Mechanical Characterization of Aluminum 6061 Hybrid Metal Matrix Composite

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Abstract- In this project efforts are made to find the effect of reinforcement (Aluminum oxide + Basalt short fiber) on mechanical properties of Aluminum alloy (Al6061) composite samples, processed by liquid metallurgy method. Sixteen set of composites were prepared with varying percentages of aluminum oxide (0%, 2%, 4% and 6%) by weight fraction in the base Aluminum 6061 alloy. The evaluated properties of the samples were tensile strength, hardness and percentage elongation. In presence of Aluminum oxide and Basalt short fibers with Aluminum, the hardness of the composite was fairly increased. Correspondingly, there was significant increase in tensile strength. But percentage elongation of hybrid metal matrix composites decreased when compared to unreinforced aluminum alloy. From the experiment it was observed that the best properties were obtained from the sample containing (Aluminum oxide (3%) + Basalt short fibers (6%)) as compared to base metal.

Keywords- Aluminum 6061 hybrid MMC's, Aluminum Oxide, Basalt short fibers, Stir casting, Tensile strength, Hardness, Percentage elongation

I. INTRODUCTION

In recent years addition of Aluminum metal to the matrix composites is having accessed comprehended attention. Hybrid metal matrix composites (HMMC's) possesses high strength to weight ratio. Hence, are suitable for applications in automobile, marine and aerospace sectors. Aluminum HMMC's have become better substitute for usual alloys because of their colossal light payload behavior, low expansion thermal coefficient (CTE) limit, cost visibility, and upgraded mechanical characteristics like shore hardness, ultimate tensile stress, and yield strength of the Aluminum alloy material. Owing to these advanced properties, Aluminum alloys are inevitable in aviation (e.g. lightweight high strength airframes) for its low weight and strength ratio, automobile (e.g., engine pistons) for its corrosion resistance behavior, and auto electronic (e.g. I C mountings) corporations lifelong working tendency. The properties and performance of various Aluminum alloys and their composites are studied in terms of microstructure, loading conditions, mechanical properties, and applications. Magnesium and silicon containing Al (6061) alloy with a low density of 2.70 g/cm^3 possesses excellent mechanical properties like toughness, fatigue, high specific strength and good weld ability. The hybrid composites developed from such Aluminum alloys possesses high strength, wear resistance, stiffness and toughness. Further, when these composites are reinforced ceramic fibers and particulates exhibits superior properties for elevated temperature applications.

Motivated by the reference works HMMC's, the present study intended at the development of Al 6061 composites containing different volume fraction ofAl_2O_3 and Basalt short fiber their hardness and tensile properties are studied.

II. EXPERIMENTAL DETAILS

2.1 Materials-

Table 1- Chemical composition of Al 6061 alloy by weight percentage

Si	Cu	Fe	Mn	Mg	Zn	Ti	Cr	Al
0.8	0.4	0.7	1.2	1.2	0.25	0.15	0.35	Rest

HMMC's having varying weight percentages of Basalt short fiber and Al_2O_3were produced by liquid metallurgy (stir casting) route. HMMC's are produced by reinforcingbasalt short fiber and Al_2O_3 particulates (average grid size of 125μm) to Al 6061 base metal matrix. The chemical composition and properties of base matrix and reinforcement are shown in table 1 and 2 respectively.

Table 2- Properties of Al 6061, Al_2O_3 and Basalt short fiber

Materials/ Properties	Density g/cc	Hardness	Strength (Tensile/Compression) Mpa	Elastic Modulus Gpa
Al 6061	**2.7**	**75 BHN**	**115(T)**	**80**
Al_2O_3	**3.89**	**22050 MPA**	**2100(C)**	**300**
Basalt short fiber	**2.67**	**---**	**3100(T)**	**87**

2.2 Composite Preparation-

A liquid metallurgy has been incorporated in fabrication of cast composites. Stir casting technique is the most economical of all the available routes for metal matrix composite production. Advantages of metal stir casting process are mixture structure can be easily controlled, flexible, simple and inexpensive processing and is applicable to large scale production. Al 6061 has been chosen as a base matrix. Upon degasifying the vortex using solid hexachloroethane (C_2Cl_6), Al_2O_3 particulates and Basalt short fiber were preheated and introduced into vortex. The reinforcements were pre-heated to a temperature of 200°C before being introducing into the metal. The total amount of reinforcements were calculated and introduced into the melt in a step of three rather introducing it in one single step. After addition of reinforcement, at every stage the mechanical stirring of molten alloy was done for a period of 10 minutes using stirrer which was run at a speed of 450 rpm. The stirrer used was made up of zirconia coated steel. The molten composite was poured (pouring temperature 750°C) into cast iron moulds. Thus, composites containing 0, 1, 3 and 5 wt% of Al_2O_3 particles and 0, 2, 4 and 6 wt% of Basalt short fiber were obtained in the form of cylinders of diameter of 26 mm and length of 320 mm.

Table 3- Composition of composite specimen

MODELS	REINFORCEMENTS		
	Al 6061	Al_2O_3	BASALT FIBER
1	100%	0%	0%
2	99%	1%	0%
3	97%	3%	0%
4	95%	5%	0%
5	98%	0%	2%
6	97%	1%	2%
7	95%	3%	2%
8	93%	5%	2%
9	96%	0%	4%
10	95%	1%	4%
11	93%	3%	4%
12	91%	5%	4%
13	94%	0%	6%
14	93%	1%	6%
15	91%	3%	6%
16	89%	5%	6%

2.3 Testing of Composites-

The mechanical behavior of the composites were investigated. The hardness and the tensile test were carried out using brinell hardness testing machine and computerized uni-axial testing machine as per ASTM standards respectively. The brinell hardness values of the samples were measured on the polished samples using tungsten carbide ball indenter of 5mm diameter with a load of 60 gms and 15 seconds as a holding time. Hardness value delineated is the average value of 3 readings taken at different locations on the polished specimen. The tensile test for the sample was carried as per ASTM E8 standards, by computerized uni-axel testing machine (Machine model: TUE- C-400K).

III. RESULTS AND DISCUSSION

3.1 Hardness Measurements-

The results of brinell hardness test which was conducted on the hybrid metal matrix containing varying percentage weights of Al_2O_3 (0, 1, 3, 5 wt %) and Basalt Short fibre (0, 2, 4, 6 wt %) is shown on table 4 and figure 2. Brinnel hardness was measured on the polished sample using tungsten carbide ball indenter with a load of 60gms and the values obtained are the average of 3 readings taken at different positions. A significant increase in hardness was observed with addition of Al_2O_3 and Basalt short fiber. Higher value of the hardness shows that the addition of particulates has increased the total hardness of the composites. This improved hardness is true because of the fact that the reinforcement materials especially ceramics material being hard contributes substantially to the hardness of the hybrid MMC.The hardness and stiffness present Al reinforcement leads to increase in constrain to plastic deformation of the hybrid MMC during the hardness test. The increase in hardness could be attributed to the high hardness of al203.further from figure 1 it can be observed that the hardness of Al6061/Al_2O_3/Basalt fiber Hybrid composite increases when there is increase in the quantity of Al_2O_3 particulates.

Table 4- Showing the Brinell hardness test results

Specimen	Composition	Mean BHN
1	Al 6061 alloy	43.3
2	Al 6061 alloy + 1% of Al_2O_3	46.6
3	Al 6061 alloy + 3% of Al_2O_3	50.5
4	Al 6061 alloy + 5% of Al_2O_3	52.2
5	Al 6061 alloy + 2% of Basalt short fiber	44.4
6	Al 6061 alloy + 1% of Al_2O_3 + 2% of basalt short fiber	49.1
7	Al 6061 alloy + 3% of Al_2O_3 + 2% of basalt short fiber	55
8	Al 6061 alloy+ 5% of Al_2O_3+ 2% of basalt short fiber	54.7
9	Al 6061 alloy + 4% of Basalt short fiber	50.2
10	Al 6061 alloy + 1 % of $Al_2O_3$4% of Basalt short fiber	59.7
11	Al 6061 alloy + 3% of $Al_2O_3$4% of Basalt short fiber	68
12	Al 6061 alloy + 5% of Al_2O_3+ 4% of Basalt short fiber	67
13	Al 6061 alloy + 6% of Basalt short fiber	51
14	Al 6061 alloy + 1% of Al_2O_3+6% of Basalt short fiber	60.2
15	Al 6061 alloy + 3% of Al_2O_3+ 6% of Basalt short fiber	69
16	Al 6061 alloy + 5% of Al_2O_3+ 6% of Basalt short fiber	68.4

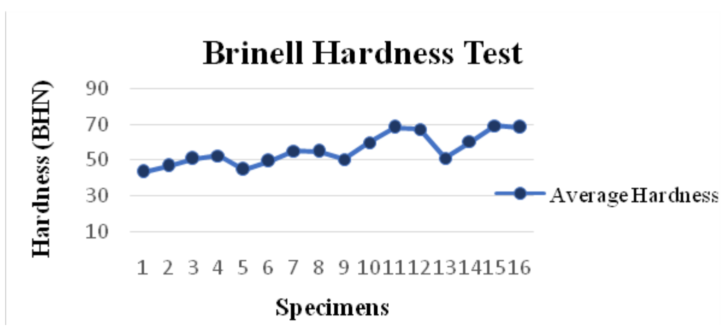

Figure 1: Graph showing variation of hardness

3.2 Tensile Properties Measurements

To investigate the mechanical behavior of the composites tensile tests were carried out on the Hybrid MMC, Computerized uniaxial testing machine was used and test was as per ASTM E8 standards. The tensile test properties such as Tensile test, yield strength and percentage elongation were tested and results are represented in table 5 and graph is shown in Figure 2. It was observed that the tensile strength of Hybrid MMC is higher when compared to base Al6061 alloy.Increase in the strength is due to thermal mismatch between the reinforcement and metal matrix which is major reason behind the increase in the dislocation density of the matrix hence, increasing the composite strength.However varying weight percentage of Al_2O_3 reinforced composites shows lower percentage elongation than the unreinforced composites. It is observed that the plastic deformation of the mixed deformable metal matrix and nondeformable metal matrix is more difficult than the base metal matrix. As a result ductility of composite decreases when compared to unreinforced material.

Table 5: Showing Tensile test results

Specimen	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Percentage Elongation
1	109.2	146.12	15
2	117.43	157.3	14
3	127.26	170.8	12
4	131.54	176.8	11
5	111.89	150.9	13
6	123.73	166.8	11.4
7	138.60	187	10.54
8	137.84	185.6	10.1
9	126.50	170.64	12.4
10	150.44	200.98	11.5
11	171.36	232.1	10.1
12	168.84	227.7	9.54
13	128.52	173.5	10.54
14	151.70	204.56	8.24
15	173.88	234.60	7.16
16	172.37	232.56	6.24

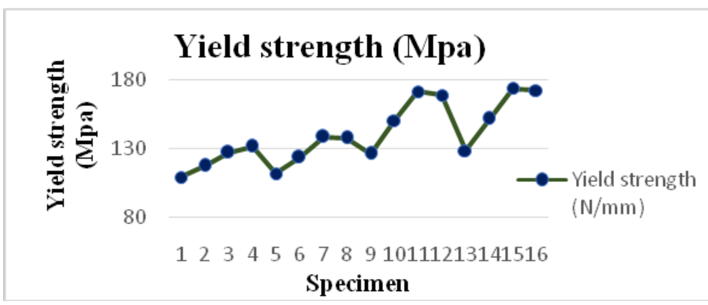

Figure 2: Graph showing variation of tensile strength

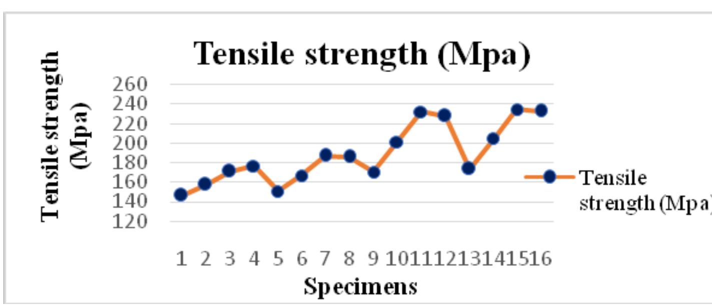

Figure 3: Graph showing variation of yield strength

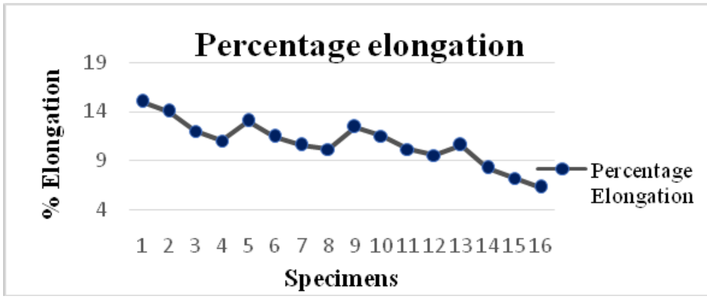

Figure 4: Graph showing variation of % elongation

IV. CONCLUSION

1. Aluminium based hybrid metal matrix composite was successfully fabricated by implementing liquid metallurgy method by 3 step addition of reinforcement combined with pre-heated particulates.
2. Tensile strength of fabricated hybrid metal matrix composites of Al6061 is higher when compared to the tensile strength of base Al6061 alloy.
3. Composite containing 3 wt% Al_2O_3 and 6 wt% basalt short fiber exhibit highest tensile strength of 234.6 MPa, when compared to other composite.
4. Addition of ceramic reinforcement Aluminium oxide (Al_2O_3) increases the tensile strength considerably with respect to base matrix Al6061. Where in addition of basalt short fibers does not vary the tensile strength much with respect to Al_2O_3 added composition.
5. Hardness of the fabricated composites are higher than the base Al6061 alloy.
6. Addition of Aluminium oxide (Al_2O_3) and Basalt short fiber increases hardness considerably, when compared to cast Al6061.
7. Composite containing 3 wt% Al_2O_3 and 6 wt% Basalt short fiber exhibit highest hardness of 69 BHN, when compared to other composites.
8. Ductility decreases with addition of Al_2O_3 particulates, which causes decrease in percentage elongation of Hybrid MMC when compared with that of the base alloy.

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