

Effect of Load Variation on the Wear Characteristics of A336/ (0-15) wt% SiC_p Squeeze Cast Composites under Dry Reciprocating Sliding Conditions

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ABSTRACT: Squeeze casting is an advanced casting process where solidification is promoted under high pressure. It is a combination of casting and forging processes. It is an efficient technique for the manufacturing of metal matrix composites as they exhibit better mechanical properties due to the presence of fewer common defects such as porosity and shrinking cavities. The objective of this study is to find out the effect of load variation on the wear characteristics of squeeze cast A336 composites. The composites were made by adding SiC particles of weight percentage varying from 0-15, using bottom pouring type stir casting furnace with squeeze casting. Wear test was conducted on reciprocating wear tester. The microstructural, hardness and tension tests were conducted. Results showed that the squeeze cast products exhibit better mechanical properties and superior wear resistance compared to gravity cast products. Also the applied load has significant effect on the wear rate.

KEYWORDS: Squeeze casting, Metal Matrix Composites (MMC), grain refinement.

I. INTRODUCTION

In the applications like automotive and aerospace industries, the use of light weight components with good mechanical and tribological properties are widely increasing over the past few decades. Since the casting processes with application of some pressure are found to be a good compromise between cost and performance, aluminium or magnesium components produced by means of pressure assisted processes can be used as a substitute for cast iron components. When this kind of substitution is possible, an advantage in terms of cost saving and component weight reduction is obtained.

Squeeze casting is a pressure assisted casting technique which fits in the general category of casting as a manufacturing process. Since the casting process has been introduced approximately 6000 years ago, squeeze casting is a relatively new development, being introduced along with other pressurized casting techniques during the mid 1800's. The squeeze casting process uses an accurately measured or metered quantity of molten metal which is poured into a preheated mould. The mould is closed to produce an internal cavity in the shape of the required component. The molten metal is forced/displaced into the available space of the die cavity. Like all other casting processes, using a permanent pattern, the mould is coated with a suitable release agent and for squeeze casting it is usually in the form of a graphite coating. Pressure continues to be applied to the molten metal until it has solidified and forms the required component. The press is then withdrawn and the component is ejected. Squeeze casting is most suited to the production of light alloy components in large production quantities. Retractable and disposable cores can be used to create complex internal features. It is also called squeeze forming, extrusion casting, liquid forging, liquid pressing, pressure crystallization etc. [12]. It employs low die filling velocity with minimum turbulence and high applied pressure. In the squeeze casting process no gating system is used and a specified amount of molten metal is poured into the mould cavity and pressure

is applied until complete solidification. Therefore the molten metal flows into shrinkage cavities and the gases like hydrogen gets dissolved and remains there in the solution. Thereby defects like porosity and shrinkage cavities are eliminated. So the main advantages of squeeze casting technique are [13],

- The parts produced are without gas porosity or shrinkage porosity.
- Feeders or risers are not required, and therefore no metal wastage occurs.
- Alloy fluidity (castability) is not critical in squeeze casting.
- Squeeze castings can have mechanical properties as good as wrought products of the same composition.

Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required. Composite materials are gaining wide spread acceptance, due to their characteristic behaviour and high strength to weight ratio [13]. A metal matrix can be reinforced with whiskers, particles, short or continuous fibres, and ceramics. Although many matrices such as lead, zinc, copper, steel, titanium and nickel have been used to form MMCs, the most research effort has been dedicated to lightweight metal alloys such as aluminium and magnesium. Aluminium metal matrix composites are finding increased applications, because of their improved mechanical and tribological properties. Particulate-reinforced aluminum-metal matrix composites (AMCs) because of their isotropic properties and relatively low cost are attracting researchers [21]. In terms of tailorability, a very important advantage in MMC applications, particulate reinforcement offers various desirable properties. Boron carbide and silicon carbide, for instance, are widely used, inexpensive, commercial abrasives that possess good wear resistance as well as high specific stiffness. Current markets for MMCs are primarily in military and aerospace applications. Experimental MMC components have been developed for use in aircraft, satellites, jet engines, missiles, and the National Aeronautics and Space Administration (NASA) space shuttle. The first production application of a particulate-reinforced MMC in the United States is a set of covers for a missile guidance system.

II. EXPERIMENTAL DETAILS

The material selected for the study is Aluminium A336 composites. Gravity cast alloy and squeeze cast composites were tested for wear, tension, hardness and microstructure. The composition of the alloy is as shown in the table below.

Table 1. Composition of A336 alloy.

Element	Al	Si	Ni	Mg	Cu	Fe
wt%	82.5	12	2.5	1	1	1

In the gravity casting, the master alloys in the required proportion were put into the diesel fired tilting furnace and heated for 3 to 5 hours. The moulds and crucible for transferring molten metal from furnace to the moulds were preheated to sufficient temperatures. After complete melting, the molten metal was poured into metallic moulds and allowed to solidify. After quenching in water the castings were taken from the mould. The temperature was measured with the help of an infrared thermometer.

The composite containing different weight percentage of SiC_p were prepared with the help of bottom type stir casting furnace with squeeze casting. Initially the alloy was heated in an electric heating furnace until complete melting. After removing the slag from the molten metal, 1% magnesium wrapped in aluminium foil was added in molten metal to increase wettability and retention of SiC particle with molten alloy. Then SiC particles were added when the temperature of the alloy reached almost 700°C and stirring was started at a speed of 200 RPM. The SiC particles were preheated at 500°C for 4 hours. After stirring the molten composite was poured into the squeeze casting mould through a pathway tube provided in the squeeze casting set up followed by the application of pressure until complete solidification. Graphene was used as a lubricant for easy removal of the final product. The squeeze casting parameters used are shown in table 2.

Table 2. Squeeze casting parameters

Melt Temperature	720°C
Stirrer speed	350 RPM
Stirring time	Addition time+ 2 Minute
Squeeze pressure	50 MPa
Pressure holding time	50 s
Pathway temperature	400°C
Mould temperature	200°C
Lubricant used	Graphene

The cast products were then heat treated in electric furnace under T6 condition. The process consists of solutionising at 500°C for 5 hours followed by quenching in water for 15 minutes and precipitation hardening at 200°C for 12 hours.

For microstructural evaluation, the specimens were cut out from cast products. Then it is mechanically polished with emery papers of grain sizes 220, 320, 400, 600, 800, 1000, 1200 and is to be taken for disc polishing using diamond

polishing (around 350RPM) suspension until mirror finish is obtained. The polished specimens were observed under LEICA optical microscope.

The specimen of squeeze cast alloy for the tensile test were prepared according to the ASTM E8M standards. After the heat treatment the test was conducted on the universal testing machine. The dimensions of tensile test specimen is shown in the figure 1.

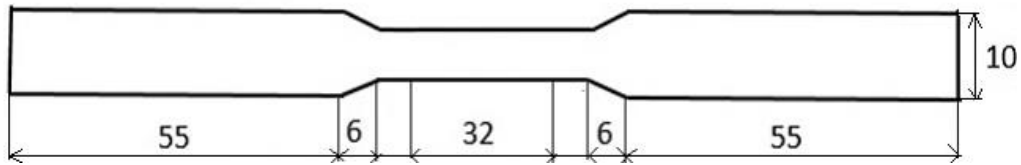


Fig. 1. Tensile test specimen

Hardness measurements were made by using Brinell hardness testing machine. Force of 500N is applied for 15s and diameter of indentation was 10mm. Four indentations were made and diameters were measured by using a microscope. The average value was taken for calculating Brinell hardness number. The Brinell hardness number is calculated from the indentation diameter by using the following formula,

$$BHN = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})} \dots\dots\dots(1)$$

Where,

P=Applied load (500N)

D= Diameter of steel ball (10mm)

d= Diameter of the indentation made on the surface.

The wear test was conducted on reciprocating wear tester. In this test the specimen of diameter 5.9 mm and length 30 mm was rubbed against a grey cast iron plate (250 HVN) of surface roughness of 0.21 mm. The weight of the specimen before and after the test was measured by using an electronic weighing balance of least count 0.0001 gm. The weight loss was taken as the indication of wear and the wear rate is the weight loss per meter of sliding distance. The test was conducted for 3 stroke lengths which are 50,100 and 150 mm. The load was varied from 15-75 N and the velocity was kept constant.

III. RESULTS AND DISCUSSION

The microstructure of A336 alloy shows that the primary alpha aluminium dendrites are embedded in the eutectic matrix. The eutectic silicon particles were found in and around the inter dendritic region of aluminium dendrites. A336 has a stripy microstructure which is called lamellar microstructure. Compared to the microstructures of as cast and heat treated alloy, the grain refinement was clearly visible in the heat treated alloy. Also the needle shaped silicon particles in the as cast alloy have transformed into a spherical like shape after the heat treatment process. The microstructures of A336 alloy before and after the heat treatment process is shown in figure 2.

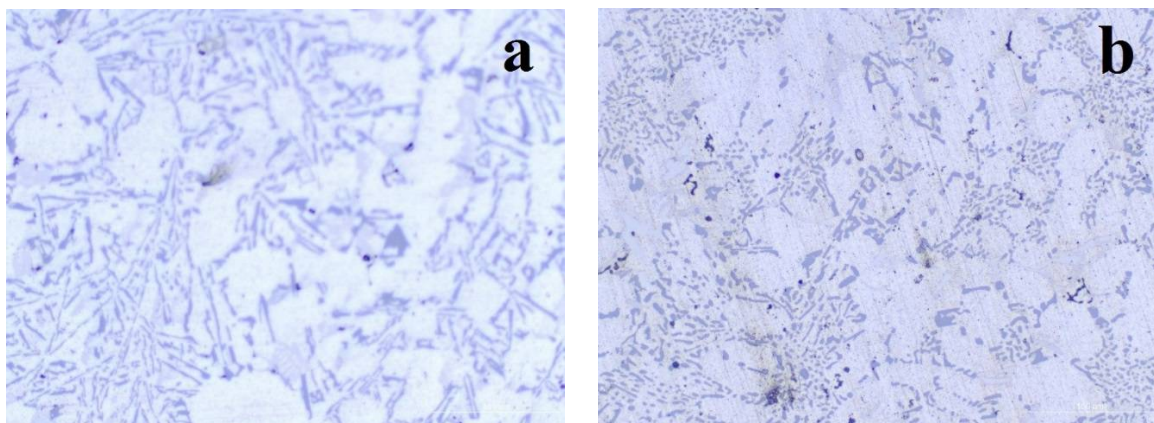


Fig. 2. Microstructure of as cast alloy a)As cast alloy b)Heat treated alloy

Compared to gravity cast alloy, the squeeze cast alloy has noticeable grain refinement and homogeneity in the microstructure as shown in figure 3. Therefore the squeeze cast products will have superior mechanical properties. In general, the fine structure of squeeze cast components are due to the following factors: (i) changes in undercooling of the molten alloy which increases the nucleation frequency, (ii) changes in the composition and percentages of the forming phases of the solidifying alloy, (iii) changes in the heat-transfer coefficient between the metallic mould and solidifying alloy i.e., greater cooling rates for the solidifying alloy due to reduction in the air gap between the alloy and the die wall and thus more effective contact area, and (iv) changes in the density of the alloy due to reduction of porosity. Squeeze casting increases the heat transfer coefficient. In the paper by Aweda et. al [19] the graph of applied pressure vs heat transfer coefficient is plotted. By increasing the pressure to 50 MPa there is 10% improvement in the heat transfer coefficient. This will cool the squeeze castings rapidly compared to gravity cast. Hence finer grains are obtained, there by improved strength. This is evident in the microstructure. The microstructure of A336/15 % SiC_p composite as shown in figure 4 reveals that the SiC particles are more or less uniformly distributed. Some agglomerations are present in the microstructure.

Tension test was conducted on the heat treated alloy in order to confirm whether the obtained alloy has properties same as that of A336 alloy. The result showed that the ultimate tensile strength obtained from the test is 276.946 MPa which is in good agreement with the actual value. The stress strain curve obtained from the test is shown in figure 5.

The hardness test results showed that, there is significant improvement in the hardness values with increase in the percentage of SiC particles. Also the squeeze cast alloy exhibited more hardness compared to gravity cast alloy as shown in figure 6.

It was observed that the wear rate for the alloy as well as the composites at a particular stroke length and sliding distance increased with increase in applied load. The effect of applied load on the wear rate was determined by plotting the wear rate v/s load graph for different stroke lengths as shown in fig.21, 22 and 23. It was observed that the wear rate of both the alloy and composite increased with increase in contact load. This increase in wear is attributed to the increased metallic intimacy between the asperities of the contacting surfaces at higher contacting loads.

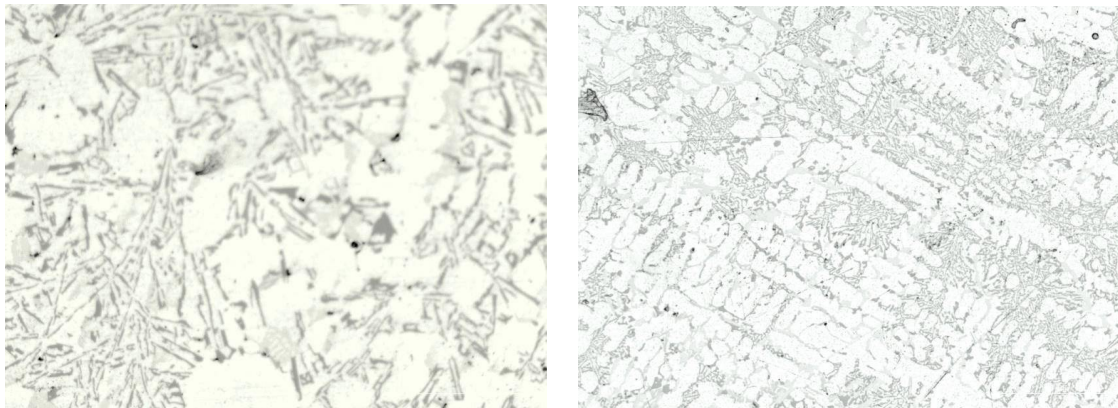


Fig.3. Microstructure of A336 alloy. a) Gravity cast alloy and b) Squeeze cast alloy.

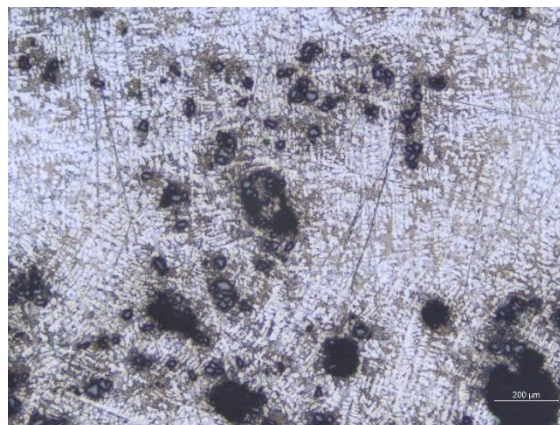


Fig.4. Microstructure of A336/15 wt% SiC_p composite.

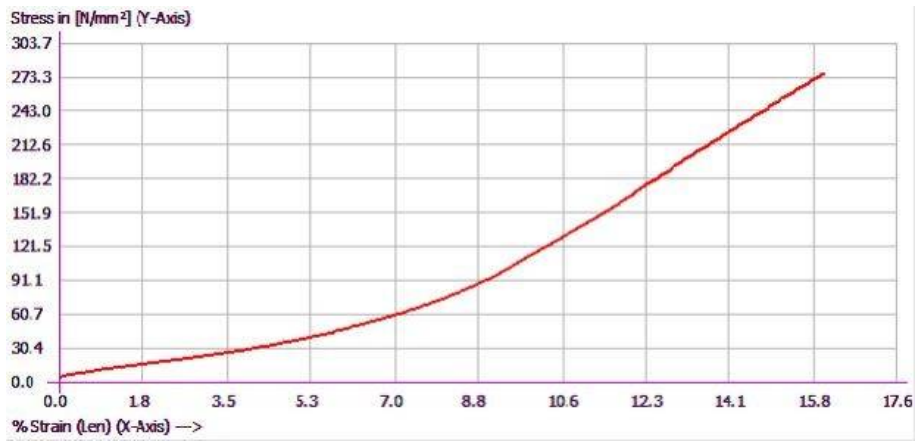


Fig.5. Stress strain graph for the A336 heat treated alloy.

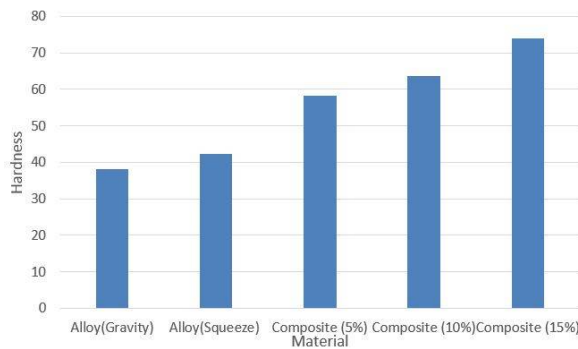


Fig.6. Increment in material hardness with increase in wt% of SiC_p particles.

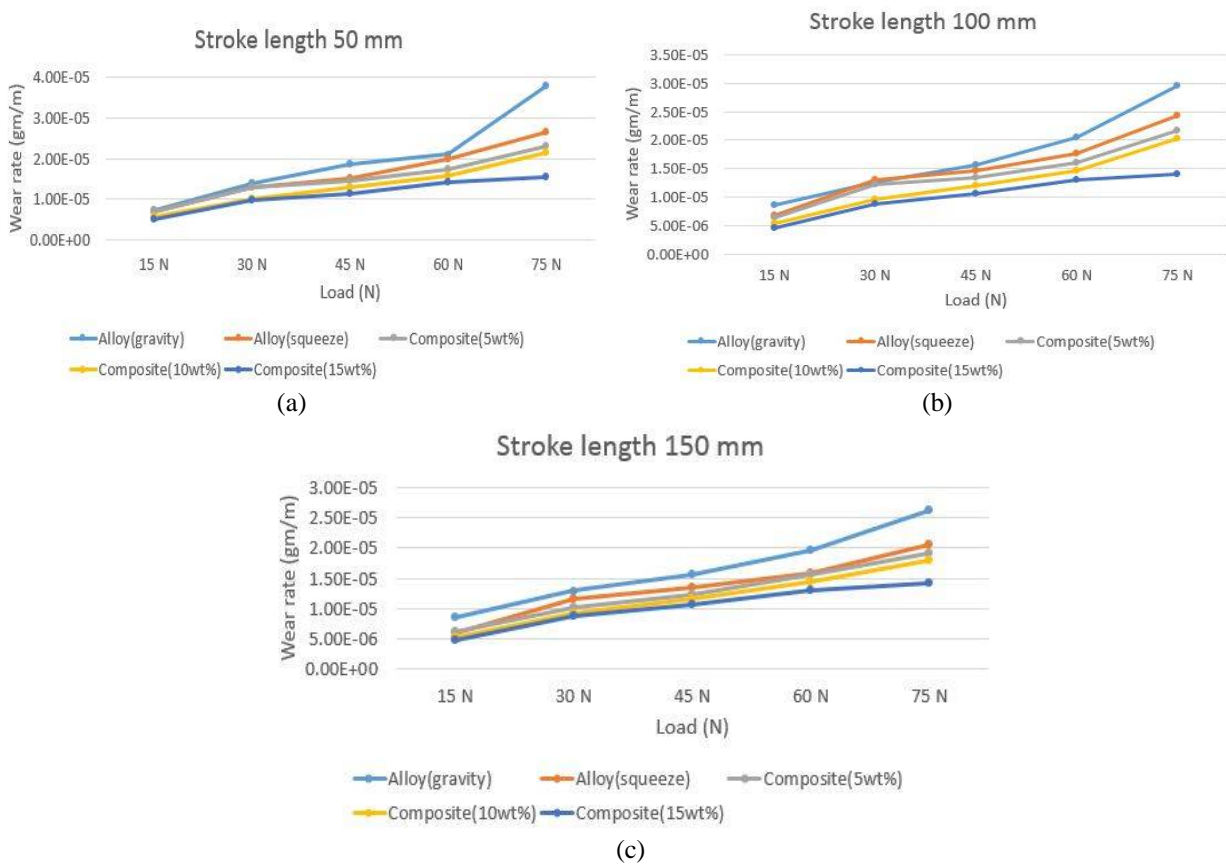


Fig.7. Variation of wear rate with increment in contact load for stroke lengths of (a) 50 mm (b) 100 mm (c) 150 mm

IV. CONCLUSIONS

1. Squeeze casting is found to be an efficient casting technique to produce porosity free high strength products.
2. The squeeze cast alloy is found to have noticeable grain refinement and homogeneity in the microstructure which in turn gives the alloy, superior mechanical properties due to the improved heat transfer coefficient and the SiC_p particles were more or less uniformly distributed for the composites produced by squeeze casting.
3. There is considerable improvement in tensile strength and hardness values of squeeze cast alloy compared to gravity cast alloy. The hardness values increased with increase in weight percentage of SiC_p particles for composites.
4. The wear resistance increased with increase in weight percentage of SiC_p particles. Also the wear rate of gravity cast alloy is greater than that of squeeze cast alloy.
5. The wear rate increased with increase in contact load due to the increased metallic intimacy between the asperities of the contacting surfaces at higher contacting loads.

ACKNOWLEDGEMENT

The authors are grateful for the research fund sanctioned by Kerala State Council for Science Technology and Environment (KSCSTWE), Government of Kerala for this work, vide letter No.ETP/06/2015/KSCSTE dated 29-09-2016 and for the support from the staffs of Kerala Technological University and College of Engineering Trivandrum.

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