Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 2,Issue 3, March -2015

INVESTIGATION OF SQUEEZE CASTING ON METAL MATRIX COMPOSITE [*Al-Sic* (P) REINFORCED]

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ABSTRACT: Squeeze casting is a pressurized solidification process whose conception in Russia dates back over a hundred years. A major market is the automotive market which is increasingly demanding lightweight components to improve fuel efficiency and considerable progress appears to have been made in the United States towards squeeze cast diesel engine pistons. The aim of this project to fabricate a Silicon carbide particle reinforced Aluminum matrix composite which finds application in automotive, aerospace, opto-mechanical assemblies and thermal management. 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. Squeeze Casting is a combination of the processes of forging and casting. In the squeeze casting process, a molten metal is solidified under an applied pressure during solidification, which leads to a high cooling rate and temperature gradient. The squeeze casting has a number of advantages, such as low density of porosities, heat treatability, consistency and soundness of mechanical properties. The microstructure of the fabricated aluminum casting will be analyzed by performing a SEM Analysis. The SEM analysis helps to identify the distribution of the reinforcements on the matrix phase based on weight of addition of the reinforced particles. The Rockwell hardness test will be carried out on the aluminum matrix composite material. The stress, strain and thermal stress and strain analysis will be carried out by using ANSYS. Thus, Aluminum matrix Composite utilization provides significant benefits including performance benefits (component lifetime, improved productivity), economic benefits (energy savings or lower maintenance cost) and environmental benefits (lower noise levels and fewer air-borne emissions).

Keywords: SEM, ANSYS, Squeeze casting and stress - strain analysis

1. INTRODUCTION

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. 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 as shown in the figure 1.1.There are two methods of Squeeze Casting - Direct and Indirect.

Direct Squeeze Casting is sometimes called Liquid Metal Forging since the process is close to that of forging. Liquid metal is poured into the lower half of a die, and then the upper half of the die is closed. High pressure is applied to the entire cavity until the metal has solidified. Indirect Squeeze Casting is performed in a manner closer to conventional die casting method. In this method metal is poured into the sleeve of a squeeze casting machine. It is injected into the die at very slow velocity and is solidified under pressure. Composites fabricated with this method have the advantage of minimal reaction between the reinforcement and molten metal because of the short processing time involved. Such composites are also typically free from common casting defects such as porosity and shrinkage cavities.

Squeeze casting or pressure infiltration process

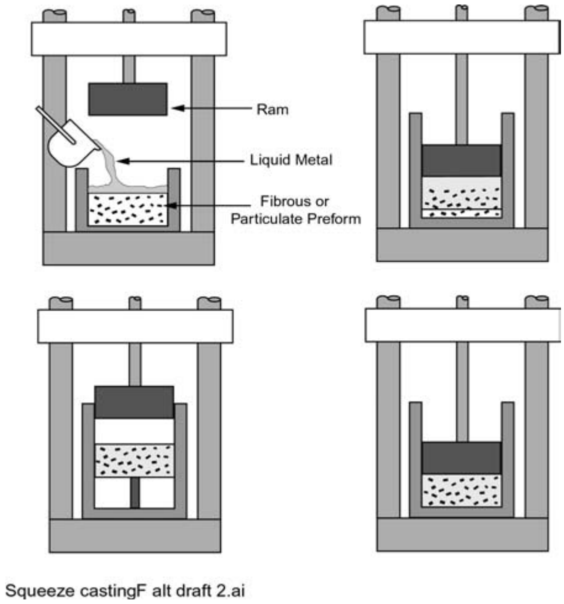

Fig 1.1 Squeeze casting process

2. LITERATURE REVIEW

L.J. Yang (2007): Tensile, impact and density measurement were conducted. It was found that generally, samples taken from the bottom of the squeeze casting mould gave higher tensile strength, higher impact strength and higher density values. This study was carried out to determine the effect of solidification time on the mechanical properties of the castings. Two analytical methods were used: a steady-state heat flow model and Garcia's virtual model. It was found that similar results were obtained with both analytical methods. Casting samples taken from the lower part of the squeeze casting mould were found to have a significantly shorter solidification time. For both types of alloys, it was found that generally the shorter the solidification time of the casting, the higher is its density, impact energy, yield strength and ultimate tensile strength (UTS).

K.H.Chang (2009): It is concluded from thermal analysis result that temperature distributions on the lower and the left side of mould increase up to 20 s, and maximum temperature of 657±C occurs at the center of lower side. After 20 s, temperatures at the low and the left side are rapidly decreased. All thermal stress distributions in the lower side show compressive when casting completes. And maximum stress occurs at the edge part about 284 MPa in the longitudinal direction. All thermal stress distributions in the lower side show compressive within the casting region when casting complete. After bound line, thermal stress of the longitudinal direction changes from compression to tensile and that of the lateral and the thickness directions decreases up to insignificant value.

Farshid Taghavi (2009): The effect of prolonged mechanical vibration on grain refinement and density of A356 aluminum alloy has been investigated. It was found that Application of mechanical vibration led to increase in grain refinement and density of A356 aluminium alloy, Increasing vibration time up to 15 min led to decrease in the size of a-Al phase for all vibration frequencies (10–50 Hz).Increasing vibration frequency up to 50 Hz led to decrease in the size of a-Al phase for all vibration times (5–15 min).Maximum achieved grain refinement was 53% in 50 Hz and 15 min. By applying mechanical vibration at this condition, size of a-Al phase reached to 173 lm. Increasing vibration time and frequency led to increase in the density of A356 aluminum alloy. It was observed that mass feeding of liquid phase and melt degassing because of applying mechanical vibration have strong effect on the density of alloy. Maximum achieved density was at 50 Hz and 15 min vibration condition. At this condition, Density of alloy was improved from 2.40 g/cm3 to 2.66 g/cm3.

3. EXPERIMENTAL SETUP:

The aluminium is first heated in a muffle furnace for temperature range of 700 degree celsius to 725 degree Celsius. The aluminium is melted to a liquid form. The die part is usually preheated to a temperature range of 150 degree Celsius – 250 degree Celsius. The molten metal is poured into the die cavity and the punch is attached to the ram of the hydraulic pressure. The pressure is applied over the molten metal by means of punch untill all of the molten metal is solidified. The punch is withdrawn and the component is ejected.

3.1 HYDRAULIC PRESS

Hydraulic press is mainly used for applying the pressure during the time of solidification. The punch is connected with the ram of the hydraulic press. The forward motion of the ram pushes the punch to hit on the molten metal which is inside the die cavity. The imposed high pressure in this project work is applied with the help of a 10 ton hydraulic press machine as shown in the fig 3.1.

Fig 3.1 hydraulic press

3.2 CERAMIC BAND HEATERS

Ceramic Band Heaters are constructed from helically wound Nickel Chrome resistance coil precisely stretched and strung through ceramic cores forming a flexible heating mat and placed in flexible stainless steel housing with ceramic fiber insulation. These heaters can be easily fit and very flexible. The heat dissipation from the heaters built in insulation will be prevented by its outer jacket. Hot air will be trapped between the gaps and the process of the heat exchange is making a uniform layer of heat all over the barrel. The jacket has insulation lining which further prevents the heat loss. The ceramic band heater is used to heat the die to the required temperature as shown in figure 3.2.

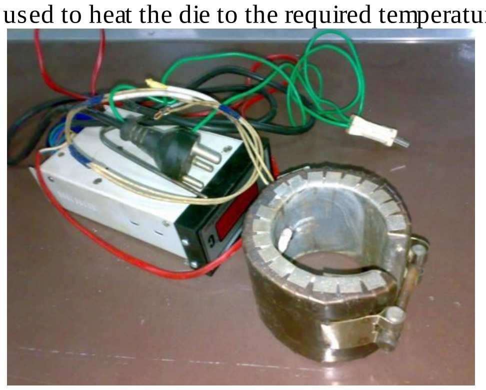

Fig 3.2 ceramic band heaters

3.3 DIGITAL INDICATOR

The temperature sensor used is thermostat which is very suitable for measuring ambient atmospheric temperatures, but it could be replaced with any other type of temperature sensor, that would function in a range that is more adequate to the specific application. The Temperature was translated to a directly proportional voltage and the relation was considered to be linear over the concerned operating range. These signals are converted to the digital signals, so that the microcontroller can read it, store it and display it as shown in figure 3.3.

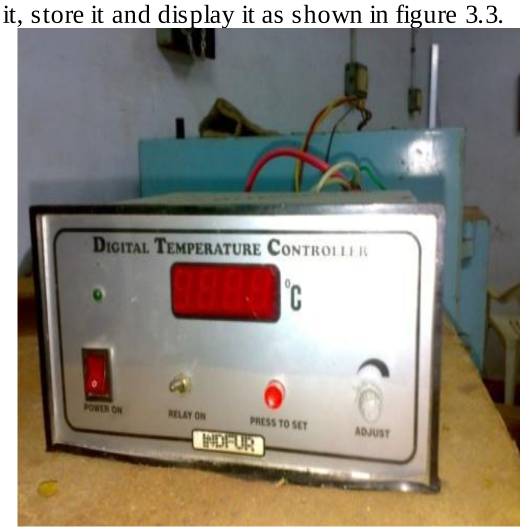

Fig 3.3 Digital Indicator

3.4 MUFFLE FURNANCE

The muffle furnace employed in this work has the temperature range up to 1200C and 750C and it is poured into the die cavity. The muffle furnace is shown in figure 3.4.

Fig 3.4 muffle furnace

4. METHODOLOGY

The process of squeeze casting involves the following steps

I. The metal is melted in a furnace.
II. The die part is preheated to a temperature range of 150C – 250C.
III. The molten metal is poured into the die cavity; the punch is placed in the hydraulic press.
IV. The pressure is applied over the molten metal by means of punch until the solidification is completed. The process is shown in figure 4.1.
V. The punch is withdrawn and the component is ejected

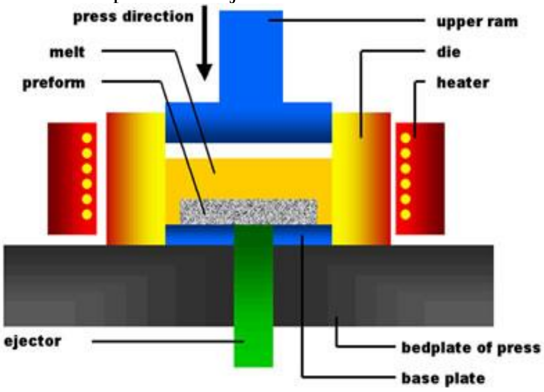

Fig 4.1 Squeeze casting or pressure infiltration process

4.1 CONCEPT OF PRODUCING VIBRATION OF MOLTEN METAL

The Advanced Casting research Centre has published a project fact sheet which is titled "The effect of mechanical mold vibrations on the characteristics of aluminum casting alloys "in which the effect of controlled mechanical vibration of the mould during alloy solidification on the dendrite coherency point, the hot tearing tendency, and the microstructure of aluminum casting alloys was evaluated. The results of this project fact sheet is reported as

- Mould vibration reduces grain size.
- Mould vibration increases grain compactness.
- Mould vibration shifts the dendrite coherency point towards lower temperatures.
- Mould vibration lowers feeding- related defects in castings - particularly the incidence of hot tears.
- Mould vibration helps distribute the primary silicon particles more uniformly. The above vibrator is used
- Mould vibration allows refinement of the primary silicon particles without the use of chemical additives.

The vibrator makes the die to vibrate constantly and the molten metal is made to break down into small grain structures which has several advantages in case of low temperature application. The vibration can be provided externally also by means of providing a magnet surrounding the die (the die material being H13 steel), which makes the die to vibrate thereby making the molten metal inside the die to vibrate and making the molten metal to break into small particle. The above vibrator can used to improve the distribution of silicon carbide particles in aluminium matrix more uniformly.

5. RESULTS AND DISCUSSION

The casting material used in the squeeze casting process is Silicon Carbide particle reinforced Aluminum matrix composite The squeeze casting of Silicon Carbide particle reinforced Aluminium matrix composite is fabricated and the microstructure of the cast product will be analyzed by Scanning Electron Microscope (SEM).

Fig 5.1 Fabricated components

5.1 ANALYSIS BY ANSYS

STRAIN ANALYSIS

The fabricated component is analyzed by ANSYS under the following parameters.

Young's modulus (E) = 1* 10^5 N/mm^2

Load applied (P) = 1000N

Poisson's Ratio = 0.3

Thermal conductivity = 0.237 W/ (m K) Melting Point = 933K

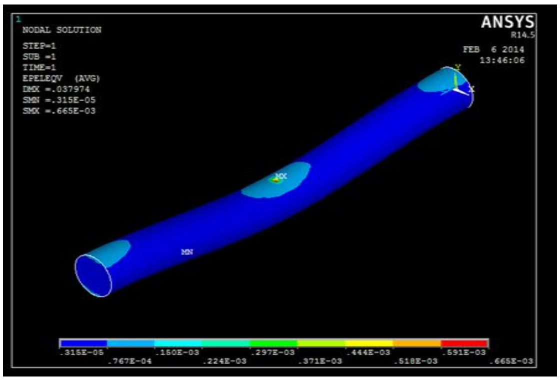

Fig 5.2 shows strain analysis for simply supported beam

It is analyzed by under two conditions,(i) Simply supported beam (ii) Cantilever beam. The results were obtained and it given below.

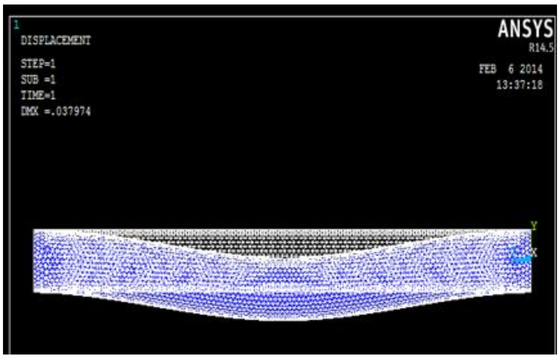

Fig 5.3 shows the deformation simply supported beam

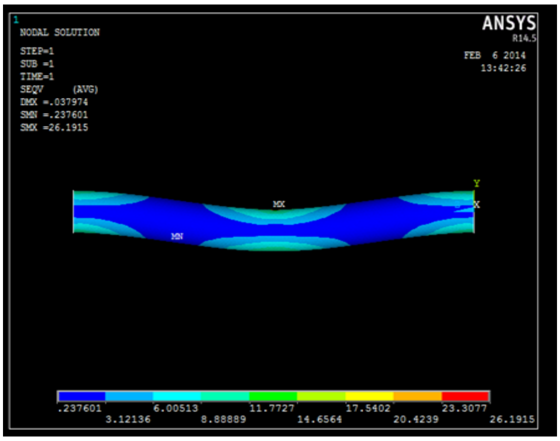

Fig 5.4 shows stress analysis Simply supported beam

Simply supported beam:

The maximum strain = 0.663*10^-3
The minimum strain = 0.315*10^-5
The maximum stress = 26.1915N/mm^2 (at the midpoint)
The minimum stress = 0.237601 N/mm^2
The maximum displacement = 0.037947mm
Cantilever beam:
The maximum strain = 0.002275
The minimum strain = 0.638*10^-5
The maximum stress = 171.225N/mm^2 (at the right end)
The minimum stress = 0.597246N/mm^2
The maximum displacement = 2.10239mm.

The SEM uses electrons for imaging, much as a light microscope uses visible light. The advantages of SEM over light microscopy include much higher magnification (>100,000X) and greater depth of field up to 100 times that of light microscopy. Qualitative and quantitative chemical analysis information is also obtained using an energy dispersive x-ray spectrometer (EDS) with the SEM. The SEM generates a beam of incident electrons in an electron column above the sample chamber. The electrons are produced by a thermal emission source, such as a heated tungsten filament, or by a field emission cathode. The energy of the incident electrons can be as low as 100 eV or as high as 30 keV depending on the evaluation objectives. The electrons are focused into a small beam by a series of electromagnetic lenses in the SEM column. Scanning coils near the end of the column direct and position the focused beam onto the sample surface. The electron beam is scanned in a raster pattern over the surface for imaging. The beam can also be focused at a single point or scanned along a line for x-ray analysis. The beam can be focused to a final probe diameter as small as about 10 Å.

6. CONCULSION

The squeeze casting of Silicon Carbide particle reinforced Aluminum matrix composite is fabricated and the microstructure of the cast product will be analyzed by Scanning Electron Microscope (SEM). The experiment is done after considering the parameters squeezing pressure, pouring temperature and melt volume. Thus three different specimens were produced by using squeeze casting Al-Sic10p, Al-Sic20p, Al will be tested for their Ultimate tensile strength on the Universal Testing Machine (UTM).The hardness of the three samples will be determined by Rockwell hardness test. The graph will be plotted taking percentage of silicon carbide addition on X-axis and the Ultimate tensile strength on the Y-axis. The fine grain structure of the cast product will obtained which will be light weight and can be used for various applications.

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