IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 7, Issue 7, July 2020

# Microstructure, Hardness and Chip Formation of an Aluminum Alloy Metal Matrix Composite Fabricated by Squeeze Casting Method

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**Abstract:** Casting is the most economical route to transfer raw materials into readily usable components. However, Porosity in cast metal matrix composite (MMC) has been found as major cause of defect. Generally, increasing content of porosity will decrease the mechanical properties of MMC such as hardness, tensile strength, and damping capacity. Also casting results in variety of grain structure like dendrite structure, chilled grains, columnar grains and there is lack of expected homogeneity. On the contrary, forging process gives directional properties. The formation of a grain structure in forged parts is elongated in the required direction of the deformation. This structure gives better mechanical properties in the plane of maximum strain but lower across the thickness. The limitations of casting and forging can be eliminated in squeeze casting process where the force is applied on the alloy in between liquidous and solidus temperature. In squeeze casting, uniform and homogeneous grain structure is found which is favorable for machining. In this work, three specimens of alumnium metal matrix composite are prepared and examined for hardness, microstructure and pattern of chips while machining. Macro-examination of chips showed improved machinability and improved surface finish Hardness is increased with increase in reinforcement and squeezing.

**Keywords:** Aluminium alloy Metal Matrix Composite, Squeeze Casting, Microstructure, Hardness, Chips

## I. INTRODUCTION

Aluminium Metal Matrix Composites (AMMC) are used for various engineering applications like aerospace, marine, automobile and mineral processing due to their light weight properties along with remarkable specific strength and thermal properties. In aluminium composites, the properties like high toughness and ductility associated with aluminium matrix are combined with superior properties of ceramics such as high strength and elastic modulus by adding ceramic reinforcements in the base matrix. Alumina ($Al_2O_3$), silicon carbide (SiC) and graphite (Gr) are the most common reinforcing materials which are used in the base aluminium matrix in the form of whiskers or particles. However, particle reinforced composites are simpler from manufacturing point of view. In this research work, alumina in the form of fine particles is used as reinforcement and aluminium silicon alloy is used as matrix.

## II. LITERATURE REVIEW

Major literature on fabrication of aluminium metal matrix composite focused on stir casting process, which is simple and there found almost uniform distribution of reinforcement in the matrix. Stir casting process is simpler than other methods of manufacturing. The frequent reinforcement used in aluminium metal matrix is silicon carbide. The specimens prepared by stir casting are then tested for mechanical properties and for machining characteristics. Belete Sirahbizu Yigezu et al [1] compared the results of the as cast

microstructures and mechanical properties like yield strength, ultimate tensile strength, elastic modulus, percentage elongation, hardness, percentage porosity and fracture characteristic of 5 wt% SiC and $Al_2O_3$ particulate reinforced Al-4% Cu-2.5% Mg matrix composites. A fairly uniform distribution of 50.8 µm $Al_2O_3$ and 49.2 µm SiC spherical particles with some clustering in few areas. The mechanical property test results revealed that, for the same weight percentage of reinforcement, composite exhibit a higher yield strength, ultimate tensile strength, elastic modulus, and hardness, respectively. In $Al_2O_3$ reinforced composite, the percentage elongation was 31% higher than that of SiC reinforced composite. N. Muthukrishnan et al [2] made experimental investigation on the machinability of fabricated aluminum metal matrix composite (A356/SiC/10p) in turning operation. The specific power consumption is less at higher cutting speeds justifying the machining of Al- SiC composites at high cutting speeds. The wear is predominantly due to the abrasive action of the SiC on the tool flank. Higher cutting speeds result in relatively easier removal of the hard SiC particles, resulting in better surface finish. M. El-Gallab et al [3] investigated surface integrity of machined Al:20%SiC particulate metal-matrix composites. Dry high-speed turning tests, at different cutting speeds, feed rates and depths of

IARJSET

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ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 7, Issue 7, July 2020

cut, were conducted. It is found that, surface roughness improves with an increase in the feed rate and the cutting speed, but slightly deteriorates with an increase in the depth of cut. Radhika. N. et.al [4] found that, at higher cutting speeds (300m/min) semi continuous chips were formed with saw toothed tip found in the inner surface of the chip. As the feed rate is increased, keeping the other two parameters constant, the length of the chips increased. The number of curls was also found to increased. C. Kannan, R. Ramanujam & A. S. S. Balan [5] conducted turning on aluminium hybrid nanocomposite specimens and found lower cutting forces under minimum quantity lubrication. They found higher flank wear at high feed rate, which can be reduced using minimum quantity lubrication and observed minimum crator wear at high cutting speeds.

## III. FABRICATION OF AMMC

The Aluminium Metal Matrix Composites(AMMCs) are fabricated by various processes. Liquid state fabrication methods like stir casting, compo-casting, squeeze casting, spray forming, liquid metal infiltration are implemented. Among these methods, it is found that stir casting is simplest and most economical method.

In this work, squeeze casting method is used to prepare specimens. Squeeze casting is a kind of pressurized casting. Pressure is applied on the casting while it solidifies, between liquidous and solidus temperature. Aluminium -Silicon (10.49%) alloy is used as matrix, having the following chemical composition (Table-1).

Table I- Chemical analysis - Test Method: ASTM E 1251: 2011

| Sr.No. | Element | Observed Value |
|---|---|---|
| 1 | % Mn (Mangenese) | 0.32 |
| 2 | % Si (Silicon) | 10.49 |
| 3 | % Cr (Chromiun) | 0.019 |
| 4 | %Ni (Nickel) | 0.065 |
| 5 | %Cu (Copper) | 1.14 |
| 6 | %Sn (Tin) | 0.0030 |
| 7 | %Pb (Lead) | 0.30 |
| 8 | % Al (Aluminium) | REM |
| 9 | %Fe (Iron) | 0.68 |
| 10 | %Zn (Zinc) | 0.52 |
| 11 | %Mg (Magnesium) | 0.037 |
| 12 | Ti (Titanum) | 0.029 |

Aluminium oxide (alumina) in the form of fine powder (1-8 micron) is added as reinforcement in the matrix prepared. Three specimens are prepared. (Fig. 1)

1) Al alloy without reinforcement
2) Reinforcement added without Squeeze
3) Reinforcement added with squeezing

Fig.1- Specimens

## IV. MICROSTRUCTURE

Small pieces of thickness 8 mm are cut from each specimen for microstructure study. All three specimens were mirror polished and etched with $NH_4OH$. Olympus GX series Inverted Metallurgical Microscope with X400 is used for the microstructure study. The images were captured by using attached webcam.

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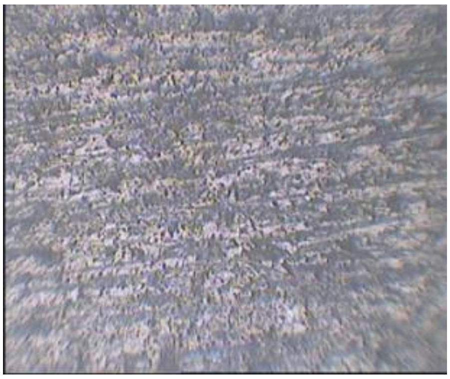

Fig.2 Al alloy without reinforcement

Fig.2 shows the microstructure of Aluminium alloy without any reinforcement which is used as reference for study. Silicon needles are clearly observed in Al-Si Eutectic in the microstructure.

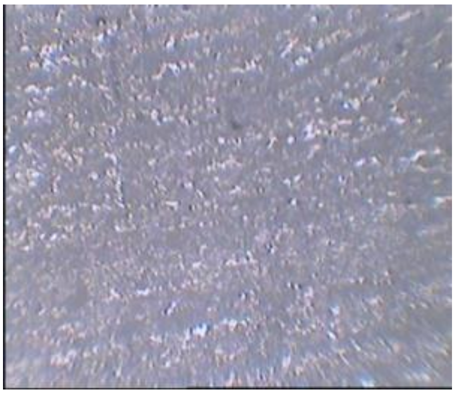

Fig.3 Reinforcement added without Squeeze

Fig. 3 shows the microstructure of the sample in which reinforcement 15 gm alumina powder is added but is not applied with squeezing pressure. In this microstructure, Alumina particles distributed in Al matrix with lineage structure.

Fig.4 Reinforcement added with squeezing

Fig. 4 shows the microstructure of the sample in which reinforcement 15 gm alumina powder is added and is applied with squeezing pressure 83 $kN/m^2$ . Uniform and fine distribution of alumina particles in Al alloy matrix is observed in the microstructure.

## V. HARDNESS

Hardness of three-specimens is tested as per IN1500:2013 with Ball indenter of diameter 10mm & load 1000kg. The hardness are tested on surface of each specimen. Three readings on each specimen are recorded and average hardness is calculated and tabulated in table no.2.

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Table-2: Hardness of Specimens

| Specimen No. | R1 BHN | R2 BHN | R3 BHN | Avg. BHN |
|---|---|---|---|---|
| 1 | 53.7 | 48.3 | 64.5 | 55.5 |
| 2 | 55.7 | 56.8 | 58.1 | 56.36 |
| 3 | 77.8 | 75.4 | 76.0 | 76.4 |

It is observed that the hardness of specimen no.3 is maximum. The average hardness of specimen: 3 is 76.4 BHN. The squeezing in Specimen: 3 increased its hardness 1.3 times.

## VI. FORMATION OF CHIPS

The types of chips formed are related to the material properties and cutting parameters such as speed, feed, etc. Compared to the non-reinforced alloy, chips of different shapes were noted during machining of the MMC


Fig.5 Chip Morphology –Specimen-1


Fig.6 Chip Morphology –Specimen-2


Fig.7 Chip Morphology –Specimen-3

The cutting speed is kept 200rpm, depth of cut 0.5 mm, feed 0.3 mm/rev. The turning operation is carried out without using any cutting fluid.

Average chip length of 10 mm with curly nature were observed in specimen-1 whereas average chip length of 6 mm was observed in specimen-2. At the given speed, chips found were segmented and discontinuous. Easy removal of chips from tool work interface was observed in the specimen-3. Average chip length observed in turning of specimen-3were found 3 mm. The length and thickness of chips were found considerably lower in the reinforced and squeezed specimen.

## VII. CONCLUSION

In the present study, an investigation is performed on three specimens namely,1. Al alloy without reinforcement, 2. Reinforcement added without squeezing and 3. Reinforcement added with squeezing. Major findings of the experimental investigation are presented below.

1. In microstructure of specimen-3, uniform and fine distribution of alumina particles in Al alloy matrix is observed.
2. It is observed that the hardness of specimen no.3 is maximum. The average hardness of specimen: 3 is 76.4 BHN. The squeezing in Specimen: 3 increased its hardness 1.3 times.
3. At the cutting speed of 200 rpm, chips found were segmented and discontinuous. Easy removal of chips from tool work interface is observed in specimen-3. The average chip length observed as 3mm.

## ACKNOWLEDGMENT

Authors are grateful to Pricipal and management of A.G.Patil Institute of Technology, Solapur for permitting to use metallurgy laboratory for microstructure examination.

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