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The Effect of Microstructure, Tensile and Fractographic studies on Al3003-Cenosphere MMCs

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Abstract – The present project is to improve and obtain superior mechanical properties in the stir casting process by attaching an adequate amount of reinforcement i.e., cenosphere in the right quantities Aluminium- Cenosphere alloy is introduced and used for the matrix of composite material attempting to make it light and strong. Cenosphere bolstered Al3003 alloy is prepared using stir casting process and varied proportion of cenosphere. This process composite has varied proportion of cenosphere composite such as Al3003 alloy+3 percent cenosphere, Al3003 alloy+6 percent cenosphere, Al3003 alloy+9 percent cenosphere. The microstructure analysis, tensile test as well as fractography test were conducted for the mentioned specimen mixes.

I. INTRODUCTION

An alloy is a combination of metals or metals combined with two or more metallic components, to provide greater strength or corrosion resistance. Cast alloys and wrought alloys are the major classifications of aluminium alloys, both further subdivided into heat-treatable and non-heat-treatable classifications. Rolled plates and extrusion are examples of the wrought alloy commodity, using 85 percent of aluminium. Traction strength of cast aluminium alloys is lower than wrought aluminium alloy.

A. Classification of Aluminium Alloys

- Wrought Alloy (1xxx)

1xxx works in this series have unthinkable poor consistency, in any case when tension is consolidated; however, they have extraordinarily high moldability and formability, so many can even be worked or framed advantageously.

- Wrought alloy (2xxx)

In this arrangement, Copper gives very extortionate efficiency as the fundamental alloy viewpoint, since it enhances the arrangement and reinforces the potential to precipitate.

- Cast alloy (1xx.x)

In the popular 1xx.x unmixed family household is an aluminium based alloy. A sufficient number of 1xx.x series alloys with a minimum of 99 percent.

- Cast alloy (2xxx)

A composite of a produced aluminium copper family (2xxx series) is used in 2xxx aluminium amalgam. It can be thermal tempera with higher quality that yield less flexibility.

B. Process of Casting

- Stir casting

Many researchers have developed metal matrix composites due to its low cost and effective particle distribution [1-6]. We use stir bar in mixing casting to shake the network of liquid metal. Stirrer is typically made of a substance that is more notable than the temperature of the grid in a mixing phase and is used in a large graphite stirrer. The agitator is composed of two poles and a rotor tunnel. The one end of the pole has an impeller connection, whilst the other end has a shaft connection. The agitator is normally held upright and rotated at rpm via the motor. The resulting liquid metal is then thrown out. Mix tossing is ideal for composites with fortification divisions of up to 30%. One main challenge with the mixing throwing is the shielding of supporting particles in non-homogeneous metal circulation due to a variety of technique limits and material properties [7].

- Rheo casting

The method of rheo casting is a phase. The melted metal is typically cooled or stirred from liquid to semi-strong temperature to create slurry with a globular structure of solid

phase particles, which is immediately injected into the die. In comparison to the Thixo technique, the main advantage of the rheo process consists in the fact that the globular slurry can be made at home and on request. Any general alloy can be forged by other techniques such as pressing, gravity or HPD casting. Added to this is the chemical composition of a solid metallic to conform with excellence and component properties[8].

- Thixo casting

Thixo Casting is fitted with excellent mechanical and capacity properties to manufacture outstanding top-class components. The supplies for billet feeding are typically manufactured in groups of up to 50,000 lbs. Aluminum organizations[9].

- Squeeze casting

Squeeze flinging is a mixture of output, throwing. The best mechanical houses in a cast can be built by this method. In a safer open door for the production of sections of an aluminium alloy which have not yet been reduced to top, the development of the press release method should be used[10].

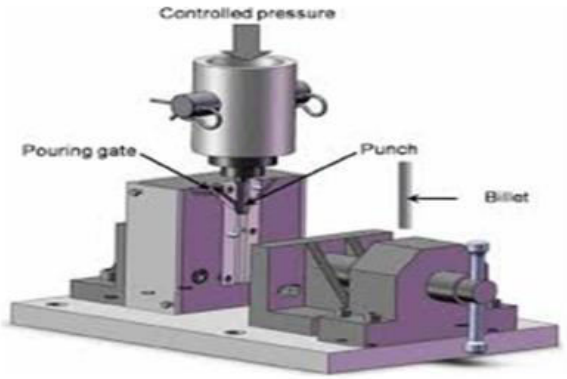


Fig 1. Squeeze casting setup

II. LITERATURE SURVEY

Baradeswaran. et al.,(2013) [11] analysed the influence of B4C on the mechanical and tribological operation of composites Al 7075. The 7075 molecule was strengthened composites by provisioning the K2TiF6 as the flow for solving the B4C wetting and fluid aluminium problem. Thus, the aluminium composites produced in this manner were subjected to T6 thermal treatment. Samples of Al 7075 composites have been tested for stiffness, tensile, compression, bending strength and wear.

Hayun S. et al.,(2015) [12] Response reinforced boron carbide is set up by pressure less invasion of boron carbide preforms with liquid silicon in a graphite heater under vacuum. The presence of Al2O3 parts in the warmed zone, despite the fact that not in contact with the boron carbide preform, makes aluminium show up in the fluid silicon. The arrangement of aluminium sub-oxide (Al_2O_3) remains behind the vehicle of aluminium into the composite..

Kalaiselvan K. et al.,(2017) [13] This work focuses on the production of aluminium (6061-T6) composites frames (AMCs) enhanced by adjusted mixing processes, with different weight levels of B4C particles. By adding K2TiF6 dissolving motion, the wettability of B4C portion of the system has been enhanced.

Lashgari H.R. et al.,(2020) [14] The current study attempted to inspect the effect of heat treatment T6 on the microstructure, the versatile properties and the dry wear behaviour of A356–10% B4C cast composites (arrangement treatment at 5 40 0C for 5 h, extinction in high temperature water and false maturation at 170 0C for 8 h). The perception of worn surfaces has shown precisely mixed layer separation that can be carried out under higher load due essentially to the delamination wear part.

III. RESEARCH OBJECTIVES

A. *Research Objective*

- The objectives of the proposed work can be stated as following:
- Materialization of Al3003/ Cenosphere composites by Liquid metallurgy route.
- Microstructure characterization of the composites by optical microscope
- Valuation of mechanical assets of the composites.
- Evaluation of Wear properties of the composites.
- Comparison of as-cast alloy wear effects and mechanical properties with composites
- Drawing Inference depending on the outcome obtained.

The present study is thus aimed at producing Al-3003 with Cenosphere as reinforcement processed by liquid metallurgy route of these composites in order to achieve mechanical and tribological properties sufficient for a wide variety of engineering applications.

IV. METHODOLOGY

Current study focuses on deeper understanding of aluminium reinforced Cenosphere production (liquid metallurgy route) and the mechanical properties of Cenosphere Composites improved by Al-3003. The goal of the work is to allow the material in automotive and other technical sectors to meet the number of tribological applications.

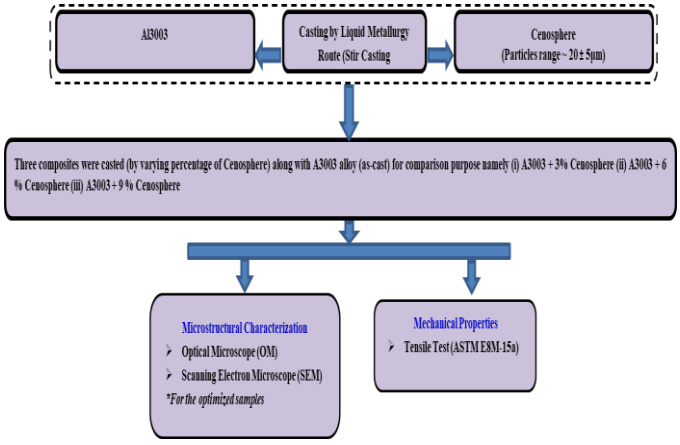


Fig 2. Methodology Flowchart

V. EXPERIMENTAL DETAILS

A. Material Selection and Sample Preparation

Al 3003 having adequate strength, good corrosion resistance, and good workability is having chemical composition given in Table 1. Also, cold work increases the strength of this alloy.

Table 1. Chemical Composition of Al3003 alloy (Wt.%)

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others	Remaining
3003	0.6	0.7	0.05-0.2	1.0-1.5	---	0.05	0.10	0.05	0.05	Aluminium

- Physical properties of Al3003

Table 2.Physical properties of Al3003 alloy

Properties	Metric	Imperial
Density	2.73 g/cm^3	0.0939 lb/in^3
Melting point	644°C	1190°C

- Thermal properties of the Aluminum/Aluminium 3003 alloy

Table 3. Thermal properties of theAluminium/Aluminium 3003 alloy

Properties		Conditions	
		T (°C)	Treatment
Thermal expansion co-efficient	23.2 (10^{-6}/°C)	20-100	-
Thermal conductivity	162 W/Mk	25	H12

B. *Cenosphere as Reinforcement Material*

A cenosphere is a compact, ambient, hollow bubble, mostly of silica and alumina, with air or inert gas produced in thermal plants, usually used as a fire sub product. Cenospheres are now used to manufacture low-density concrete as cement fillers.

Fig 3. (a) Cenosphere Powder (b) SEM of Cenosphere Powder

C. *Microstructure Study*

Essential Description: To uncover its microstructure, ASTM E407 is a technique for scratching a metal example. Metal is comprised of a few grains for a tiny scope that may vary in structure and size. Alloying components frequently partition into little particles with independent structures in the composite. It is conceivable to examine this microstructure by introducing cross-separating and cleaning as indicated by ASTM E3 followed by carving as per ASTM E407.

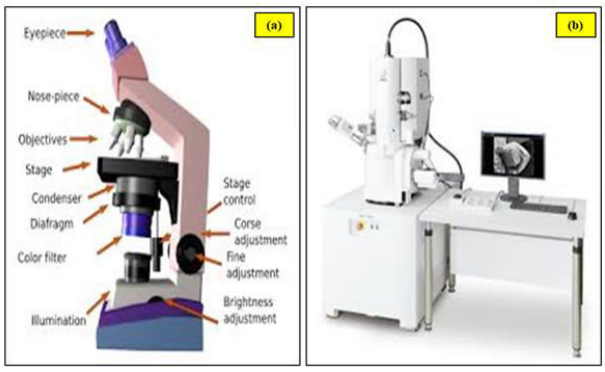


Fig 4. (a) Optical Microscope (b) Scanning Electron Microscope

D. *Tensile Test*

The most common exploration apparatus for deciding the elastic properties of metallic materials is ASTM E8/E8M. It was initially called ASTM E8 and was first distributed in 1924 and is the most established effectively utilized norm for metal testing. ASTM E8 has likewise gone through ordinary, slight enhancements, similarly as with most standards. Be that as it may, recently, one of these enhancements has been significant. ASTM E8/E8 M was part into two distinct principles preceding 2011: E8 for clients of royal units and E8 M for clients of measurements.

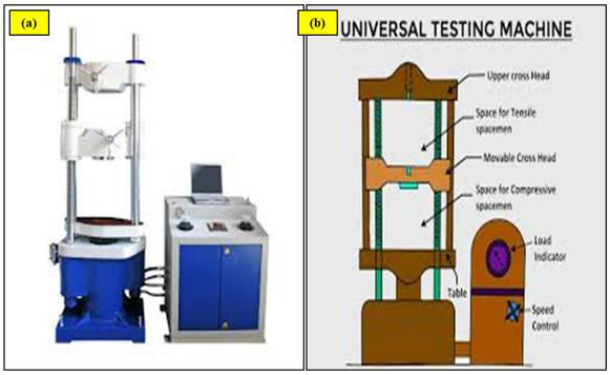
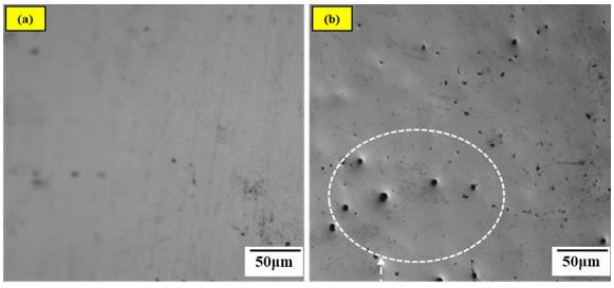


Fig 5. (a) Universal Testing Machine (b) UTM Line Diagram

VI. RESULTS AND DISCUSSION

A. *Microstructure Analysis of Al3003/Cenospheres Composites*



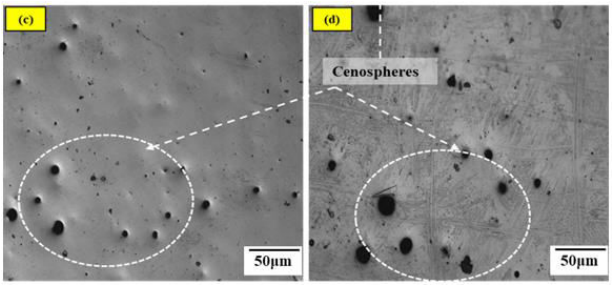


Fig 6. Microstructure Characterization of Al3003- Cenospheres MMC's using Optical Microscope.

From the Fig 6 (b to d) we can see the even dispersal of Cenospheres (CNP) in the Al3003 matrix with least porosity or any casting defects in the Al3003 alloy and its composites. By the Figure 6 (b) we see few Cenospheres particles distributed in Al3003 matrix. Compared to Figure 6 (b) and (d), Figure 6 (c) shows more Cenospheres particles distributed in Al3003 matrix. This comment is in accord with several examinations [15].

B. Tensile Test Results of Al3003-Cenosphere MMC'S.

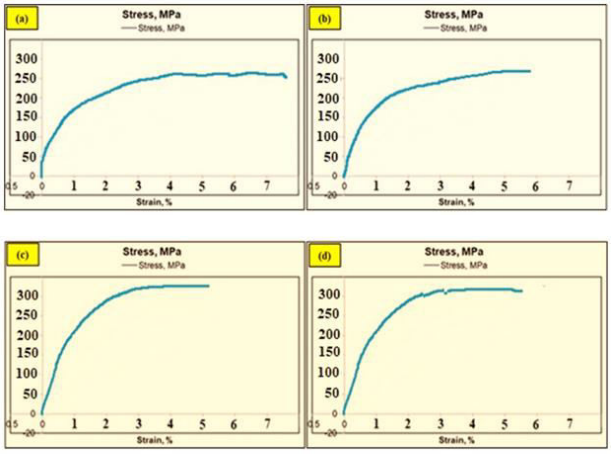


Fig 7. Stress Strain curve of Al3003/Cenosphere MMC's

Table 4. Tensile test values (UTS) of Al3003/Cenospheres composites.

S/No	Alloy/Composite	Ultimate Tensile Stress (UTS)		% Improvement in UTS
		Strain rate (mm/s)	UTS (MPa)	
1	As-Cast (Al3003 alloy)	0.20	250.01	----
2	Al3003 alloy + 3% C_{NP}	0.20	261.15	4.455
3	Al3003 alloy + 6% C_{NP}	0.20	305.18	22.06
4	Al3003 alloy + 9% C_{NP}	0.20	295.57	18.22

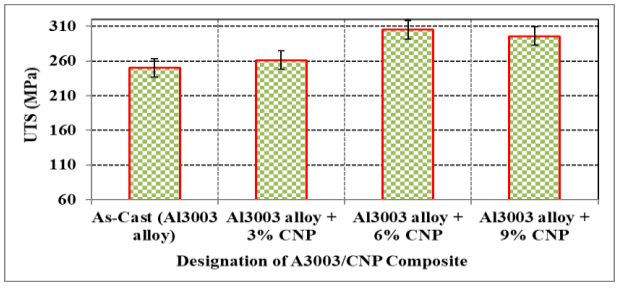


Fig 8. Tensile test values (UTS) of Al3003-Cenospheres MMC's

Figure 8 expounds the tensile test results (UTS) of Aluminium 3003- Cenospheres MMC's. From Figure 5.5 it shows that the strength increases along with of increase in Cenospheres particles in the A13003 matrix material. when compared to As-Cast (3003 alloy), Al 3003 alloy + 3% CNP increase in strength of 11.14 MPa (4.45 %), Al 3003 alloy + 6% CNP increase in strength of 55.17 MPa(22.06 %) and Al 3003 alloy + 9% CNP increase in strength of 45.56 MPa (18.22 %). By the figure we can see that as reinforcement ratio of Cenospheres increases up-to 6 % there is an increase in strength , once the reinforcement is increased further i.e., from 6 % to 9 % there is a drastic decrease in strength . This may be due to the clustering of CNP in the Al3003 matrix. By the figure we can see that as the ratio of Cenospheres is increases the composite strength also increases. Similar observations were made by several researchers [16].

C. Fractographic Analysis of Al3003/Cenospheres MMC'S

Figure 9 shows the Tensile surface fractography of Al3003/Cenospheres MMC's , where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% Cenospheres (c) Aluminium 3003 alloy + 6% Cenospheres (d) Aluminium 3003 alloy + 9% Cenospheres. Figure 9 (a) shows the fractography surface with few microcracks in them along with alpha dendrites. Figure 9 (b) and (c) shows the fractography surface with few microcracks in them along with cleavage surfaces. Figure 9 (d) shows the fractography surface with few micro cracks in them. Overall, it can be analysed that as-cast alloy undergoes ductile fracture and Al3003- Cenospheres composites shows brittle fracture. Similar observations were made by several researchers [17].

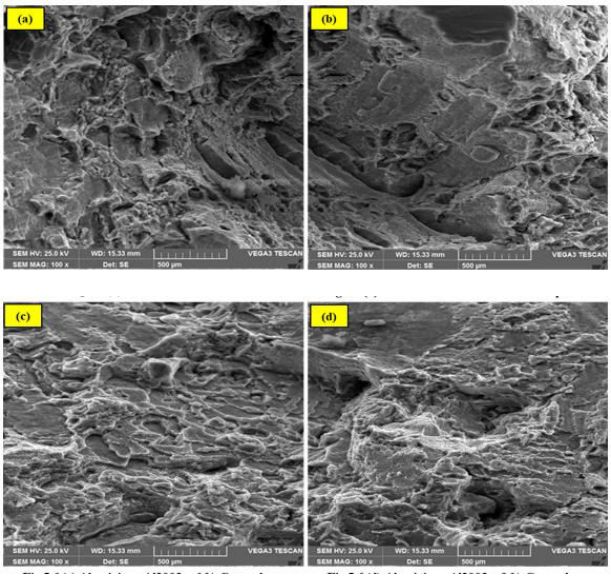


Fig 9. Tensile surface Fractographs of Al3003-Cenospheres MMC's

VII. CONCLUSION

The Optical Micrographs of polished specimens were observed such that even spread of CNP is found on the Al3003 alloy.CNP Particles performed with the Al3003

matrix as virtuous moistening that added to the improvements of mechanical and wear properties.

As the ratio of CNP particles increases in the matrix the ultimate tensile strength UTS of Al3003 alloy increases upto 6 % and there is a slight dip in strength when percentage increases to 9 %. The dip in strength may be due to clustering of CNP particles in Al3003 matrix. Also, improvement in strength is due to fact that CNP particles act as load bearing materials.

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