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Study Of Mechanical And Tribological Properties Ofal-6061 Reinforced With Silicon Carbide And Graphite Particles

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ABSTRACT: Aluminium based Hybrid Metal Matrix composite (HMMC) Exhibit Excellent Wear Resistant,Strength – Weight Ratio and Tribological Properties in comparison with the base alloy for wide variety of Engineering Applications in Automotive, Aerospace and Heavy Machinery Industry. However the Particulate Reinforced Hybrid–Metal Matrix Composites for Engineering Applications has been challenged by several reasons such as High Manufacturing Cost, Poor Machinability and achieving uniform distribution of Reinforcement within the Matrix. However economical Liquid Metallurgy technique – Stir casting, can be used to overcome these challenges. In the present work, efforts has been made to develop Aluminium based HMMC with Silicon Carbide Particulates (50µm) and Graphite Powder (60µm) as Particulate reinforcement using Stir – Casting Furnace by Proper Selection of Operating Parameters for achieving enhanced properties. Hardness, Tensile strength, Compressive strength and toughness are testedas per ASTM standards. Wear test has been carried out with Pin on Disc dry sliding test rig with sliding velocity of 2 m/s and 4m/s under load of 30N and 50N.Wear test indicate better wear resistant properties of the composite as the percentage of reinforcement increases. It is found that addition of SiC and Gr reinforcements have enhanced the properties of the base aluminium.

Keywords: Al 6061, HMMC's, SiC, Graphite, Stir Casting, Pin on Disc, Wear rate.

1 INTRODUCTION

Aluminium alloy Al 6061 alloys is one of the most extensively used Material for its superior Properties such as Hardness, tensile strength, high specific modulus, low coefficient of thermal expansion and good wear resistance [1,2].These combined properties are Predominantly required in various engineering applications such as Automotive, Aerospace and also in Structural Industries [3].It is an alloy of Al-Mg-Si which is heat treatable with age hardenable Properties. Among several metal matrix composites, aluminium matrix composites (AMC) form a new class of advanced materials. In particular discontinuously Reinforced Metal Matrix Composites (DRMMC) holds several promising features for wider adoption in engineering applications. In DRMMC, the addition of ceramic reinforcements strengthens the matrix by transferring the load to the ceramic particulates and increasing the dislocation density in the matrix [4],[5]. The increase in mechanical properties such as elastic modulus, tensile strength and hardness of the material are mainly due to the thermal mismatch between the matrix and the reinforcement during processing[6]. Aluminium Matrix Composite (AMC) is widely regarded as good matrix material because of its abundant resources in earth's crust [7]. Reinforcement materials such as SiC, B_4C, Fly ash, B_4N, Graphite and $Al_2O_3$are used in the forms of Particulates, Whiskers or fibers for attaining specific tailored properties [8],[9] .Silicon carbide has high thermal conductivity coupled with low thermal expansion and high strength giving exceptional thermal shock resistant properties to it. Silicon carbide can maintain its strength at very high temperature approaching 1600˚C. Graphite is a solid lubricant which enhances the wear and anti-frictional properties. In the present study effort has been made to investigate the effect of adding SiC of 50µm and graphite of 60µm in the form of particulate for improving the tribological characteristics of Al 6061 matrix using stir casting technique.[10] By varying the volume fraction of reinforcement, appropriate composition for high wear resistance is determined by conducting wear tests under varying sliding and load conditions. In the stir casting process the operational parameters such as mould preheating temperature, stirring speed, pouring temperature, and Stirring time are optimized to obtain better properties. The aim of the study is to analyze the influence of adding silicon carbide and graphite reinforcements to the base Al-6061.

2. EXPERIMENTATION

The matrix material used for study is Al-6061.The Stir casting is a simple and economic process for fabrication of MMC and HMMC inlarge quantities upto 30% reinforcement volume fraction[11].In this process aluminium-6061 is melted in a furnaceand stirred vigorously, after effective degassing with solid hexachloroethane predetermined mass of reinforcements are added into the vortex in three stage mixing process.Addition of wetting promoters into the melt enhances the particle distribution and its bonding with the matrix. This method is commonly used for fabricating discontinuous reinforced MMC and HMMC.The hybridization is carried out by simultaneously introducing both the reinforcements in to the matrix alloy while stirring.

Figure1: *Stir Casting Furnace*

The reinforcements are added in volume fraction percentage of the base aluminium metal. The volume fraction of the samples are calculated from the densities of the metals and reinforcements [12]The reinforcements are mixed thoroughly before adding it into the molten aluminium for uniform dispersion.

TABLE 1
COMPOSITION OF BASE Al-6061

Mg	**Si**	**Fe**	**Cu**	**Ti**	**Cr**	**Zn**	**Mn**	**Al**
1.15	0.41	0.050	0.618	0.0354	0.217	0.100	0.0602	98.02

TABLE 2
COMPOSITION OF SAMPLES

Sample	**S1**			**S2**			**S3**			**S4**		
Elements	**Al 6061 (%)**	**SiC (%)**	**Gr (%)**	**Al 6061 (%)**	**SiC (%)**	**Gr (%)**	**Al 6061 (%)**	**SiC (%)**	**Gr (%)**	**Al 6061 (%)**	**SiC (%)**	**Gr (%)**
Composition	100	0	0	92	8	0	90	8	2	88	8	4

The reinforcementsare added at 700˚C in semimolten state while stirring at 300 rpm for 17 minutes[13].The reinforcements are preheated to a temperature of 500˚C for 1 hour to oxidize and to prevent the decrease in temperature of the molten metal during addition of reinforcements[14].The size of reinforced silicon carbide particles plays a major role in the properties of the composite, as the size of the reinforcement particles increases the wear resistance increases but the particles segregates and accumulates.[3] The molten composite is poured into preheated cast iron mould at 400˚C.

TABLE 3
PROCESS PARAMETERS

Pouring temperature(˚C)	**Stirring speed(rpm)**	**Preheating temperature(˚C)**
700	300	500

3. RESULT AND DISCUSSION

To investigate the mechanical properties of the composite material tensile strength and hardness of the composite is tested as per the ASTM standards. Wear and friction tests were done on pin on disk test rig as per the ASTM G99-95.

3.1 Tensile Testing

The tensile strength analysis were performed as per the ASTM E8/E8M standards. The specimen selected is of circular cross section with nominal diameter of 10mm. The test is carried out using UTM Machine of 100 ton capacity under room temperature.

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TABLE 4
TENSILE TEST RESULTS

S.NO	Sample number	Yield Strength (MPa)	Percentage elongation	Ultimate tensile strength (MPa)
1	Al-6061	110.000	25.00	200.000
2	Al+8%SiC	127.431	6.67	205.970
3	Al+8%SiC+2%Gr	135.240	500	209.210
4	Al+8%SiC+4%Gr	132.729	6.67	218.713

It is seen from the test results that the proof strength and ultimate tensile strength has increased and percentage elongation has decreased. From the results it is visible that the material is brittle and has greater ultimate strength than the T4 temper Al-6061.

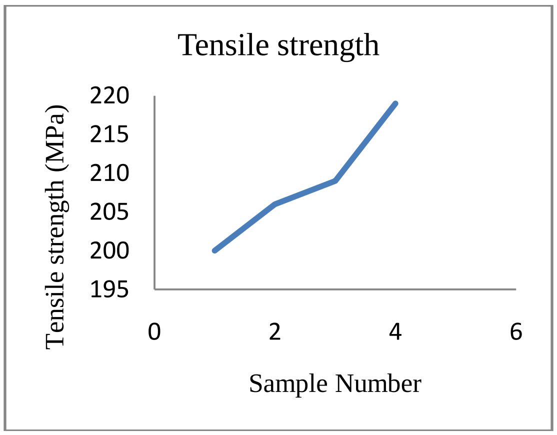

***Figure 2**: Variation of tensile strength Vs Sample number*

The decrease in the ductility of the material is clearly attributed to the addition of Silicon Carbide and Graphite. The decrease in the ductility of the material is because of the resistance to the plastic flow of layers in the material caused by the breakage of the continuity of the layers by the Silicon carbide particles and the increase in strength of the material is because of the restriction to the material flow between the layers due to obstruction by the reinforced particles in the matrix. The load carrying capacity has been enhanced due to the load sharing capability of the composite and uniform load transfer between the layers of the composite by the reinforcements particles .

3.2 Hardness Testing

The tests were performed on the 10mm indenter with load of 500 kg applied for 30 seconds on cast composite samples, flattened with minimum thickness of 10 times the indentation height.

TABLE 5
HARDNESS TEST RESULTS

S.NO	Material	Brinell hardness BHN
1	Al - 6061	60
2	Al+8%SiC	76.3
3	Al+8%SiC+2%Gr	69.3
4	Al+8%SiC+4%Gr	66.2

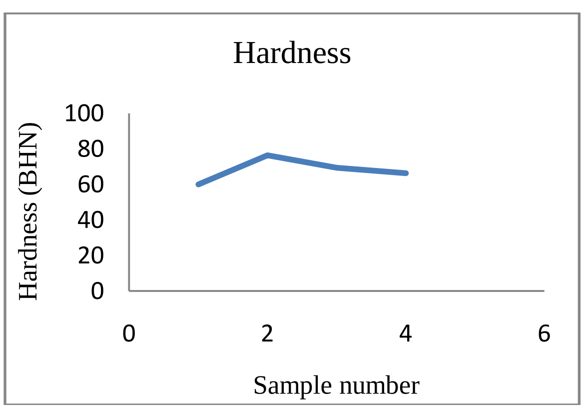

***Figure 3:** Variation of hardness Vs Sample number*

Hardness improved due to the reinforcement of the hard silicon carbide particles which has hardness of 9 on the Mohr'sscale, the other reason for the increase in the hardness is because of the increase in binding strength between the molecules which restricts the plastic flow of material. The reason for decease in the hardness value with the increase in graphite content is the hardness of the graphite is less and due to the decrease in binding energy between the crystals. The segregation of the silicon carbide and graphite particles was also found to be a reason for the decrease in hardness of the composite post increase.

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3.3 Wear and Friction Testing

TABLE 6
WEAR RATE RESULTS

Wear (mm^3/N-m)								
Composition	**S1**		**S2**		**S3**		**S4**	
Sliding velocity (m/s)	**Load (N)**							
	30	50	30	50	30	50	30	50
2	0.2101	0.1202	0.1421	0.1510	0.0999	0.0628	0.0754	0.06210
4	0.3105	0.1650	0,2130	0.1215	0.1413	0.0910	0.0901	0.0550

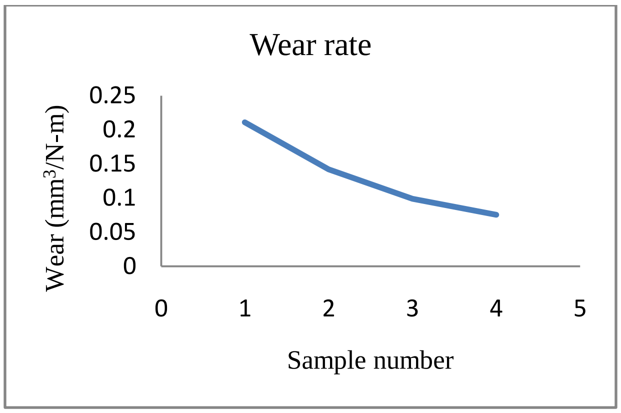

Figure 4: *Variation of Wear rate at 4m/s and 50N Vs Sample number*

Variation of wear rate with the percentage of reinforcements are studied and it is observed that as the percentage of reinforcements increases the wear rate decreases .It is also observed that as the sliding velocity is increased the wear rate increases . The influence of load is minimum on the applied load range on wear rate .

TABLE 7
COF RESULTS

Coefficient of friction								
Composition	**S1**		**S2**		**S3**		**S4**	
Sliding velocity (m/s)	**Load (N)**							
	30	50	30	50	30	50	30	50
2	0.5300	0.4810	0.5101	0.4610	0.4144	0.4092	0.4044	0.4030
4	0.4717	0.4670	0.4668	0.4510	0.3706	0.3906	0.3680	0.3850

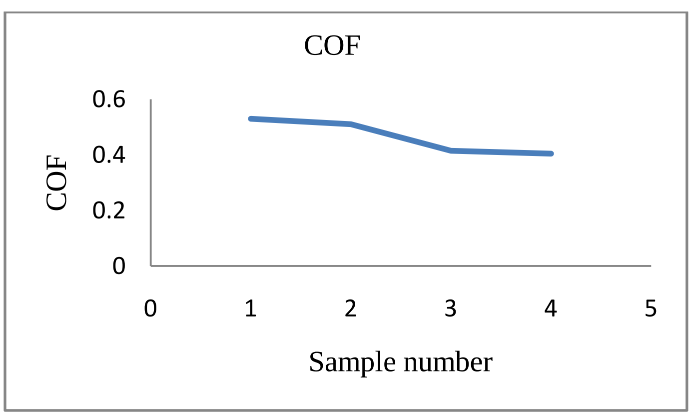

Figure 5: *Variation of COF at 2m/s and 30N Vs Sample number*

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It is evident from the results that Co-efficient of friction decreases as the percentage of reinforcement of Silicon carbide and Graphite increases.

4 CONCLUSION

The present study can be concluded with the following points.

I. The tensile strength of the composite increases linearly with the addition of both SiC & graphite reinforcements, whereas hardness improves with the SiC addition and shows decreasing trend with the graphite particle reinforcement.

II. Wear rate of the developed HMMC has decreased with the addition of both SiC and graphite reinforcement.

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