casting for MMC manufacturing. Process parameters play important role for achieving better mechanical properties. Squeeze pressure plays a primary role and melt temperature plays secondary for achieving better mechanical properties.**

***Keywords:* - MMC, Squeeze casting, Mechanical properties**

I. INTRODUCTION

The automotive and aerospace industries have been driving research communities to search for materials with improved mechanical properties and new casting processes [28].Conventional casting process cannot produce parts as strong as forged parts. The major drawback of casting processes is the formation of casting defects such as porosity, segregation, hot tears etc. [29]. A distinctly different approach to component making is possible with squeeze casting, an emerging metal forming process. The major advantage of this process is its ability to eliminate micro-porosity to provide isotropic properties and minimize component machining [31]. This process has been applied on a wide range of metals, ranging from low melting alloys of lead and zinc to high melting alloys of iron and nickel.

Metal matrix composites (MMCs) have made in useful properties of metals and alloys with regards to the traditional way of alloying and heat treatment. Metal matrix composites content discontinuous whiskers or particulates dispersed in a metallic alloy matrix. These reinforcements with properties not achievable in monolithic alloys (Rohatgi 1993). There are wide applications of matrix composites. It offers several important applications in every industries so when it is in comparison to metals, MMCs have better level of resistance, higher strength-to-density ratios, better mechanical properties, high thermal conductivity, lower coefficients of thermal, good damping characteristics, overall flexibility in design and excellent wear properties. MMCs will vary from materials in lots of ways. The use of solid composites is large in India especially in regions of energy, transport, electromechanical equipment. The comprehensive use of composites helps in conserving energy, materials, and in minimizing environmental air pollution. Since cast aluminium-graphite particle composites were first synthesized in 1965, metal matrix composites have been progressing significantly.

Stirring and pressure infiltration have surfaced as major techniques to make composites. Furthermore, Aluminium or its alloy matrix composites well-liked by all metal matrix composites and are necessary for many engineering applications. According to to Surappa (2003), Aluminium or its alloy Matrix Composites (AMCs) has {the next} major advantages {when compared with} unreinforced materials:

- Higher strength
- Reduced density (less weight)
- Thermal shock resistance
- Enhanced electrical performance
- Improved {scratching} and wear resistance
- Improved stiffness
- Improved high temperature properties
- Controlled coefficient of thermal expansion
- Control of mass (especially in reciprocating applications)
- Improved damping capabilities.

There's a demand for usage of aluminium matrix composites in every sectors due to its better performance, economical and environmental benefits. There is an interest for use of a aluminum based Metal matrix composites in all areas due to its better execution, financial and ecological advantages. Accentuation on improved mileage and stringent ecological guidelines makes aluminum based Metal matrix composites increasingly attractive in transport part. In transportation part, aluminum based Metal matrix composites are requested for lower fuel utilization, lower airborne discharges and less commotion. MMCs contend with plastics, pottery, keen amalgams, and updated steel parts in different car and aviation applications.

Vortex or stir casting is the most commonly used method to produce composite particulates. This is mostly due to its simplicity, low production cost and flexibility to produce a wide range of MMC's. Addition of hard ceramic particles into a ductile metallic matrix results in the production of composites that possess the properties of both phases [2-4]. Many researchers have been done to study the effects of such second phases as SiC [5, 6], TiB_2 [7], Al_2O_3 [8], and B4C [9] on reinforcing the aluminum matrix. All reports emphasize the positive effect of these materials on enhancing the mechanical properties of the resultant composites. Zirconia is a refractory material with melting point of about 2680oC. ZrO_2 possesses good properties such as the low coefficient of thermal expansion, good thermal shock resistance, high melting point, low thermal conductivity, and excellent thermodynamic stability. Its density, Young's modulus, and hardness are 5.76 g/cm3, 190 GPa, and 1200 HV, respectively [10-14]. Production of Al- ZrO_2 composites by stir casting is associated with problems such as low wet ability of ZrO_2 by molten Al and a higher density of ZrO_2 compared to that of Al, which results in deposition and therefore non-uniform distribution of ZrO_2 particles. Based on the reasons mentioned above, at the time of this investigation, no successful production of Al-ZrO_2 composites via Vortex method has been reported. In the present study, Al-ZrO_2 composites were produced by optimizing the Vortex method parameters such as stirring duration. The effects of ZrO_2 content and casting temperature on the tensile strength of the composites were studied.

II. LITERATURE REVIEW

In recent years, a new casting technology called squeeze casting has been developed to make better use of aluminium alloys. Squeeze casting (as liquid metal forging) is a casting process which solidifies the molten metal under pressure on the closed die positioned between the plates of hydraulic press. Compared with conventional casting methods, squeeze casting possesses many pronounced advantages, such as free shrinkage and gas porosity, to provide components with high integrity with improved mechanical properties. Yue et al. [15] found that the squeeze casting process was an ideal process to produce high quality light metal components with near net shape. Kim et al. [16] stated that squeeze casting accounted for a 15%–40% improvement in mechanical properties from the gravity die casting process. Vijian et al. [17] reported that squeeze casting exhibited remarkable grain refinement and substantial improvement in mechanical properties.

Many research works on squeeze casting parameters of aluminium alloys and magnesium alloys as well as their composites have been reported in the literature. The intensity of applied pressure, the melt temperature and the die temperature have been shown to be among the most important parameters affecting the quality of squeeze cast components [17]. An understanding of the effects of process parameters is particularly important since the mechanical properties of components are related to the microstructure and the casting variables to a large extent. In this regard, Malki et al. [18, 19] have investigated effects of squeeze casting parameters on the macrostructure, microstructure, density and hardness of LM13 aluminium alloy. The results indicated that an increase in applied pressure decreased the grain size and SDAS (Secondary Dendrite Arm Spacing) of the primary α-phase (Al), as well as modifying the eutectic silicon particles and improving hardness. A decrease in the die or melt temperature rendered similar effects on the microstructure, macrostructure and hardness of the as-cast samples [18, 19].

III. SQUEEZE CASTING METHOD

Though the idea of squeeze casting periods back towards 1800 [20]. Till 1931 squeeze casting research was not accompanied [21]. Squeeze casting methods remains mixture of the closed die forging plus gravity die casting. Applied pressure in closed die halves metals has changed to solidifies. The functional pressure then the sudden interaction of melted metal through the die surface generates quick heat transfer that crops a porous free casting by mechanical properties imminent the twisted product. The Squeeze casting technique has various names such as extrusion casting, liquid metal, Squeeze forming. Its offers low operating costs, low shrinking porosity, high metal yield, excellent surface finish. Premium quality castings and higher rates of heat removal through the metal mold boundary are found due to the close interaction among the mold and liquid metal. Squeeze casting process is illustrated schematically in Fig. 1 [20]. The method is essentially separated hooked on two types: indirect and direct method. Squeeze pressure is applied through the die-closing punch this action is direct process, such the Squeeze pressure is applied as after closing die by the secondary ram this method is indirect process, particular feature of the squeeze casting technique over predictable die casting method.

- Squeeze casting method has suitable prospective for critical application due to internal soundness obtained under pressure in solidification process.
- Absence of shrinkage porosity.
- Wrought alloys as well as casting alloys can stay squeeze casting to finish suitable for long freezing alloys too.
- Squeeze casting has earlier cycle times.
- Good dimensional reproducibility is possible with Combination of thin die coatings and high quality of reusable dies, applied corresponding pressure to die is recycled to form the components.
- In squeeze casting has formed forging quality of the components.
- Dimensional precision, extraordinary grade of surface finish, clear shape.

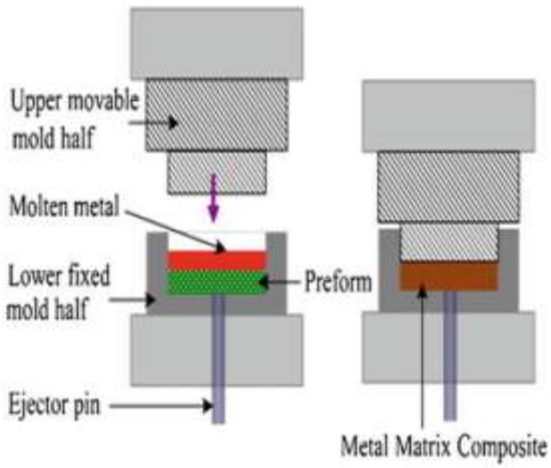

Fig. no.1 Squeeze casting method

Compared the mechanical and microstructure properties, Al-8% SiC particles has fabricated through chill casting, sand casting and squeeze casting methods [22]. Chill and sand casting products has increased in the grain size of microstructure, therefore chill and sand cast used in less quality parts for requiring engineering and non-engineering applications, though squeeze cast yields might remain used in as cast state in industrial requests demanding high excellence parts.

IV. SQUEEZE CASTING PROCESS ADVANTAGES

Gurusamy P. (2015) [23]investigated the effect of melt temperature and die temperature on the mechanical and microstructural properties of the A356 aluminium alloy reinforced with 10 vol.% SiC particles. Preheated ceramic particles were added to the molten metal maintained at a temperature of 750°C and stirred for 10 minutes. Then the slurry is poured in the preheated die. Eight set of specimens of size 50 mm diameter and 150 mm height were fabricated at varying melt temperatures of 750, 800, 850 and 900°C by keeping 400°C as the die temperature value. Like, another eight set of specimens were fabricated for varying die temperatures of 250, 300, 350, 400°C keeping the melt temperature value constant at 800°C. The squeeze pressure was maintained at 100 MPa during the entire specimen manufacturing process. It was concluded that both melt & die temperatures have a significant influence on the microstructure, impact strength, tensile strength and hardness. Also, there was hardly effect on density due to both melt and die temperatures. The particles distribution is more uniform, and the resultant mechanical properties improve when the melt and die temperature are at 850°C and 350°C, respectively. The microstructure was found to be uniform for the corresponding processing condition.

Ali Kalkanli & Sencer Yilmaz (2008)[24] investigated the squeeze casting of aluminium alloy 7075 reinforced with 10, 15 and 20 wt.% SiC particles. The alloy was melted in the furnace at 750-780°C, and the ceramic particles were added to the melt using vortex method. Then the molten melt is poured into the preheated die, which is maintained at 280-300°C. Subsequently, the squeeze pressure of 80 MPa was acted upon the melt. It is observed that the homogeneous distribution of SiC particulates was obtained using vertical pressure/squeeze casting of the SiC composites. Some agglomeration was observed, but there was no evidence of porosity among the SiC particles when they were close to each other. Both for as-cast (450 MPa) and heat treated conditions (588 MPa) 10 wt. % SiC aluminum matrix composites showed the maximum flexural strength. It is increased to about 40 MPa (10%) for the as-cast and 180 MPa (44%) for heat-treated composites. Hardness test was conducted to find the maximum value. For the as-cast specimens, the hardness value increased from 133 to 188 Vickers due to an increase in silicon carbide content from 0 to 30 wt. % and for the heat treated specimens the hardness values increased from 171 to 221(Hv) Vickers hardness.

Young–Ho Seo & Chung-Gil Kang (1995) [25], fabricated Al-Si matrix composite through squeeze casting process with varying pressure of 70-130 MPa. The silicon carbide particles of 15% and 22-micron size were added to the melt theory vortex method. The size of the casting was 44 mm diameter and 80 mm height. The optimum conditions of the melt stirring process were that the temperature of the molten metal alloy was 680-700°C, the stirring speed was 750 rpm and the stirring time was 5 min. He observed that applied pressure improved the wettability and the bonding force between Al alloy/SiCp and approximately 10% also increased tensile strength. The greatest strength was shown at an applied pressure of 100 MPa in this study. The hardness increases with increase in pressure and found to be maximum at 130 MPa.

Sukumaran K. et al (2008) [26] developed 2124 aluminium alloy matrix composite with 10% SiC by squeeze casting process. The improvement in the mechanical properties can be attributed to the refinement of the microstructure obtained by the application of pressure during solidification. The slurry is poured into the die maintained at the temperature 120-130°C. The squeeze pressure of 45-120 MPa is acted upon the melt. The composite shows lower UTS initially compared to the alloy due to the presence of higher defects. However, the value of UTS for the alloy and composite are well comparable when the applied pressure is around 100 MPa, at which the porosities are eliminated entirely. Applied pressure not only demolished shrinkage and porosity but also it helps in the distribution of second phase particles.

Zhang Wei-Wen et al (2007) [27] investigated the particle distribution, and the interfacial reaction of Al-Si alloy reinforced with B4C particles processed by pressure die casting. The pressure varies between 30-80 MPa. He discussed the mechanism of the particle migration duration solidification, at the early stage of crystallization; the solid fraction of particles near the wall surface was maximum. As the primary alpha grain grows it pushes the particles to the centre of the casting, longer solidification range lead to the formation of particle clusters. Since the B4C was not stable in the aluminium melt small amount of Ti particles were added to avoid the formation of inter-metallic phases.

V. CONCLUSION

Aluminum based metal matrix reviewed for different reinforcements resulted in fine micro-structures with higher strength components, good surface texture and low levels of porosity. In this paper a vast study on the various grades of aluminium alloys, reinforcement type, size and the process parameters of stir casting and squeeze casting were done. It was concluded that there should be a proper control over reinforcement type, weight fraction and size for uniform distribution of the particles. From the study the weight fraction and should be within 15 wt.% and 30-80 micron respectively above which the agglomeration occurs in both the cases. Squeeze casting has the potential to destroy the defects like porosity and shrinkage due to the pressurization on the molten melt. The process parameter for the squeeze casting may vary according to the size and volume of the casting and ranges between 40-150 MPa of squeeze pressure, 650-800˚C of melt temperature and 150-300˚C of die temperature.

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