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Investigation of Aluminium Metal Matrix Composite by Prepared Squeeze Casting Method

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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 Aluminum Metal Matrix Composites in all aspects: squeeze pressure, casting (melt)/perform preheat/die temperature, solidification rate, reinforcement particle sizes, porosity and mechanical properties. Composite materials have led to increase the rate of development in engineering field, Metal matrix composite (MMC) are generally reinforced with other metal, ceramic organic compounds. Reinforcements significantly improved the properties such as high tensile strength, toughness, hardness, low density and good wear resistance compared to base metal. It has increasing attentiveness to fabricate composites at low cost, commonly AMMCs are used now automobile, airplane, aerospace then many supplementary fields, silicon carbide (SiC), graphite (Gr) and aluminium oxide (Al₂O₃) are most generally used reinforcements. Al alloy-SiC reinforcement gets increases the toughness, thickness, ductile strength then wears resistance. Al₂O₃ reinforcement has good compressive strength and wear resistance. Gr used as the solid lubricant, between these materials, SiC and Gr particles reinforcement in hybrid composite gives low friction coefficient and high wear resistance. Al/SiC/Gr hybrid composite revealed that the presence of SiC particles has improves the strength and hardness, compensate the wearying properties of Gr. AMMC properties particle distribution has shown a very spirited role and is better by intensive shearing.

I. INTRODUCTION

Composite materials have led to increase the rate of development in engineering field, Metal matrix composite (MMC) are generally reinforced with other metal, ceramic organic compounds. Reinforcements significantly improved the properties such as high tensile strength, toughness, hardness, low density and good wear resistance compared to base metal. It has increasing attentiveness to fabricate composites at low cost, commonly AMMCs are used now automobile, airplane, aerospace then many supplementary fields, silicon carbide (SiC), graphite (Gr) and aluminium oxide (Al₂O₃) are most generally used reinforcements. Al alloy-SiC reinforcement gets increases the toughness, thickness, ductile strength then wear resistance. Al₂O₃ reinforcement has good compressive strength and wear resistance [29]. Gr used as the solid lubricant, between these materials, SiC and Gr particles reinforcement in hybrid composite gives low friction coefficient and high wear resistance. Al/SiC/Gr hybrid composite revealed that the presence of SiC particles has improves the strength and hardness, compensate the wearying properties of Gr. AMMC properties particle distribution has shown a very spirited role and is better by intensive shearing.

II. RELATED WORK

R Muraliraja, (2019) “Aluminum metal matrix composites, which exhibit significantly high compressive strength, were produced through the squeeze casting process using aluminum 7075 alloy as the matrix material and 2.5 wt% alumina as reinforcement. The process parameters of squeeze casting were prudently selected based on the literature in order to obtain better mechanical properties such as compressive strength and hardness. Samples were examined using an optical microscope, energy dispersive spectroscopy, a scanning electron microscope, and X-ray diffraction analysis. The optical micrograph showed low porosity in the produced composite, which matched the porosity measured using the Archimedes principle.[1]

T Adithiyaa, (2020) “Rapid globalization and demand for the advanced material, hybrid materials are possessing an up marketed strategy in the field of material research. Due to the demand for lightweight and strong nature of materials,

aluminium is considered as largely utilized material for manufacturing components in industrial and other manufacturing sectors. However, aluminium materials are being researched through the decades for improving the mechanical properties. Therefore, hybrid matrix composites are introduced to improve the mechanical properties.[2]

L Natrayan, (2020) “Hybrid metal matrix composites (HMMC) have gained importance in industrial applications owing to their tailorable properties. The properties of HMMC are influenced by the casting process parameters. In this work, AA6061-reinforced Al₂O₃/SiC HMMC were fabricated by squeeze casting technique. The effect of four levels and four input parameters are squeeze pressure, pressure holding time, die material, and melt temperature is investigated. L16 orthogonal array was selected to perform the experiments. Taguchi technique identified best process parameters that exhibited highest hardness, ultimate tensile strength (UTS), and yield strength.[3]

M Senthil Kumar, (2017) “Currently, Aluminium (Al) 6061 material is used in Automobile and industry applications, Al 6061 matrix material gives good formability with excellent mechanical properties. Reinforcement of distribution is a major problem in some casting methods and to overcome this casting problem, squeeze casting technique was used in this research work, where Aluminium 6061 act as a matrix material and SiCp was used with different volume percentage. The effects of volume in ractions of reinforcements on the composite properties were investigated. The micro structural characterization results revealed a homogenous distribution of SiC particles in the matrix, which is almost free of pores can be obtained by squeeze casting method.[3]

M Ramachandra, (2018) “Squeeze casting is one of the processes in liquid metallurgy in which a molten metal is poured into a metallic die and is solidified under the action of a relatively high external pressure. The primary objective of this paper is to study the influence of the process parameters on wear resistance and hardness of squeeze cast LM6 Al-flyash composite. In this investigation Aluminium metal matrix composites, reinforced with flyash (from 5% to 12.5%wt.) was synthesized using stir-squeeze casting route. The influence of parameters like reinforcement content.[4]

K Sekar, (2015) “The effects of nano particles on double shear strength and tribological properties of A356 alloy reinforced with Al₂O₃ nano particles of size 30 nm were investigated. The percentage inclusions of Al₂O₃ were varied from 0.5 to 1.5 wt%. The particles were added with stirring at 400 rpm and squeeze casting at 750 °C and pressure of 600 MPa in a squeeze casting machine. Comparison of the performance of as cast samples of A356/Al₂O₃ nano composite was conducted. The tribological properties of the samples were also investigated by pin-on-disk tests at 10, 30 and 50 N load, sliding speed 0.534 m/s and sliding distance 1100 m in dry condition. SEM images of microstructure analysis of the composite, Al₂O₃ (0.5 and 1 %) particles were well dispersed in the A356 alloy matrix.[5]

Hasan Ali Alhashmy, (2015) “Carbon fiber reinforced aluminum matrix composites show an excellent combination of lightweight, mechanical properties, ease of processing and low costs. However, standard liquid infiltration squeeze casting often requires complex preforms in order to control fiber configuration and distribution. It also requires relatively high pressures to overcome the pressure drop across the preform, which can lead to preform compaction and damage and can limit the maximum component thickness that can be thoroughly infiltrated. Therefore, a laminate squeeze casting process is investigated as alternative whereby alternate layers of fiber fabrics and aluminum sheets are hot consolidated.[6]

Srinivasan, (2020) “In this experimental investigation, aluminium hybrid metal matrix composites (HMMCs) is fabricated through stir cum squeeze casting process. Zirconium Di-oxide (ZrO₂) and graphite (C) is used as reinforcement. ZrO₂ ceramic particles are used to increase the tensile strength of aluminium. Whereas C improves heat transfer properties that increases reliability of the product. Aluminium HMMCs used in this investigation with the following weight proportions – 100%. [7]

Hatem Akbulut, (2007) “In this study, the effects of volume fraction of SiC on microstructure, hardness and tensile properties as well as density have been investigated in Al–4.5Cu–3Mg matrix alloy and its 5, 10, and 15 vol.% SiC particle reinforced composites. The results showed that squeeze casting resulted in refining microstructure, porosity and other casting defects such as shrinkage cavities were minimised due to pressure application during solidification. Hardness and tensile properties of matrix alloy were increased by squeeze casting. In composites, hardness increased with increasing volume fraction of SiC. Increasing volume fraction of particles caused to increase porosity and to decrease the elongation and reduction in area. Fracture surface analysis showed that, the failure in composites occurs in both the matrix and particles simultaneously. Furthermore, this indicated that there is a good bonding between matrix and SiC particles and the fracture initiation did not occur at matrix particle interface.[8]

Yi-qi Wang, (2011) “Al₂O₃ fiber (Al₂O₃f) and SiC particle (SiCp) hybrid metal matrix composites (MMCs) were fabricated by squeeze casting method. The tests were carried out using a pin-on-disk friction and wear tester by sliding these pin specimens at a constant speed of 0.36 m/s (570 r/min) against a steel counter disk at room temperature, 100 °C and 150 °C, respectively. To observe the wear characteristics and investigate the wear mechanism, the morphologies of the worn surfaces and specific wear rate were analyzed by using scanning electron microscope.[9]

III. METHODOLOGY

Aluminum alloy is an aluminum alloy, with zinc as the primary alloying element. It has excellent mechanical properties and exhibits good ductility, high strength, toughness, and good resistance to fatigue. It is more susceptible to embrittlement than many other aluminum alloys because of micro segregation, but has significantly better corrosion resistance than the alloys from the 2000 series. It is one of the most commonly used aluminum alloys for highly stressed structural applications and has been extensively utilized in aircraft structural parts.

Silicon carbide (SiC) nanoparticles exhibit characteristics like high thermal conductivity, high stability, high purity, good wear resistance and a small thermal expansion co-efficient. These particles are also resistant to oxidation at high temperatures. Silicon belongs to Block P, Period 3 while carbon belongs to Block P, Period 2 of the periodic table. An important point to be noted about their storage is that they must be kept away from moisture, heat and stress.

Graphite archaically referred to as plumbago, is a crystalline form of the element carbon with its atoms arranged in a hexagonal structure. It occurs naturally in this form and is the most stable form of carbon under standard conditions. Under high pressures and temperatures it converts to diamond. Graphite is used in pencils and lubricants. It is a good conductor of heat and electricity. Its high conductivity makes it useful in electronic products such as electrodes, batteries, and solar panels.

IV. EXPERIMENTAL RESULTS

Tensile Testing Process

Tensile testing, also known as tension testing,[1] is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area.[2] From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics.[3] Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. Some materials use biaxial tensile testing. The main difference between these testing machines being how load is applied on the materials.



Figure 1 Tensile testing Process

Hardness Testing Process

Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion. In general, different materials differ in their hardness; for example hard metals such as titanium and beryllium are harder than soft metals such as sodium and metallic tin, or wood and common plastics. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behaviour of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness.

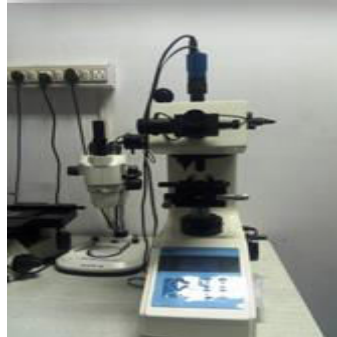


Figure 2 Hardness testing Process

Impact Testing Process

Impact testing of metals is performed to determine the impact resistance or toughness of materials by calculating the amount of energy absorbed during fracture. The impact test is performed at various temperatures to uncover any effects on impact energy.



Figure 3 Impact Process

V. CONCLUSION

The following are conclusions on the review of Squeeze casting: Aluminium based metal matrix reviewed for different reinforcements resulted in fine micro-structures with higher strength components, good surface texture and low levels of porosity. Aluminium alloys with reinforcement of Al₂O₃ increased the tensile strength and hardness along with ductility. SiC reinforced matrix improved the tensile and hardness behaviour up to 10 wt.% and decreased the tensile strength and hardness with the increasing wt% due to agglomeration of the hard ceramic particles that leads to porosity. SiC reinforced AMMCs reported better wear resistance than Al₂O₃ reinforced MMCs. Addition of graphite particles increased the wear resistance. The coefficient of friction has reduced and wears resistance gets increase due to increase the reinforcement on the wear behaviour of MMCs.

1. The optimum pressure used in the squeeze casting of Aluminium alloys and composites, which gives a better microstructural refinement and increase in the mechanical properties, is 100 MPa.
2. The selection of the reinforcement particle size also influences the strength of the material in the squeeze casting process. The smaller the grain size the better the improvement in the properties.
3. The suggested melt and die temperature during the squeeze casting of Aluminium alloys and composites are 600°C to 700°C and around 250°C respectively.
4. There is a refinement in the microstructure with the combined effect of undercooling and a higher cooling rate, due to the high pressure level in the squeeze casting process.



5. The mechanical properties are enriched for both the alloys and the composites when fabricated through the squeeze casting technique, under controlled process parameters

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