Tribological Characterization of SiC/Co Hybrid Reinforced 6061 Aluminum Alloy Composites

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***Abstract-* Vehicles and aviation applications require materials that have adjusted mechanical and tribological properties. It is truly challenging to accomplish these altered properties in any mono-lithic material. Aluminum compounds are the most taken advantage of materials in different fields of applications including Automobiles and aviation because of a portion of its fundamental properties.**
The Al 6061 alloy has been used as matrix material while % wt of cobalt is fixed at 3% while silicon carbide altered from 0% to 3% has been used as reinforcement materials.
The center target to examine the impact of air erosion conditions on wear pace of devel-oped MMCs of SiC and Co powder filled Al 6061 Composites. In the current work, the alu-minium based metal framework composites have been manufactured. It was uncovered that MMC with 3%wt of SiC 3% wt of Co showed brilliant mechanical properties among the all manufactured metal framework composites.

Keywords- Aluminum, Metal Matrix Composites, sic, Cobalt

1. INTRODUCTION

Inside the present era, aluminium matrix composites (AMCs) are broadly used due its top properties of strength and stiffness, suitable in-creased wear resistance, aluminium components has a very lower coefficient of thermal enlargement and it has accurate dimensional stability at higher temperatures. In this kind of composite, the matrix element is aluminium/aluminium alloy and the other levels are reinforcement which might be Gr, SiC, Al2O3, B4C, and so on [1]
Wear is the continuous removal of material from a surface. Wear causes the shape of the component to change from its original shape. It is therefore of great technical and economic importance, as wear and tear cause the part to change to its original shape [2]. Aluminum-based metal matrix composites are commonly used in the construction of high-speed vehicles and aircraft operating in desert environments where solid-particle erosion due to friction between metal and sand particles plays a dominant role [3,4].
Solid particle erosion is the loss of material due to repeated impact of small, solid particles. Thus, the area of interest for researchers is increasing with the increasing use of composites in the aerospace, transportation, and manufacturing industries, where they may be subjected to multiple impacts from solid or liquid particles. Therefore, there is a need to explore this area [5,6].

2. MATERIALS AND METHOD

In this work, The Al 6061 alloy has been used as matrix material while wt.% of cobalt is fixed at 3% while silicon carbide altered from 0% to 3% has been used as reinforcement materials.

Table 1 Electronic block diagram of a potentiostat

Element	Wt %
Si	0.4
Fe	0.5
Cu	3.7-4.7
Mn	0.3-.08
Mg	1-1.7
Zn	0.24
Ti	0.15
Al	Remaining

This study used the automated stir-casting process to manufacture metal matrix composites (MMCs). Initially, cut the Al 6061 in specific sizes then put these pieces in a graphite crucible and heated up to 750 degrees centigrade, and then mixed preheated reinforced particles of SiC and Co in different weight percentages. The mixture was stirred for 15-20 minutes at 400 rpm to obtain the uniform distribution of reinforcements in the MMC. Afterward, the mixture was left to stay in the mould for one hour to allow the MMC to solidify at room temperature. The solidified MMC has been removed from the mould in the form of a plate.

Fig. 1 Electronic block diagram of a potentiostat

The erosion test was performed by using an erosion test rig as per ASTM G 88 Test standard. As per ASTM test standards, the dimensions of all

specimens were kept as 50 mm x 50 mm. The different components of the erosion test rig are an air particle mixer and an accelerating chamber, an air compressor, and a conveyor belt-type particle feeder. A mixture of silica sand and dry compressed air is fed continuously into the mixing chamber via a conveyor belt feeder. A convergent brass nozzle of 3mm internal diameter was used to accelerate the mixture by passing through it [7].
This overall arrangement is sufficient for helping solid particle erosion wear resistance of the composite sample [8].

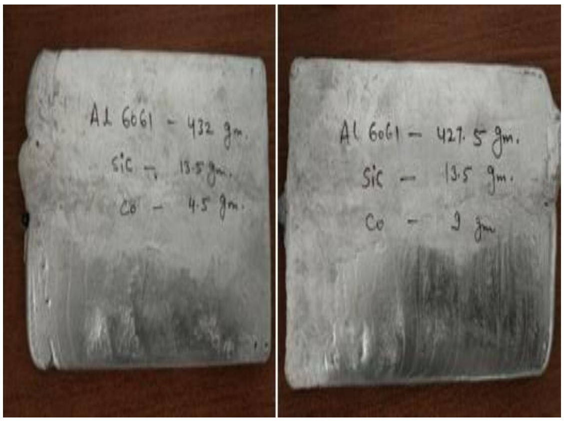

Fig. 2 MMCs after the solidification

Fig. 3 Specimen after erosion test

Fig. 4 Solid particle erosion by sir jet erosion test set up (MNIT Jaipur)

3. AIR EROSION ANALYSIS

The objective of this study is to optimize the air erosion conditions for a minimum erosion rate. The impact velocity, erodent rate, impingement angle, and percentage weight of particulates were considered as air erosion conditions. To achieve the sub-objective, the air erosion tests on all fabricated MMCs were carried out using an erosion test rig according to L16 orthogonal array-based Taguchi methodology. As per ASTMG88 test standards, the dimensions of all specimen were kept as 50 mm x 50 mm. Silica sand of 160 µm was used as an erodent particle. The air erosion analysis using Taguchi methodology is divided into the group "A". The 0SAl3C, 1SAl3C, 2SAl3C and 3SAl3C (composites in which % wt of cobalt is fixed at 3% while silicon carbide altered from 0% to 3%) were kept.
The measured values of erosion rates also presented in the respective table.

Table-2: **Air erosion factor and levels of Factor**

Erosion Factor (conditions)	Levels			
Impact velocity (m/s)	45	55	65	75
Erodent rate (gm/kg)	1	2	3	4
Impingement angle (degree)	30	45	60	75
SiC loading (%wt)	0	1	2	3

Table-3: **Design matrix and measured values of erosion rate**

Impact velocity (m/s)	Erodent feed rate (gm/Kg)	Impingement angle (Degree)	Composition (%wt.)	Erosion (mg/kg)
45	1	30	0	376
45	2	45	1	292
45	3	60	2	191
45	4	75	3	97
55	1	45	2	163
55	2	30	3	139
55	3	75	0	414
55	4	60	1	437
65	1	60	3	69
65	2	75	2	167
65	3	30	1	496
65	4	45	0	540
75	1	75	1	247
75	2	60	0	454
75	3	45	3	198
75	4	30	2	428

4. RESULT AND DISCUSSION

4.1 ANOVA (Analysis of variances) for erosion rate

In present study of work, the test ANOVA (analysis of variance) is performed at α = 0.05 that is significance level, means confidence level is 95%.

The analysis of variance tests for erosion rate for the group are presented in Table 4

Table-4: Analysis of variances table for group "A"

Source	Degree of freedom	Sum of squares	Mean square	F-Value	p-value Prob> F
Impact velocity	3	20238	6746	15.61	0.025
Erodent feed rate	3	59976	19992	46.24	0.005
Impingement angle	3	33236	11078.7	25.63	0.012
Composition % wt	3	240351	80117	185.31	0.001
Residual	3	1297	432.333		
Total	15	355098			
R-square	99.60%			Adj. R-Square	98.20%

For the group "A", the table 4, shows that "Prob. > F" values for Impact velocity, Erodent feed rate, Impct angle and Composition % wt are less than 0.05, that represents these parameters are significant so they affect the erosion rate. The R2 value and adjusted R2value are equal to 0.996 and 0.982 respectively. By the result this is clear that the adjusted R2 value is very near to the ordinary R2value, which show that the erosion conditions strongally effect on erosion rate.

4.2 Contribution of erosion factor on erosion rate

Tables 4 and 5 show the mean sum of squares for the erosion conditions at all levels and the difference between the maximum and minimum mean square sums for the erosion conditions for this group' erosion rates.

Table-5: Responses for erosion

Erosion Factor (Conditions)	Levels				Max.-Min.(Δ)	Rank
	1	2	3	4		
Impact velocity	238.9	288.2	318.1	331.6	92.7	4
Erodent feed rate	213.7	263	324.6	375.6	161.9	2
Impingement angle	359.7	298.2	287.6	231.3	128.4	3
Composition % wt	445.9	368	237.2	125.8	320.1	1

The important condition affecting performance properties is get by comparing the value of "Δ". "Δ".is the difference between highest and lowest mean value of sum of squares of all controllable conditions. This results gives the rank (level of importance) of controllable factors. Rank one is given to the maximum value of "Δ". Therefore, we found that wt% composition was the most important parameter affecting erosion rate, followed by erosion feed rate, impact angle and impact velocity for these groups

4.3 Effect of air erosion Factor (conditions) on erosion rate

Fig. 5 shows the effect of erosion conditions on the erosion rate. In figure 5 value of x direction shows levels of erosion factor and value of y direction shows the erosion. Fig 5 is divided into four group Fig 5(a) used for factor impact velocity, Fig 5(b) for factor erodent feed rate, figure 5(c) for fator impingement angle and figure 5(d). for factor composition. From Fig. 5(a), it becomes clear that the erosion rate also increases with increasing impact velocity. This is due to the increased kinetic energy and momentum of the eroding particles.

Upon impact, the erosion particles shift their momentum kinetic energy to the specimen surface, removing large amounts of material from the surface.

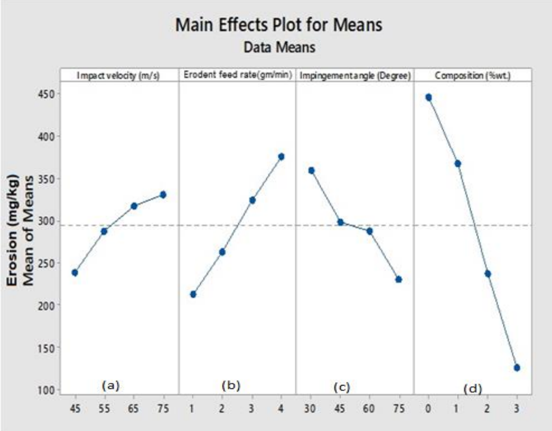

Fig. 5 Effect of erosion Factor on erosion rate

The maximum erosion rate is found at the fourth level of impact velocity and minimum erosion rate is found at first level of impact velocity. In the same manner, it is also cleared form the figures 5 (b) that as the erodent rate increases than erodent feed rate also increase. As the erodent feed rate increases, the number of erodent particles collides with the test specimen also increases. Therefore, highest erosion rate is achieved with 4th (maximum) level of erodent feed rate. The lowest erosion rate is got at 1st level of erodent feed rate.

An inverse trend was observed with impingement angle and % wt of composition for erosion rate for this groups as shown in figures 5(c) From the figures 5(c) between impingement angle and erosion rate, it was observed that erosion rate decreases with increase in impingement angle. It is due to the reduction in contact area with increase in impingement angle between the specimen and erodent particles. The minimum and maximum erosion rates are achieved at 4th level (maximum) and 1st level (minimum) of impingement angle. Also, it was also revealed from the figures 5(d) between the % wt of composition and erosion rate that erosion rate decreases with increase in % wt composition i.e increase in % wt of SiC and Co in MMCs. The lowest erosion rate is get for this group at 4th level of % wt composition i.e for 3SAl3C (composites with 3% wt of cobalt and 3% wt of SiC).

From the analysis of figures 5 it was revealed that lowest erosion rate is achieved with 1st level of impact velocity (45 m/s), 1st level of erodent feed rate (1 gm/min), 4th level of impingement angle (75°) and 4th level of 4th level of % wt composition (3SAl3C).

5. CONCLUSION

1. Among all erosion conditions (impact velocity, erodent rate, impingement angle and percentage weight of particulates) We found that the weight percent of the composition was the most important parameter affecting the erosion rate, followed by erosion feed rate, impact angle and impact velocity.
2. The erosion rate improves with increasing impact velocity and erodent feed rate but decreases with increasing impact angle and percentage of composite weight.
3. Least erosion rate is achieved with 1st level of impact velocity (45 m/s), 1st level of erodent feed rate (1 gm/min), 4th level of impingement angle (75°) and 4th level of 4th level of % wt composition (3SAl3C).

In the present work, SiC and Co are employed as a reinforcement particulate to fabricate the Al based MMCs. There is a very extensive scope for future work to explore this area of research. Some recommendations for future work are as follows:

- Use of other particulate fillers such as Al_2O_3, fly ash, Cu, B4C, etc.
- Use of other aluminium alloy such as Al7075, al 6068 etc for development of new MMCs and characterization of their mechanical, thermo-mechanical, tribological properties.
- Uses of other type of wear test like pin of disc, slurry abrasion wear etc.

6. REFERENCES

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