The effect of Hardness and Wear properties on Al3003 and Cenosphere alloys

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***Abstract* –** The present project is to improve and obtain hardness test and wear test 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 (C_{NP}). This process composite has varied proportion of cenosphere composite such as Al3003 alloy+3 %C_{NP}., Al3003 alloy+6 % C_{NP},Al3003 alloy+9 % C_{NP}. The hardness test and wear test were conducted for the mentioned specimen mixes. From the results it was inferred that Al3003 alloy + 6 % C_{NP}gave superior hardness and wear properties compared to Al3003 alloy + 9 % C_{NP}.

I. INTRODUCTION

An alloy is a mixture of metal or minerals paired with two or more metal parts to provide greater strength or resistance to corrosion. Cast alloys and wrought alloys are the major classifications of aluminium alloys, further subdivided into heat-treated and non-heat-treated classifications. Rolled plates and extrusion are examples of the manufacture of alloys using two - thirds per cent aluminium. The tensile strength of cast aluminium alloys is lower than that of wrought aluminium alloys. The low melting point of the cast aluminium alloy produces cost-effective goods. The most basic combination machine for solid aluminium is aluminum-silicon, with exorbitant types of silicon (four to thirteen per cent) committed to flexibly ideal throwing attributes. Aluminum amalgams are widely used in the development of buildings and components requiring obstruction of consumption or low weight. Created aluminium composite is used in the forming process as cast aluminium combinations come after long-lasting grinding, sand throwing, constant throwing, throwing, tossing, flinging, and chucking out. [1-5].

II. LITERATURE SURVEY

A. Canakci et al.,(2014) [6] In this research, the micro-structure and abrasive wear properties of a fluctuating portion of B_4C particles of up to 12 percent were investigated in 2014 for aluminium alloy metal gauze composites developed by an aluminium stir casting technique. Further analysis of mass, porosity and composite hardness is carried out. For the wearing actions of the hardened aluminium composites from the B_4C molecule, a block-on-disc abrasion test device was used, which included example slips to the row (10% SiC with 90% oil) at room level. The wear tests for a new three body rough were conducted on the grating suspension mixture with 92 N. The wear activity was measured by the volume tragedy and explicit rate of examples and the effects of sliding time, and contents of B_4C particles on the raw wear characteristics of the composites. The main instrument of wear was known as SEM. Minute perception of the microstructure shows that the dispersion of B_4C particles is consistent in general, since volume expansion leads to the conglomeration of particles and porosity. With the increasing volume distribution but with the increasing molecular content the porosity and hardness have improved, the composite thickness has reduced. In comparison, with a growing volume division of the molecule the composite real wear rate decrease. It has been shown that the wear block is much higher relative to the network compound, and the molecular content is increasing.

Yuhai Dou et al.,(2014) [7] B_4C/6061Al composite was focused on grinding and wearing activities by

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 12 | Dec -2020 ISSN: 2582-3930

considering the effect of slipping time, the load added, sliding speed and heat treatment. The findings indicate that the mass misfortune and grinding coefficient (COF) improve considerably as the sliding period, applied burden and sliding speed achieve basic qualities (to be 120 mins, 30 ms^{-1} and 240 rms separately). The fundamental wear method after a sliding phase for 120 minutes and under an applied heap of 30 N is extreme delamination wear. Wear happens at a pace of 240 rpm during worrying wear. The composite exhibits the most unusual wear opposite due to ms^{-1}(Mg_2-Si) precipitation at the network and the strong interface between B_4C and the grid compound, after the structure is treated at 550^0C for 1 Hour and later matured at180^0C for 15 Hours.

Ipek R. (2016) [8] Adhesive wear attributes of 4147 Al/B_4C, 10, 15 and 20 wt.% B_4C molecule and Al/SiC metal framework composites 20 wt.% SiC contain created by fluid metallurgy have been explored under the dry sliding conditions and their wear practices are contrasted and 4147 Al/SiC-fortified 20 wt.% SiC. The outcomes indicated that the wear opposition of Al/B_4C lattice increments impressively with expanding wt.% B_4C molecule content in Al combination framework. At the point when Al amalgam network material is in serious glue rough wear, the Al/B_4C composites are in light-mellow cement wear stage at a similar wear condition. B_4C substance and its conduct in Al network is resolved factor for wear rate and component of the MMC. The connection between the wear opposition and wear system is likewise watched, and it relies upon salability of B4C molecule by the grid. At the point when Al/B_4C wear conduct is contrasted and Al/SiC MMC, Al/SiC wear oppose is high, and the well-used example of Al/SiC just shows a light glue wear follows a similar condition.

Kumar Paras and Ravi Parkash (2019) [9] This review explores the effect on material evacuation rate (MMR), anode wear rate (EWR) and surface hardness (SR), during Al–B4C manufacturing, of electronic release machinery (EDM) measuring boundaries (current pulse-on-time (sound), time-off (toff) and terminal materials. In view of its different cycle and reaction borders, function, and machinery content in accordance with their volumes, dielectric fluids and distinctive advancement methods used this article sum up a concisely defined writing audit of aluminium metal matrix composites (Al-MMCs). The MMC used during the current work is a combination that uses 5% (wt) B_4C particles of a size of 50 microns in the metal grid Al 6061. The Taguchi approach is used by the research plan (L9-symmetric exhibit), and the test outcomes are split by the transition study. The Reaction table indicates that the current factor for MRR and SR is the largest, while the anode content is normally critical for EWRs, for norms of estimation MRR, EWR and SR. ANOVA also notes identical findings. It is also found that the optimal period limits for the largest MRR are A3B1C3D3, A1B2C3D1 and A1B3C3D3 for the least EWR.

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.
- Evaluation of Hardness properties 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[10].

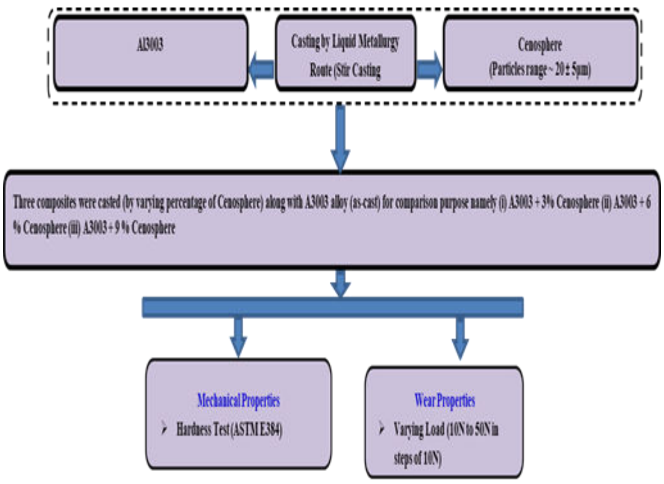


Fig 1. Methodology Flowchart

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 2. (a) Cenosphere Powder (b) SEM of Cenosphere Powder

C. *Hardness Test*

The Vickers hardness test is likewise known to be simpler to use than different hardness tests: the technique should be possible on a widespread or miniature hardness analyser; the estimations required are free of the size of the indenter; and for all parts, independent of the hardness, the equivalent indenter (a pyramidal precious stone) can be utilized. Despite the miniature hardness analyser that you use, the space can twist the hidden material and change its properties when you run a Vickers hardness test. The necessities of Vickers hardness research suggest a specific stretch between a few spaces to forestall misinterpretations of saw hardness[11].

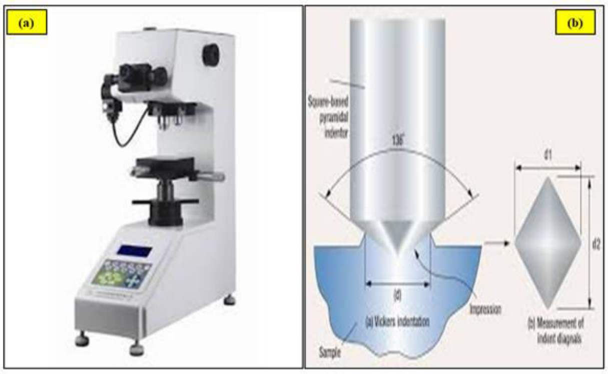


Fig 3. (a) Vickers Hardness Test (b) Vickers Indentation

D. *Wear Test*

The pin-on - disc evaluation method was used in this analysis for tribological portrayals. The test convention is The pin surface has been smoothed at first with the end objective to preserve the heap in the cross-face, which is the key step. In the following process and second stage before the Run-in-wear measurement was carried out the surface areas of the pin test soil using emery paper (80 coarseness). A strategic distance from this point is preserved in the first aggressive stage, compatible with touch and wear curves. The last stage/third stage is the true appraisal called clear wear. This is the severe rivalry between the processes of material exchange (movement and potential evacuation of material from the pin to the plate and wear flows and jetsam). Both pins and circles were washed out with cotton with ethanol before the testwas conducted[12].

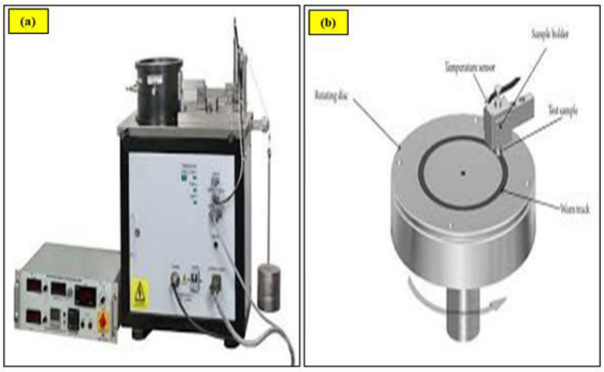


Fig 4. (a) Wear Testing Machine (b) Line Diagram of Wear Disc

VI. RESULTS AND DISCUSSION

A. *Hardness Test Results of Al3003/Cenospheres MMC's*

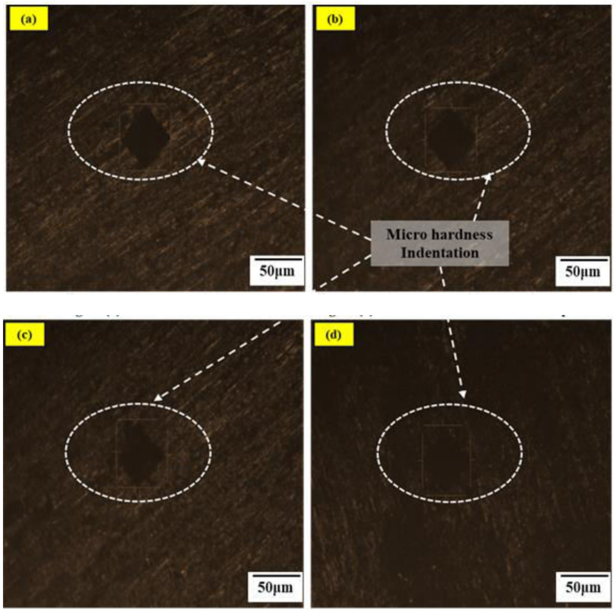


Fig 5. Vickers Micro hardness test optical microscope images of Al3003/Cenospheres MMC's.

Table 4. Hardness test values of Al3003/Cenospheres composites.

S/No	Alloy/Composite	Hardness			% Improvement in Hardness
		Diagonal X(mm)	Diagonal Y(mm)	VHN	
1	As-Cast (Al3003 alloy)	0.105	0.104	70.1	----
2	Al3003 alloy + 3% C_{NP}	0.107	0.103	76.3	8.84
3	Al3003 alloy + 6% C_{NP}	0.106	0.107	79.2	12.98
4	Al3003 alloy + 9% C_{NP}	0.102	0.100	77.7	10.12

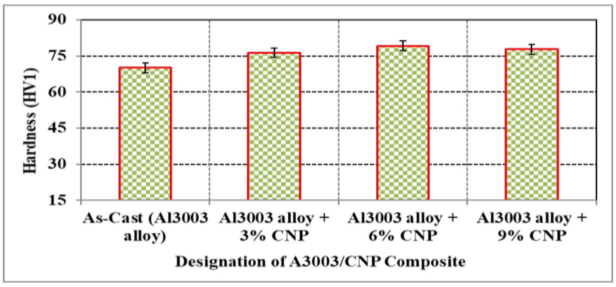


Fig 6: Hardness test values of Al3003/Cenospheres MMC's

Figure 6 expounds the hardness test results of Aluminium 3003-Cenospheres MMCs. From Figure 7 it shows that hardness of the composite increases with Cenospheres particles increase in A13003 matrix material. when compared to As-Cast (3003 alloy), Al 3003 alloy + 3% Cenospheres increase in hardness of 6.2 VHN (8.84 %), Al 3003 alloy + 6% Cenospheres increase in hardness of 9.5 VHN (9.1 %) and Al 3003 alloy + 9% Cenospheres increase in hardness of 7.6 VHN (10.12 %). By the figure we see that as the reinforcement ratio of Cenospheres increases up-to 6 % there is an increase in hardness, once the reinforcement is increased further i.e., from 6 % to 9 % there is a drastic decrease in hardness. This may be due to the clustering of Cenospheres in the Al3003 matrix. By the figure see that as the ratio of Cenospheres is increases there is an increase in hardness of composite . Similar observations were made by several researchers [13-15].

B. Wear Test Results of Al 3003- Cenospheres MMC'S

Table 5. Wear test values of Al3003- Cenospheres composites.

S/No	Alloy/Composite Designation	Wear rate ($mm^3/mx10^{-3}$) v/s Load (N)				
		10	20	30	40	50
1	As-Cast (Al3003 alloy)	1.542	1.545	1.551	1.554	1.559
2	Al 3003 alloy + 3% C_{NP}	1.535	1.538	1.541	1.544	1.547
3	Al 3003 alloy + 6% C_{NP}	1.524	1.529	1.533	1.545	1.551
4	Al 3003alloy + 9% C_{NP}	1.528	1.531	1.538	1.543	1.547

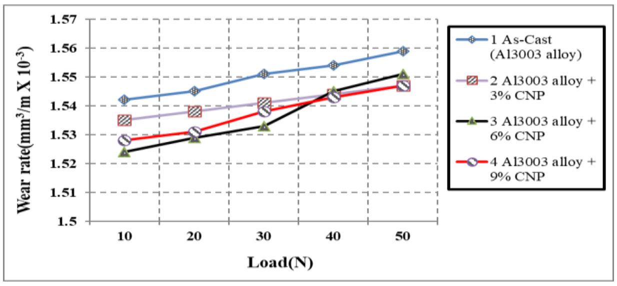
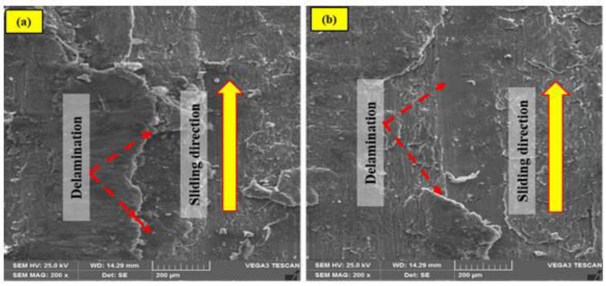


Fig 7. Wear rate (mm3/m) v/s Load (N) of Al3003-Cenospheres composites.

A figure 7 show that as the load increases the wear rate also increases. Highest wear rate is to the Al3003 alloy of 0.1542 x 10-3 mm3/m for 10N and 0.1559 x 10-3 mm3/m for 50N. Al3003 alloy + 3% CNP i.e. 0.1535 x 10-3 mm3/m for 10N and 0.1547 x 10-3 mm3/m for 50N is the moderate wear rate. Followed by Al3003 alloy + 9% CNP i.e. 0.1528 x 10-3 mm3/m for 10N and 0.1547 x 10-3 mm3/m for 50N. Least wear rate is in Al3003 alloy + 6% CNP i.e. 0.1524 x 10- 3 mm3/m for 10N and 0.1551 x 10-3 mm3/m for 50N. CNP particles act as load bearers to avoid the wearing out of the matrix [16-18].

C. Wear Surface Morphology of Al3003- Cenospheres MMC's



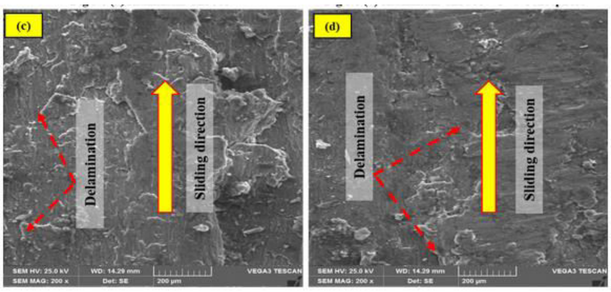


Fig 8. Wear surface Morphology of Al3003-Cenospheres MMC's.

Figure 8 shows the Wear surface Morphology images of Al3003-CNP MMCs, where (a) As- cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% CNP (c) Aluminium 3003 alloy + 6% CNP (d) Aluminium 3003 alloy + 9% CNP. From the Figure 8 (a) we can see more delamination surface which is due to the lower hardness and higher wear rate due to the absence of reinforcing material i.e., CNP as shown in section 5.1 and 5.5. Moderate delamination of wear surface can be found out in Figure 8 (b) followed by Figure 8 (d). Least delamination was found out in Figure 8 (c). These observations are in accord several researchers [19-20].

VII. CONCLUSION

As the ratio of CNP particles rises in the matrix the hardness of Al3003 alloy rises gradually as the reinforcement percentage increases upto 6 % and there is a slight dip in hardness when percentage increases to 9 %. The dip in hardness might be because of clustering of CNP particles in Al3003 matrix. Also, improvement in hardness is due to fact that CNP particles act as load bearing materials.

The rate of wear of the Al3003 reinforced composites is less than the as-cast Al3003 alloy. Highest wear rate is for Al3003 alloy, moderate wear rate is for Al3003 alloy + 3% CNP and least wear rate is for Al3003 alloy + 6% CNP.

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