PARAMETRIC STUDY ON MECHANICAL & TRIBOLOGICAL PROPERTIES OF ALUMINIUM METAL MATRIX COMPOSITES

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ABSTRACT

Over the last thirty years composite materials, Plastics & ceramics have been the dominant emerging materials. The volume & number of applications of composite materials have grown steadily, penetrating & conquering new markets relentlessly. In view of above fact and understanding the importance of application of Aluminum Matrix composites, I have carried out work involving formation of Aluminum alloy (Al6061) with Titanium di boride (TiB_2)&Alumina (AL_2O_3) metal matrix composites. The present study is aimed at evaluating the mechanical & tribological properties of Aluminums 6061 alloy in the presence of Titanium di boride and alumina reinforcements. The composites are prepared by stir casting technique .They are casted in 0%,3%,6% &9% weight fractions of reinforcement. They are fabricated & tested to evaluate the various mechanical & tribological properties.

Keywords: Titanium Di Boride, Aluminum, Stir Casting, Taguchi Analysis

I. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. In matrix-based structural composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force.

Metal Matrix Composites are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase. Metal matrix composites (MMCs), as the name implies, have a metal matrix.

Metal matrix composites (MMCs), as the name implies, have a metal matrix.Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminum and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications.

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II. LITERATURE SURVEY

The superior property of composite materials over the conventional materials has been acknowledged by the research community. Now a day's AMC's are commonly used in automobile, aerospace, ship building industries and nuclear plants etc. In order to understand the nature and morphology of AMC's and their behavior, the literature survey has been focused on the mechanical properties and various influencing factors such as volume fraction, microstructure, homogeneity and isotropy of the matrix and reinforcements as well as the shape, size and amount of individual

Suresh et al. [1] has faced various challenges in preparation of Aluminum Al6063-Titanium Diboride composite. In his study, he has discussed the parameters affecting of the TiB_2 particles like holding time, temperature etc. G.Shaikshavali et.al.[2] has investigated the effect of age hardening on tensile characteristics in MMC's reinforced with ceramics particulates. A.R.Ravikumar et al.[3] has investigated about the parametric optimization of squeeze Cast AC2A-Ni coated SiC_p composite using Taguchi technique.

S.Rama Rao et al.[4] has investigated that the stir casting processed samples exhibits improved mechanical properties through various tests.C.Neelima Devi et al.[5] studied the micro-structural aspects of aluminum Silicon Carbide Metal Matrix Composite. H.C.Anilkumar et al.[6] studied the mechanical properties of fly ash reinforced aluminum alloy (Al6061) composites.

Antaryamini Mishra et al.[7] performed wear investigations of Al-SiC_p-Fly Ash Composites. He also found the effect of these parameters on co-efficient friction. D.Sujan et al.[8] studied physio-mechanical properties of Aluminium Metal Matrix Composites reinforced with Al_2O_3 and Sic.

Zeeshan Ahmad et al.[9] studied tribological and mechanical properties of Aluminium metal matrix composites manufactured by different routes.

Suryanarayanan.K et al. [10] examined the use of Silicon Carbide Reinforced Metal Matrix Composites for Aerospace Applications. Muruganandhan.P et al.[11] investigation reveals that the fly ash plays a key role in enhancing the mechanical properties.

Venkatesh.D et al.[12] studies reveals that increased better mechanical properties along with reduction in weight and cost.in AMC's

Sri Prayer et al.[13] investigated& concluded that mechanical properties of Aluminium 6061 reinforced with SiC and Al_2O_3.Exhibits better properties on comparison with base alloy.N.Radhika et al.[14] through her study, she concludes that sliding distance have greater influence on the wear rate.

A.K.Senapati et al. [15] studied the mechanical behavior of Aluminium Matrix Composite reinforced with untreated and treated Waste Fly Ash.

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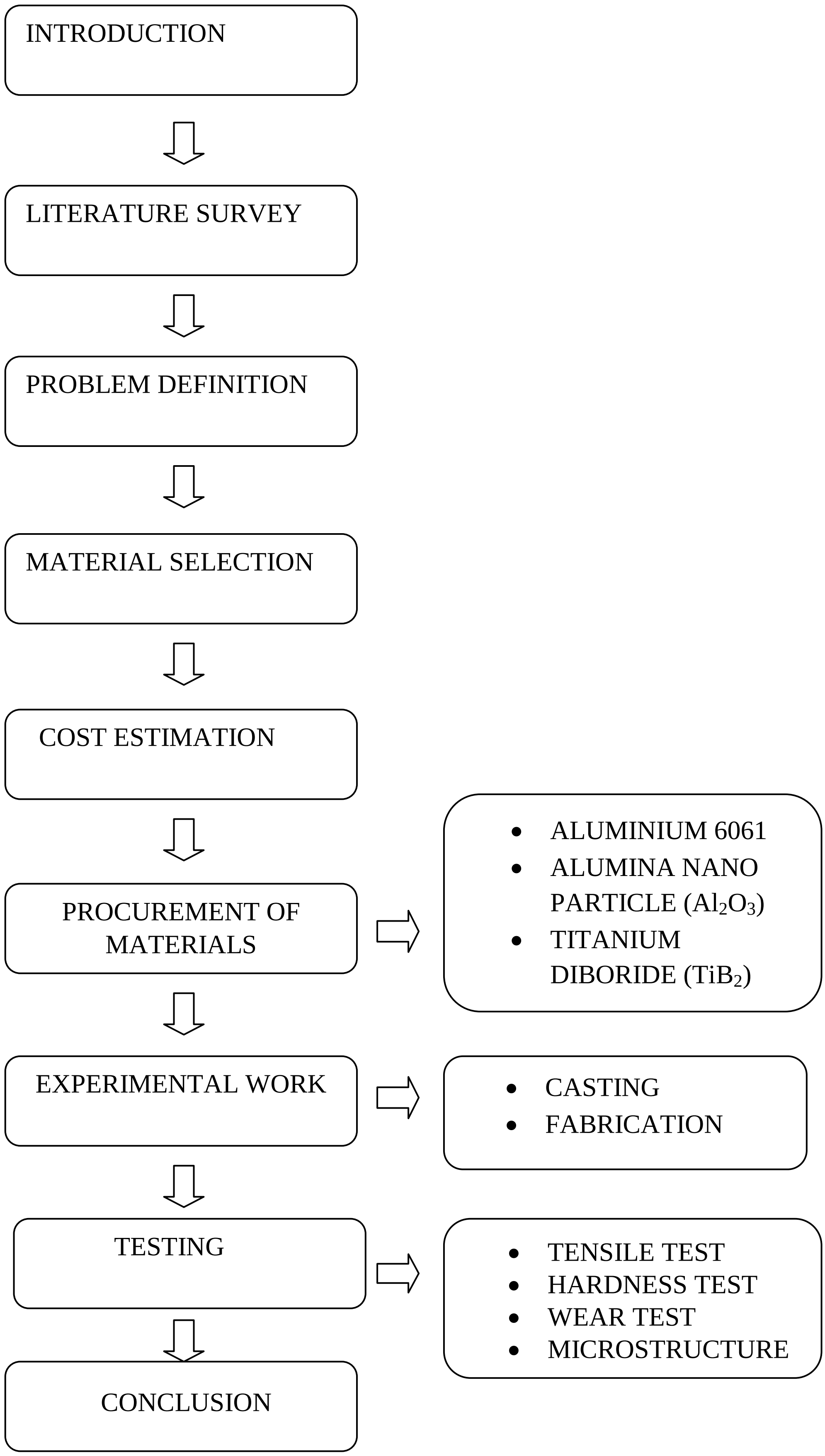
III. METHODOLOGY



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IV. EXPERIMENTAL STUDY

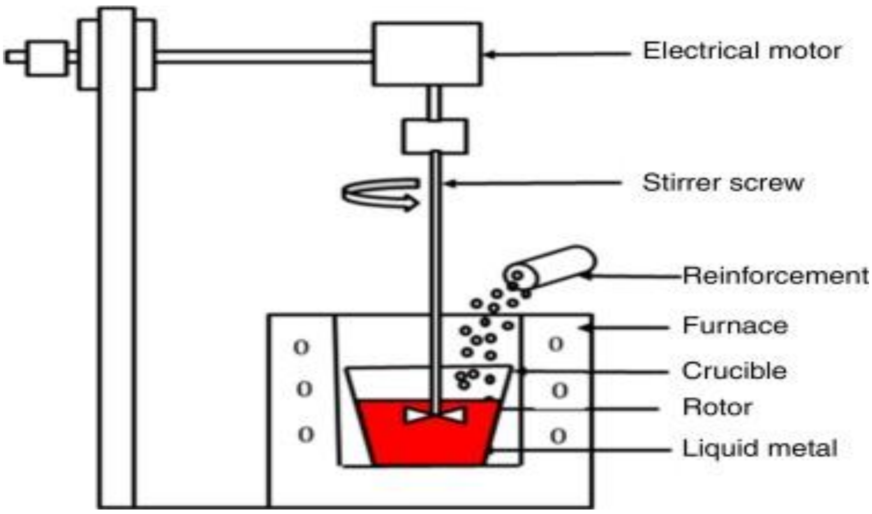
Liquid stte fabrication of Metal Matrix Compositesinvolves incorporation of dispersed phase into a molten matrix metal, followed by its solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained.The methods of liquid state fabrication of Metal Matrix Composites are Stir Casting, Compo Casting, Squeeze Casting, In Situ Casting, and Ultrasonic Assisted Casting.

V. STIR CASTING

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring.

Stir casting is characterized by the following features:

- Content of the dispersed phase is limited (usually not more than 30 volume %)
- The technology is relatively simple and of low cost.



VI. FABRICATION

Amongst different processing techniques discussed earlier in chapter “Processing of aluminium matrix composites” liquid state process, stir casting is employed for this present work. The major components of the casting process consist of electrical resistance furnace, ceramic coated chromium steel impeller and permanent moulds. The power rating of electrical furnace used was 60 kW, 440V and maximum temperature limit was 1000ºC.The mechanical stirrer used for stirring the molten alloy during the preparation of composites was made of chromium steel blades coated with aluminize to withstand high temperature and to prevent migration of ferrous ions from the stirrer material into the aluminium alloy melt. The permanent type of mould boxes made of cast iron used in the fabrication.

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Fig 1

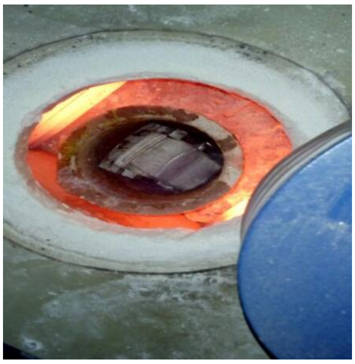

Fig 2

The ingots were charged into the furnace for melting. The melting point of aluminium alloy is 660°C. The melt was superheated to a temperature of 730°C. The temperature was recorded using a chrome-alumel thermocouple. The molten metal was then degassed using hexachloroethane (C2Cl6) for 5 min. A stainless steel impeller or stirrer coated with aluminize was used to stir the molten metal and to create a vortex. The aluminize coating is necessary in order to prevent the migration of ferrous ions from the stirrer material to the melt .The stirrer was rotated at a speed of 300-500 rpm and a vortex was created in the melt shown in.

The depth of immersion of the impeller was 60 % of the height of the molten metal from the surface of the melt. Both the reinforcements Al_2O_3 and Tib_2 nano particles were preheated in a furnace were introduced into the vortex. Stirring was continued until interface interactions between the reinforcement particulates and the matrix promotes wetting. Then at superheat temperature, poured into the preheated dies at 200°C.Hence by stir casting process the composite was fabricated successfully.

Fig 3: Preparation of INGOTS

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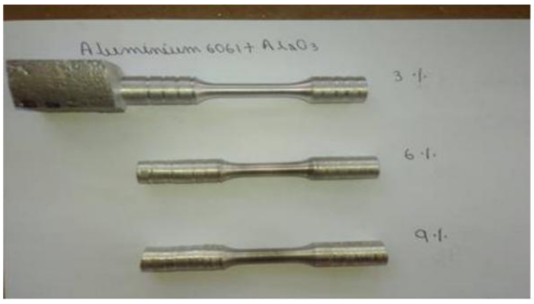
V. TEST SPECIMEN

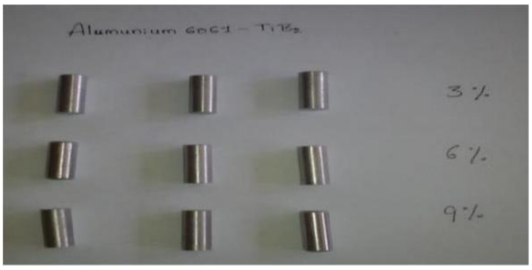
ASTM codes	Test Specimen
ASTM E8	Tensile test
ASTM E10	Brinell hardness test
ASTM	Scanning Electron Microscopy
ASTM En-8	Wear test

The specimens are as shown in the following figures shown below,

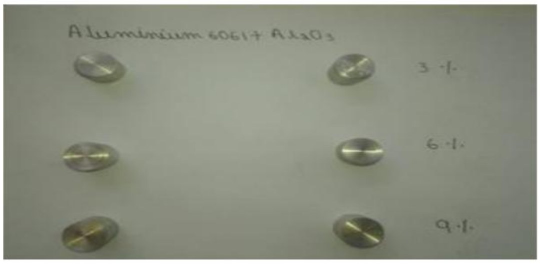
Composite1 Composite2

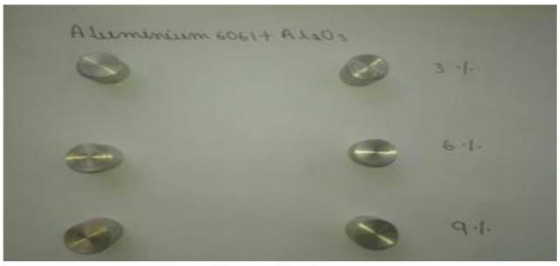


Tensile specimens



Wear specimen





Hardness specimen

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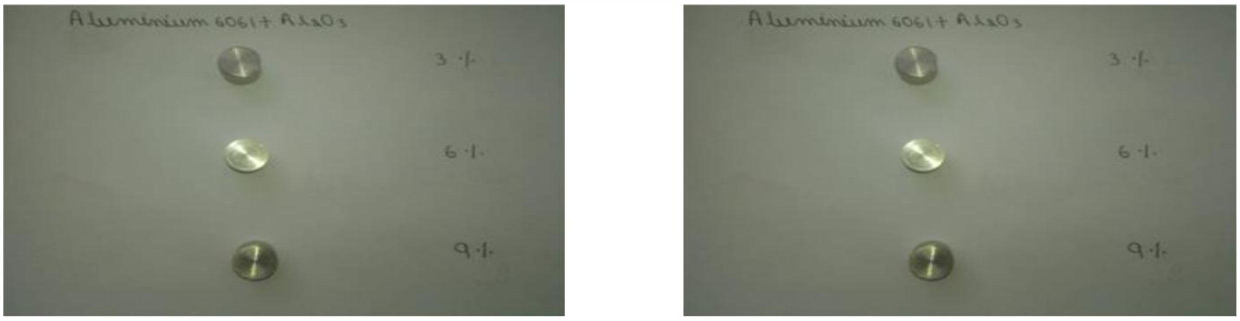

Fig 4: Test specimens

VI.TESTING

6.1.Tensile test:

The tension test specimens machined as per ASTM E8M standards were tested at room temperature in a Universal Testing Machine.

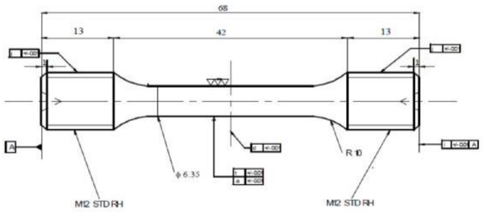

Fig 5: Computerized UTM **Fig 6: ASTM E8 specimen sketch**

The mechanical properties such as YS (Yield strength), UTS (Ultimate tensile strength), and % Elongation (ductility) were obtained from the data acquisition system of the machine.

6.2. Brinell Hardness test

The hardness tests were conducted as per ASTM E10 norms using Brinell hardness tester. Tests were performed at randomly selected points on the surface by maintaining sufficient spacing between indentations and distance from the edge of the specimen.

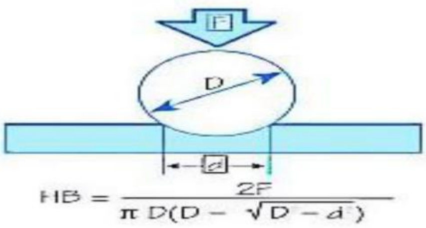

Fig 7: Hardness Testing Machine

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A Brinell hardness result measures the permanent width of indentation produced by a carbide indenter applied to a test specimen at a given load, for a given length of time. Typically, an indentation is made with a Brinell hardness testing machine and then measured for indentation diameter in a second step with a specially designed Brinell microscope or optical system.

6.3 Scanning Electron Microscope:

In scanning electron microscopy (SEM) an electron beam is focused into a small probe and is raftered across the surface of a specimen.

- Several interactions with the sample that result in the emission of electrons or photons occur as the electrons penetrate the surface.
- These emitted particles can be collected with the appropriate detector to yield valuable information about the material.
- The most immediate result of observation in the scanning electron microscope is that it displays the shape oof the sample. The worn surfaces of as-cast alloy and MMCs were observed through Scanning Electron Microscope (SEM).

T

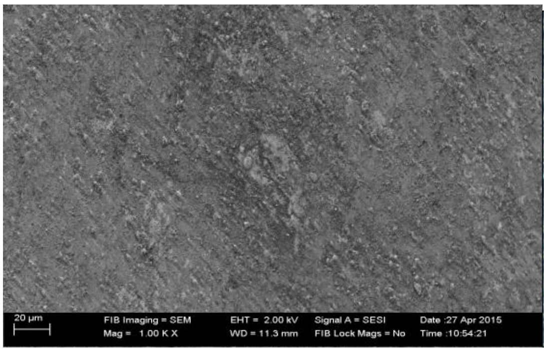
Fig 8: JOEL Scanning Electron Machine

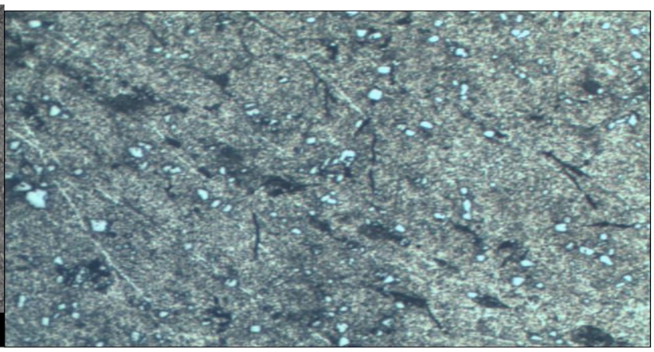
VII. RESULTS

7.1 Microsturucture Test

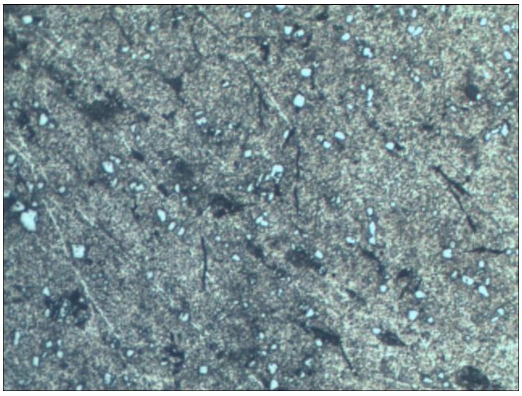
The samples for microstructure examination were prepared by following standard metallurgical procedures, etched in etchant prepared using 90 ml water, 4ml of HF, 4ml H_2SO_4 and 2gm CrO_3 and were examined using Optical Microscope.

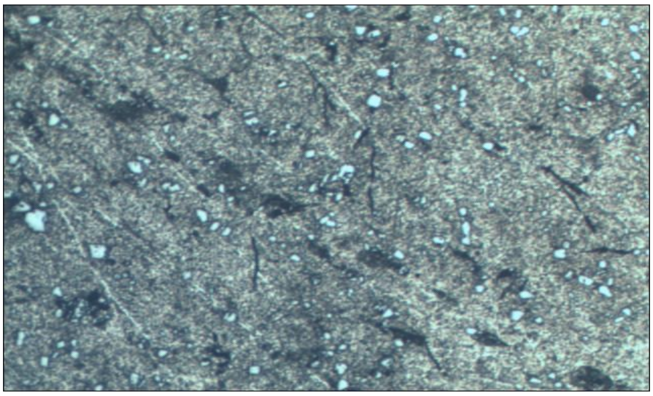
AL6061-TIB$_2$ SAMPLES





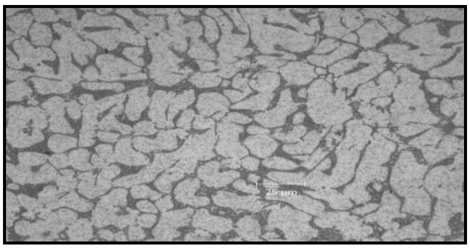
ASCAST AL ALLOY **3% Wt of TiB$_2$**

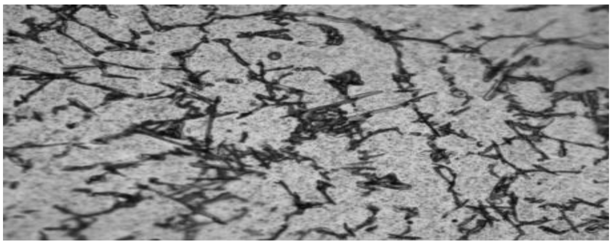




6% Wt of TiB$_2$ **9% Wt of TiB$_2$**

AL6061 –AL$_2$O$_3$ SEM PHOTOGRAPHS





VIII. TENSILE TEST

The tension test specimens machined as per ASTM E8M standards were tested at room temperature in a Universal Testing Machine. The test results are as follows-

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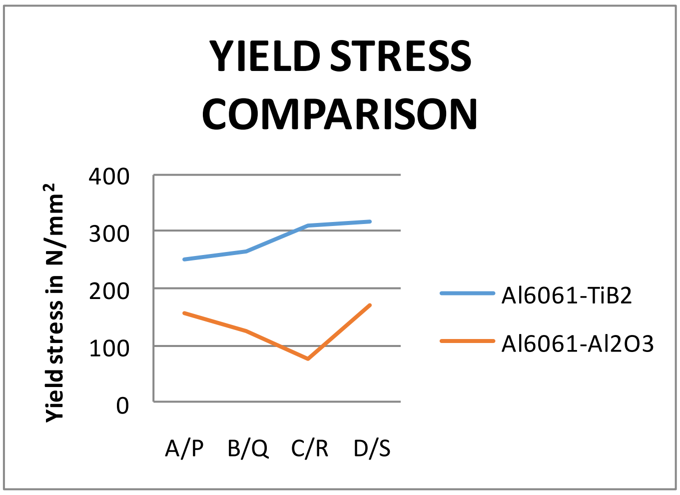
Al6061-TIB$_2$

Specimen designation	**Ultimate Tensile strength (N/mm^2)**	**Yield stress (N/mm^2)**	**% Elongation**
A	281.975	249.645	17.6
B	282.765	263.28	16.55
C	348.495	310.56	12.165
D	361.63	317.24	11.8

AL 6061-AL$_2$0$_3$



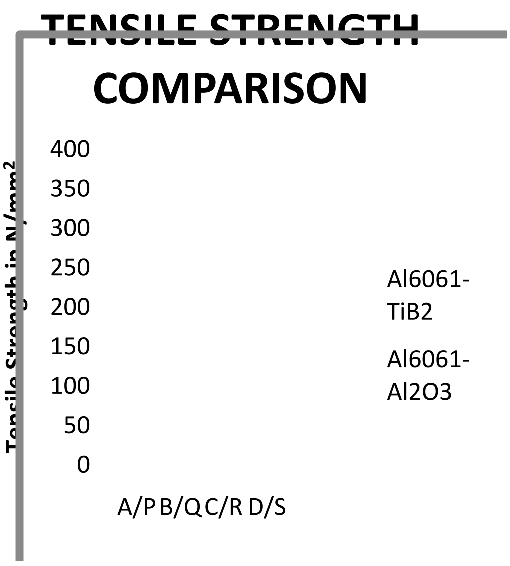


Fig 9

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From the graph (Tensile strength), we can understand that the tensile strength values of TiB_2 reinforced composite are greater than that of Al_2O_3 reinforcedcomposite.

From the graph we can see that the yield stress of the Al6061-TiB_2 composite is greater than that of LM20-Al_2O_3 composite.

IX. HARDNESS TEST

The hardness tests were conducted as per ASTM E10 norms using Brinell hardness tester. Tests were performed at randomly selected points on the surface by maintaining sufficient spacing between indentations and distance from the edge of the specimen. The hardness values obtained are as follows-

AL6061-AL_2O_3

Specimen designation	Peak load (KN)	Tensile strength (N/mm^2)	Yield load (KN)	Yield stress (N/mm^2)	% Elongation
A	5.28	170.44	4.84	156.24	1.73
B	4.60	149.92	3.88	126.45	2.63
C	2.68	91.99	2.20	75.52	2.90
D	6.29	192.63	5.35	170.93	1.43

Specimen Designation	Hardness values			
	Reading 1	Reading 2	Reading 3	Average value
A	77.1	76.3	76.3	76.6
B	77.9	77.8	78.7	78.2
C	78.8	78.2	78.2	78.4
D	47.5	47.9	47.5	47.6

AL6061-TIB_2

Specimen Designation	Hardness values				
	Reading 1	Reading 2	Reading 3	Reading 4	Average value
A	91	93	92.5	91.9	92.1
B	95	96.21	95.1	94.9	95.3025
C	97.25	98.1	97.9	96	97.3125
D	93.64	93	93.1	93.58	93.33

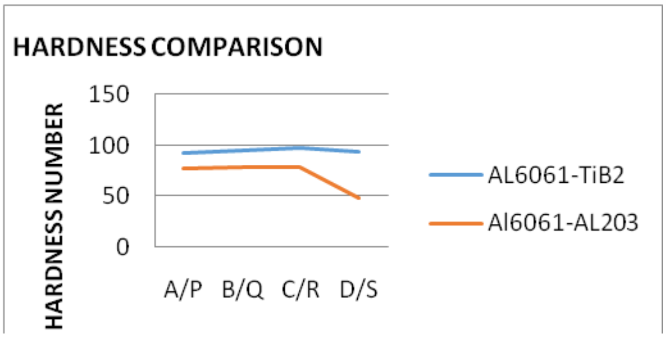

Fig 10

From the graph, we can understand that the hardness values of the TiB_2 reinforced AMCs are more than that of Al_2O_3 reinforced AMCs.

The influence of control parameters such as load, sliding speed and Sic content on wear rate has been evaluated using S/N ratio response analysis. The control parameter with the strongest influence was determined by the difference between the maximum and ratios, the more influential was the control parameter minimum value of the mean of S/N ratios. Higher the difference between the mean of S/N.

Wear test

The wear test is carried out in Pinnon disc machine.

Load	speed	Reinforcement	distance	wear rate
20	1.05	3	314	0.003159
20	1.83	6	548	0.002538
20	2.62	9	784	0.001306
40	1.05	6	784	0.002901
40	1.83	9	314	0.001268
40	2.62	3	548	0.002686
60	1.05	9	548	0.00224
60	1.83	3	784	0.01116
60	2.62	6	314	0.002599

The S/N ratio response analysis, presented in fig 11 shows that among all the factors, reinforcement was the most influential and significant parameter followed by load, speed and sliding distance. Figure 11 shows the mean of wear rate graphically and Figure 11 depicts the main effects plot for means of S/N ratio for wear rate. From the analysis of these results, it can be inferred that parameter combination of L = 60 N, S = 1.83 m/s and F = 3% gave the minimum wear rate for the range of parameters tested.

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Level	Load	Speed	Reinforcement	Distance
1	0.002334	0.002767	0.005668	0.002342
2	0.002285	0.004989	0.002679	0.002488
3	0.005333	0.002197	0.001605	0.005122
Delta	0.003048	0.002792	0.004064	0.002780
Rank	**2**	**3**	**1**	**4**

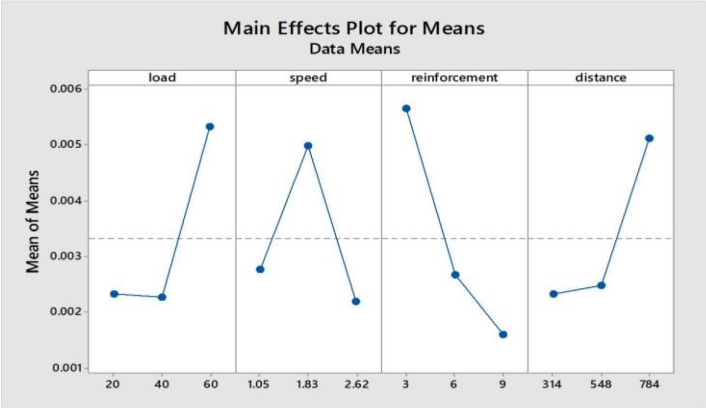

Fig 11

Taguchi Analysis: wear loss versus load, speed, reinforcement, distance

load	Speed	reinforcement	Distance	wear loss	SNRA1
20	1.05	3	314	0.003159	-50.00900748
20	1.83	6	548	0.002538	-51.91016764
20	2.62	9	784	0.001306	-57.68113646
40	1.05	6	784	0.002901	-50.74904542
40	1.83	9	314	0.001268	-57.93761493
40	2.62	3	548	0.002686	-51.41787983
60	1.05	9	548	0.00224	-52.99503963
60	1.83	3	784	0.01116	-39.04671611
60	2.62	6	314	0.002599	-51.70387441

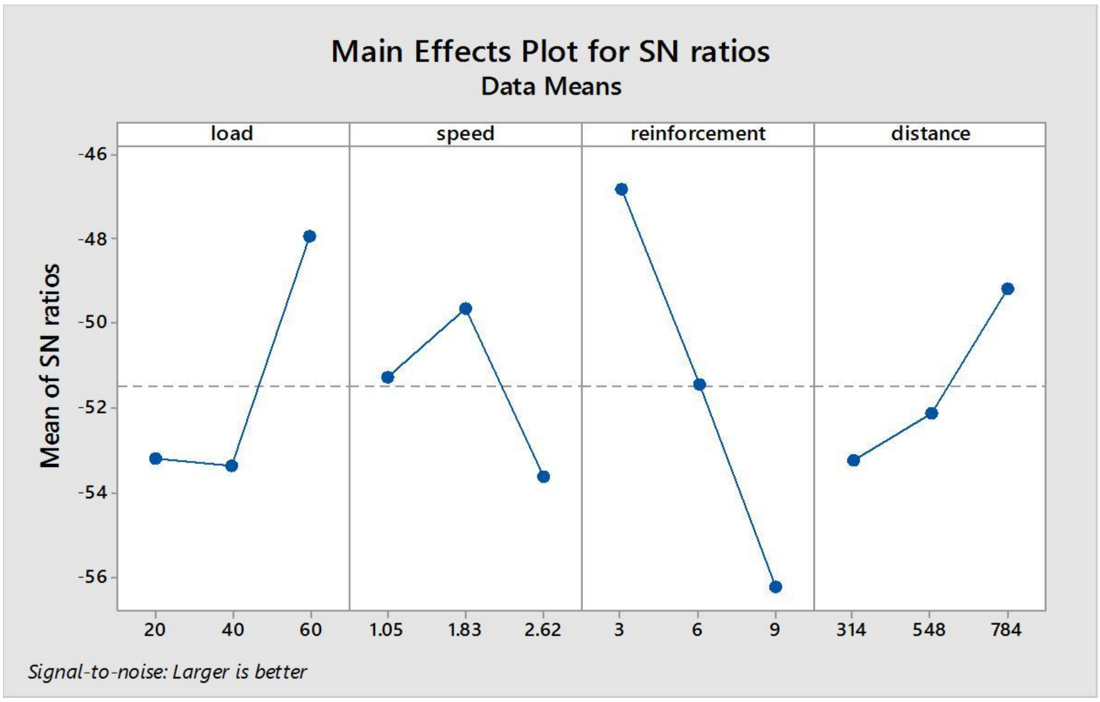

Fig 12

CONCLUSIONS

1. Stir casting method was helpful to produce a good dispersion of Al_2O_3 and TiB_2 particles in the alloy and very low agglomeration was found.

2. Microstructure and SEM analysis shows the proper distribution of reinforced Nano particles in metal matrix.

3. The fabrication process used in this study (stir casting) improved the mechanical and tribological property of the reinforced alloy thus by showing good porosity by microstructure images and better distribution of Al_2O_3 and TiB_2.

4. Test results indicate there is increase in hardness and tensile strength for reinforced composites. Compared to As Cast alloy. It is also observed further increase in Al2O3 decreases the hardness i.e. for 3% wt alloy. Optimum hardness was found to be for 9% wt alloy.

5. Specimen D and S i.e. with 9 wt% shows the minimum % elongation than as cast and other specimen; hence it will be preferred in terms of its tensile strength.

6. It is also found that the variation (increase or decrease) in UTS and % of elongation properties is not linear which may be attributed to the problem of the dispersion of Al_2O_3 and TiB2 Nano particles into matrix material.

7. The concentration of Al_2O_3 particles increases with increase in content of mass fraction which was showed in the SEM results; it was also observed that with increase in mass. Concentration of Al_2O_3 and TiB_2 the elongation decreased. The higher the concentration leads to less slip dislocation and hence the elongation

decreases. To overcome all the drawbacks the different processing techniques can be implemented and the investigation can be progressed.

8. Hence there is significant research as to be carried out to overcome this problem.

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