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MECHANICAL PROPERTIES OF AL MATRIX HYBRID COMPOSITES

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Abstract- Hybrid composites are new class of material and offer enhanced mechanical properties than single reinforcement reinforced Aluminum matrix composites. To study the properties of hybrid composites; Aluminum matrix hybrid composites are manufactured with stir casting method. The reinforcement used are SiC and Al_2O_3. The fabricated hybrid composites are characterized using tensile test, hardness test, optical microscopy and density measurement. The fabricated hybrid composites exhibit improved mechanical properties than Al matrix. This class of composites can be used for varies engineering applications.

Key Words- Hybrid composites, mechanical properties

I. INTRODUCTION

Aluminum matrix composites are studied by various researchers over decades. Aluminum matrix composites find application in different fields (e.g. aerospace, automobile, defense etc.) due their improved mechanical properties. Hybrid composites are new class of material offer better mechanical properties than single reinforcement reinforced composites. Due to this it become point of attraction for researcher. Hybrid composites consist of hybrid combination of two or more different type, size and shape of reinforcements. The hybrid combination helps to improve its mechanical properties hybrid composites by taking advantage of the properties of combined reinforcements.[1-4]

II. EXPERIMENTAL PROCEDURE

In this study the Aluminum matrix used is LM 4 (Al – Si_5Cu_3) alloy. The reinforced used is micron sized Al_2O_3 and SiC particulates with mesh size 60 each. The hybrid composites are manufactured by using stir casting method. This method is used as it is simple and low cost. Chemical composition of LM4 is given in Table 1. Properties of Al matrix and reinforcements (Al_2O_3 and SiC) are given in table 2. Fig 1 a), b) and c) shows SiC, Al_2O_3 powders and LM4 alloy respectively used to fabricate hybrid composites. The fabricated composites are characterized using tensile test, hardness teat, optical microscopy and density measurement. To fabricate hybrid composites the sand mould is prepared as shown in the Fig. 2. The Al rod procured from local market is cut in to small pieces and placed in graphite crucible for melting. When Al matrix melts the Al_2O_3 and SiC particulates are feed into crucible. To mix reinforcement in Al matrix, stirrer is used. Fig.3 show stir casting setup. The stirring action is carried out for 5 to 10 minutes. Uniformly mixed molten Aluminum is poured into mold cavity. After solidification specimen of hybrid composites are used for mechanical characterization. Table 3 show the hybrid composition reinforcement by wt.% mixed in LM4 alloy. Fig. 4 show cast specimen of hybrid composites. Fig.5 show the samples used for testing.

Table 1 Chemical composition of LM4

Element	Cu	Mg	Si	Fe	Mn	other	Al
%	3	0.15	5	0.8	0.4	1.2	89.45

Table 2 Properties of Materials used to Fabricate Hybrid composite

	Tensile strength MPa	Elastic Modulus GPa	Hardness BH	Density Kg/m³	Coefficient of Thermal Expansion m/m K
LM 4	140-170	71	73	2730	21 X 10^{-6}
Al_2O_3	2000	310	1200 Kg/mm²	3690	8.1 x 10^{-6}
SiC	3900	400	2800 Kg/mm²	3200	4x 10^{-6}

Fig. 1 a) SiC powder

Fig.1 b) Al_2O_3 powder

Fig.1 c) LM4

Fig.2 a) Sand Mould

Fig. 2 b) Sand mould after casting

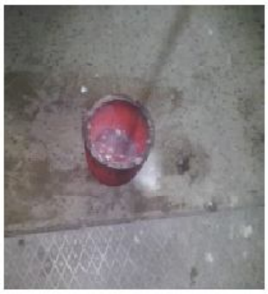

Fig. 2 c) Crucible

Fig. 3 Stir casting setup

Fig. 4 Solidified hybrid composite rods

Table 3 Hybrid composition of reinforcement by wt.%

Sample by wt.%	Al-LM4 (g)	Al_2O_3 (g)	SiC (g)
0	504.1	0.0	0.0
5	509.0	12.5	12.5
10	510.3	25.1	25.1
15	505.1	37.6	37.6

III. RESULTS AND DISCUSSION

3.1 Density Measurement

Table 4 Results of density and porosity measurements

Materials	Nano sized SiC (wt %)	Nano sized Al_2O_3 (wt %)	Theoretical density Kg/m^3	Experimental density Kg/m^3	Porosity (%)
LM4 alloy	0	0	2700	2663	1.38
LM4+ 2.5% SiC +2.5% Al_2O_3	2.5	2.5	2703	2561	5.25
LM4+ 5% SiC + 0.5% Al_2O_3	5	5	2706	2513	7.13
LM4+7.5% SiC +7.5% Al_2O_3	7.5	7.5	2710	2481	8.45

Density measurement is carries of hybrid composites is carried to know the amount of porosity in fabricated composites. The theoretical density is obtained by using rule mixture. The experimental density is measured using Archimedes principle. Porosity shows increasing trend as the wt.% of reinforcement is increased. This is attributed to low wettability of reinforcement with aluminum alloy. The wettability of SiC is better than Al_2O_3. The contact angle of SiC with aluminum is less than 90° whereas the contact angle of Al_2O_3 is greater than 90° [5-6]. So SiC has better wettability than Al_2O_3. Another reason could be the use of sand mold to fabricate hybrid composite. The presence of porosity is detrimental to mechanical properties of hybrid composite. The use of metallic mold lower the amount of porosity. It is not possible to completely eliminate the porosity but it can be reduced by treating the reinforcement, coating the reinforcement to improve the wettability and by using the secondary processing methods like extrusion, rolling etc.

3.2 Optical Microscopy

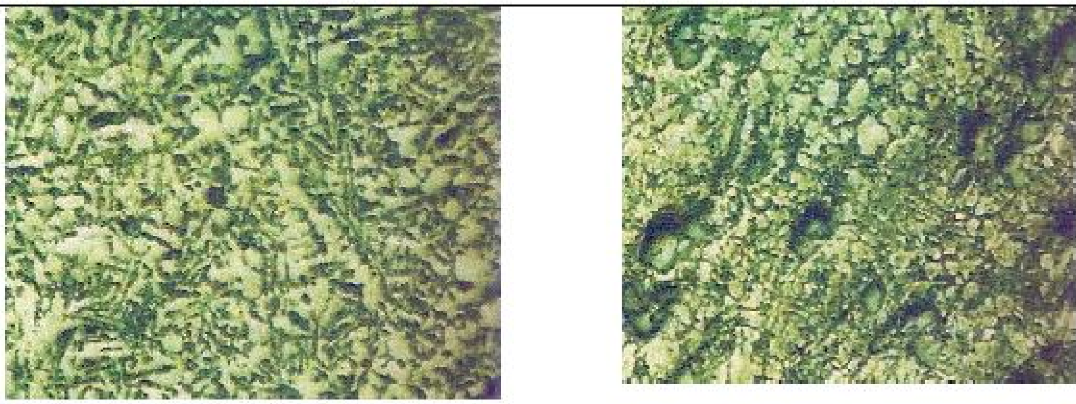

Fig. 5 a) Optical microscopy image of 5 wt.% hybrid composite

Fig. 5 b) Optical microscopy image of 10 wt.% hybrid composite

The optical microscopy results are obtained for the hybrid composite to study the microstructure and to know the distribution of particles in matrix. It is observed [Fig. 5 a) and b)] from the results the particles are distributed uniformly. The uniform distribution of particles is desirable to enhance the mechanical properties of hybrid composites.

3.3 Hardness Test

The Vickers micro-hardness test is carried out on Lieca Vickers harness tester as per ASTM E384 standard for all hybrid composites. The hardness test shows that increased wt.% of reinforcement resulted increased hardness. This is attributed to increased obstruction to motion of dislocations, increased dislocation density due residual stresses in the composite because of thermal mismatch between matrix and reinforcement. The higher thermal mismatch is due to higher difference between the melting point as well as coefficient of expansion of matrix and reinforcement. Fig. 6 show the micro-hardness Vs hybrid reinforcement composition graph. [5, 7, 8,9].

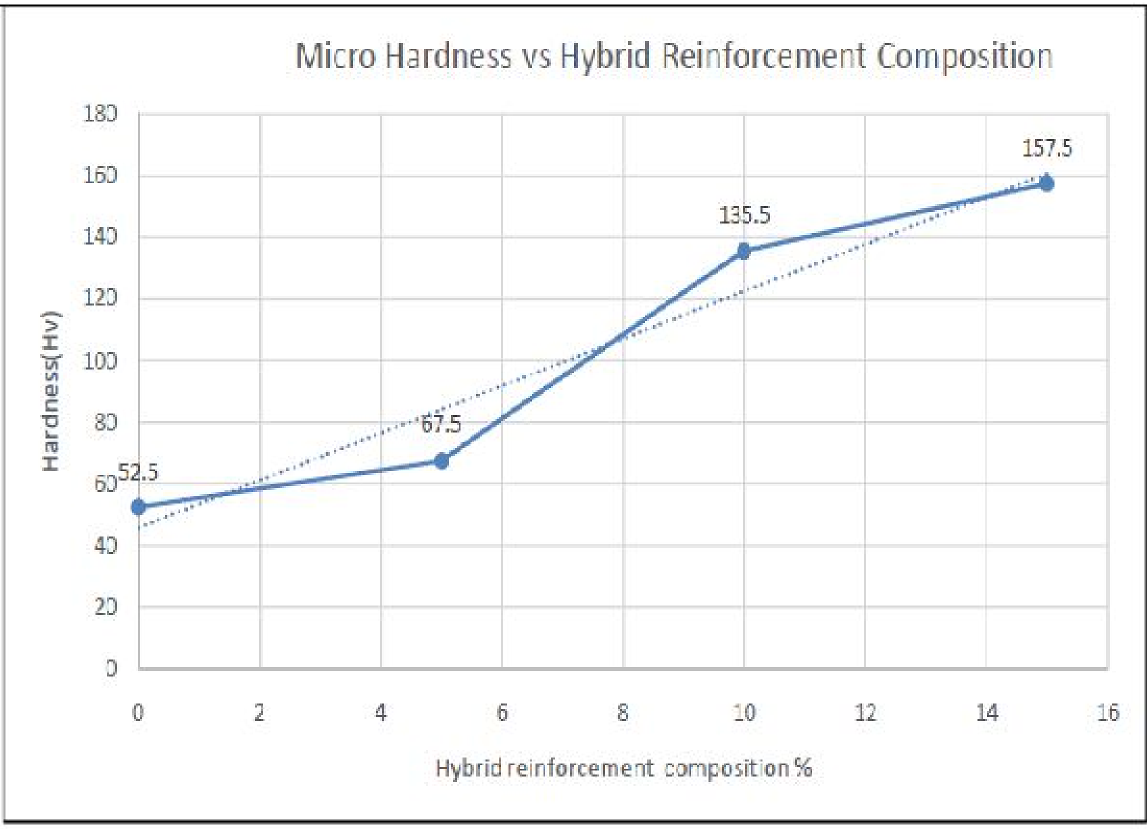

Fig. 6 Micro hardness Vs Hybrid composition

3.4 Tensile Test

Fig.7 Sub size tensile test specimen of hybrid composites

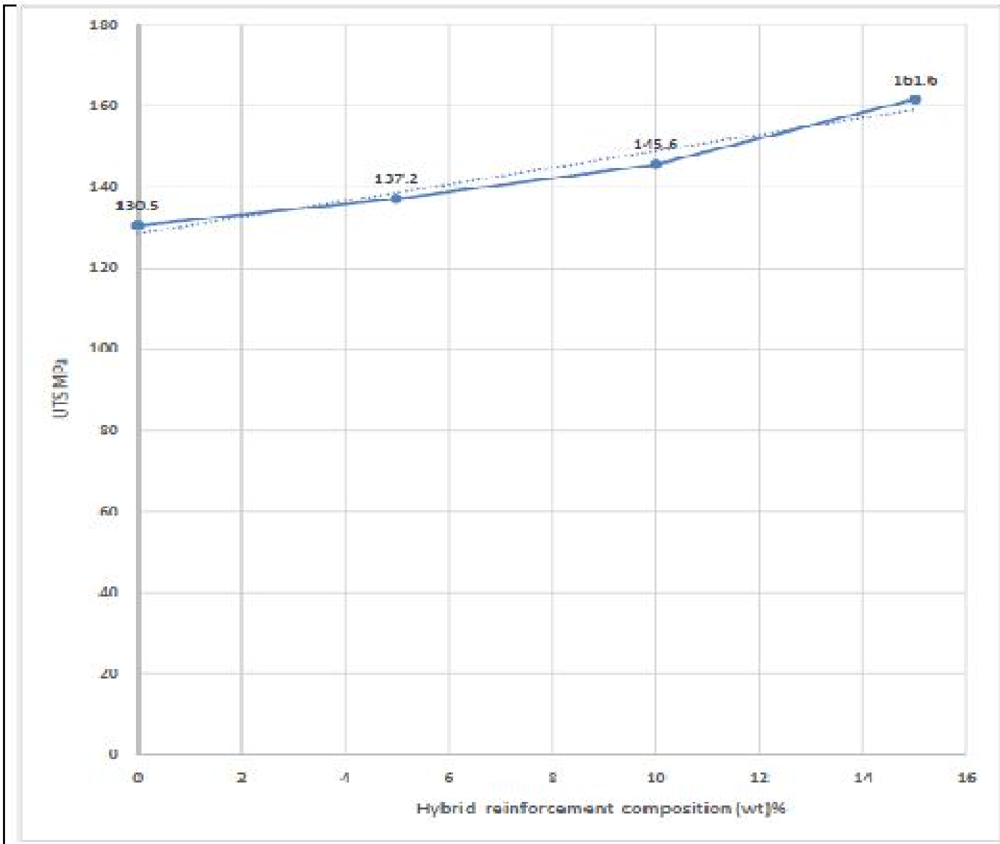

Fig. 7 Tensile strength Vs Hybrid reinforcement composition

Tensile test of hybrid composites is carried out on INSTRON tensile testing machine as per ASTM E8 M4 standard. Fig. 6 show the sub size test specimen used for tensile test. It is observed from the Fig. 7 that the with increased hybrid reinforcement composition wt.% the tensile strength is increased. This is also attributed to higher obstruction provided by reinforcement to dislocation motion and thermal mismatch exited between the matrix and reinforcement. The increase in tensile strength can be also attributed to the different strengthening mechanism like thermal expansion dislocation strengthening, small sub-grain size strengthening, Secondary dislocation strengthening and geometrically necessary dislocation strengthening. The effective load transfer from matrix to better bonded and uniformly distributed reinforcements also contributed to increase in tensile strength [3,7,10,].

IV. APPLICATIONS

Hybrid composites can be used for different applications in aerospace, defense and automotive industry. High wear resistance and high coefficient of friction are basic requirement of braking system in automobile. The hybrid composite offer better alternative to existing materials used for it.

CONCLUSION

Hybrid composites exhibits better mechanical properties than the mono reinforcement reinforced AMCs. The increased wt.% in of hybrid composition of reinforcement resulted in increased tensile strength and hardness. The increased hardness is 66.6 % (15 wt.%) more compared to aluminum matrix. The increased tensile strength is approx. 24 % more than aluminum matrix. Further improvement in properties can be achieved by optimizing the process parameter of stir casting and using secondary processing method to reduce the porosity.

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