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Friction and Wear Properties of Al7075-BA-Gr Hybrid Composites

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ABSTRACT

The experimental investigation of A7075 matrix reinforced with Bagasse Ash (BA) particle with 1,3,5,7,9,11 and 13wt% composites was fabricated by stir casting technique and also hybrid composites processed at 5wt% Gr with same wt% of BA particles. The abrasive wear behaviour of composites was carried out by using dry sliding pin on disc machine. The various parameters affects like applied load, sliding speed, wt% of BA particle and Gr particles were considered for this study of wear resistance and friction effect under dry sliding condition. The wear rate and coefficient of friction are found by effecting parameters such as increase in load (10, 20, and 30 N), increase in sliding speed (0.42, 0.84, and 1.68 m/s) and wt% BA (1,3,5,7,9,11 and 13t%) has been obtained. The effect of load and speed on dry sliding wear rate and coefficient of friction performance of Al7075 casting alloy and its composites was evaluated using a pin-on-disc with three different loads and three different speeds at room temperature. Significant effect of factors and conditions was identified, experiments results shows that, the wear rate and coefficient of friction increased with increase in load and decreased with increase in sliding distance, however the coefficient of friction decreased with increasing sliding speed before stable state reached. The influence of graphite particle performs as self lubricant element towards controlling the wear behaviour shows in hybrid composites which improves wear resistance. This investigation use of Taguchi method to minimizing experiments wear rate and coefficient of friction AMMCs. A experiments plan, based on orthogonal array L_9 design used to obtain signal- to- noise ratio of response parameters wear rate and coefficient of friction. Finally analyzing effected parameters and results shows that optimal combination and compatible level of affecting parameters.

Keywords: Wear rate, Frication, Al7075, Bagasse ash, Graphite, Taguchi method.

I. INTRODUCTION

The utilization of advanced performance of wear resistance material for various tribological function in the development of hybrid composite materials. The use of ceramic reinforcement in monolithic Al matrix, composite has increases in mechanical and tribological properties appreciably[1-21]. The recent type of composites are known as hybrid composites, in which properties of more than one suitable reinforcement have been exploited to improve the overall properties of composite including tribological properties. This paper give an current development about tribological properties of hybrid composites. Over the last few decades particle reinforced MMCs (Metal Matrix Composites) most popular. The recent development for potential applications is to optimize the mechanical properties and tribological properties of MMCs. AMMCs (Aluminum metal matrix composites) reinforced with discontinuous dispersoid in the forms of fibers, whiskers, and particulates reveal amplify strength significance at good wear resistance, low coefficient of friction, low thermal expansion and stiffness compared to base alloys. AMMCs has application in automobile engine block pistons and brake drum. These automotive engine components are subjected to dry sliding wear [10],[14]. Wear resistance of aluminum (Al) alloys are improved by introducing particulate reinforcement such as SiC [5,8,11], Al2O3 [6,11], TiC [8,19], Beryl [9], boron carbide [15] and Bagasse Ash (BA) [20-21].

Hence AMMCs are possible materials for tribological application[10-14]. The level of enhancement in the dry sliding wear resistance of particulates reinforced Al-matrix composites depends on type of reinforcement used, manufacturing technique and contact condition. The interfacial bond strength, mechanical properties of matrix and reinforcement are essentially affect on wear resistance of composites [11,14,13]. The two major types of tribological factor control the friction and wear behaviour of Al based composites are physical and mechanical factors [20-21]. Many researchers and investigators stated that, wear performance of SiC , Al2O3, Gr and BA particles reinforced composites are shows better tribological properties hybrid composites. Graphite reinforcement act as solid self lubricating element under dry sliding condition [3]. Taguchi method used for minimizing the experiments on wear rate and coefficient of friction in BA based AMMCs. A map of experiments, based on the orthogonal array L_9 Taguchi design give signal- to- noise ratio, it employed to examine the influence of factors like applied load (L), sliding speed(S) and wt% of reinforcement of the corresponding material [3,12].

II. Experimental Details

A. Material Processing

The material Al7075-bagasse ash and Al7075-bagsse ash-Graphite composites synthesized by using liquid metallurgical with stir casting process at the Metal R&D Lab in Ghousia College of Engineering. The base metal used for the metal matrix composite is aluminium 7075 alloy and reinforcement used Bagasse Ash and Graphite. The particle size of bagasse ash reinforcement is 400 mesh (below 105 μm). The base metal Al7075 is melted in electric melting furnace at 750^0C. The reinforcement is preheated and then mixed with the melt. The mixture of composites is by stirring with the help of motor stirrer to incorporate the reinforcements in the base alloy. The mixture is then poured in permanent metallic mould and after cooling the cast material is machined specimen sizes of 23mm height x 10mm dia. These specimens were used for wear testing to examine the tribological properties by using pin on disc wear testing machine.

B. Wear Tests

Wear and friction tests are performed in a pin on disc testing machine under dry sliding conditions at room temperature. The pin on disc vibrometer shown in Fig. 1. The disc is made up of EN8 steel and load is applied by placing dead weight in the loading pan connected by a lever. The experiment is conducted by following the orthogonal array L_9 by Taguchi Method and experimental data is recorded by a computer attached to the machine. The wear rate is measured with affecting parameters Load, Sliding distance, Sliding Speed and wt% of reinforcement. Microstructure study of the worn surface is then carried out by using scanning electron microscopy to observe the worn out surface, delamination and wear pattern.

Figure-1: Pin on Disc Machine

C. Design of Experiment

Design of experiment introduced is statistical technique which dealing with the process of designing, planning and analysing the experiment. The experimental design is constructed using the design or control or levels of factors. There are three of design factors which can affect the wear behaviour of Al7075-bagasse ash and Al7075-bagsse ash-Graphite composites. The design factors used for this experimental optimization are applied load, sliding speed and sliding distance. Table-I shows the three levels of design factors used for the study of response factors are wear rate and coefficient of friction. Considering Taguchi method with degree of orthogonal array L_9 to reduce the number of experiments. The 1st factor is assigned applied load (L), 2nd factor is assigned maintained sliding speed (S) and the 3rd factor is assigned sliding distance (D). Table 2 shows the orthogonal array.

TABLE I. DESIGN FACTORS USED FOR THE EXPERIMENT

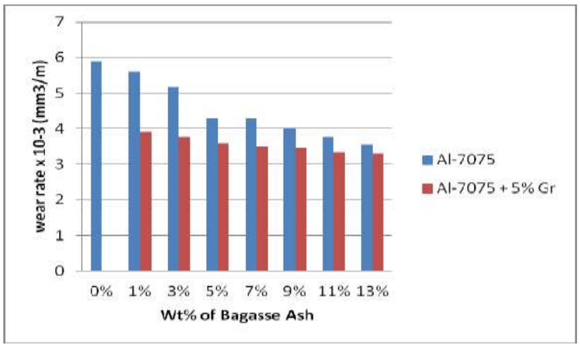
Sl. No.	Load (N)	Sliding Speed (S) in m/s	Sliding distance (D) in m
1	10	0.42	500
2	20	0.84	1000
3	30	1.68	2000

III. RESULTS AND DISCUSSION

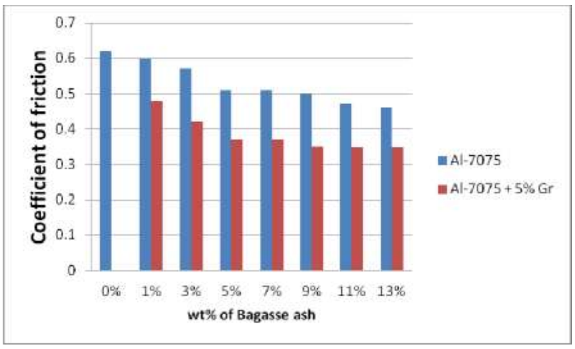
A. Wear and Coefficient of friction

Wear rate and coefficient of friction of composites has observed experimentally based on effect of load (L), effect of sliding speed (S) and effect of reinforcement (R). Decreasing wear rate with increasing in load and reinforcement, increasing in wear rate with increasing in sliding speed and distance.

(i) Effect of wt% of reinforcement



(a)

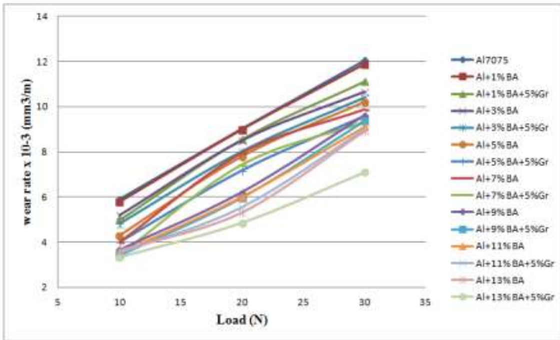


(b)

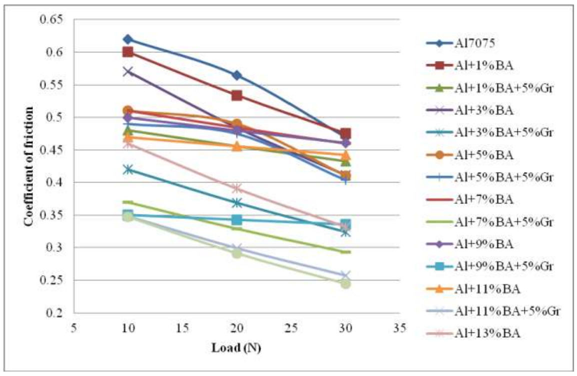
Figure 2 : Effect of second phase on (a) Wear Rate (b) Coefficient of Friction.

With the increased load and sliding distance wear rate increases. It can also be observed from the graphs that wear loss is decreased with the increased reinforcement weight fractions at any applied load and sliding distance. Hence it is very much clear that shows in figure-2 (a) and (b) can be concluded that wear resistance increased and friction decreased of hybrid composites with the increasing reinforcement fractions.

(ii) Effect of increasing load



(a)



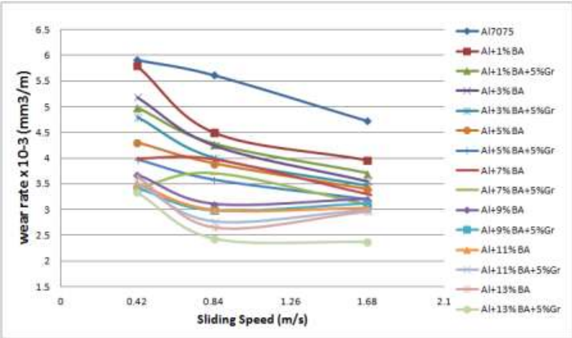
(b)

Figure 3: Effect of Load on (a) Wear Rate (b) Coefficient of Friction.

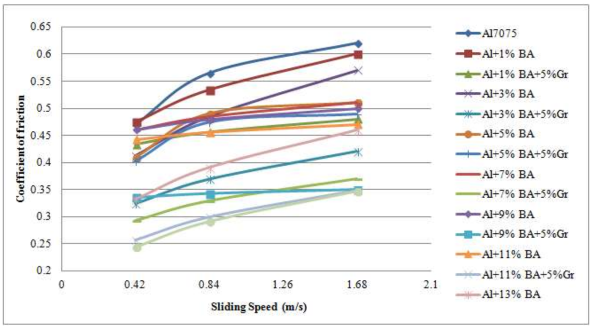
With the increased load wear rate increases coefficient of friction deceased. It can also be observed from the graphs that wear loss is increased with the increased applied load. Hence it is very much clear that shows in figure-3 (a) and (b) can be concluded that wear resistance decreased and friction increased of hybrid composites with the increasing load.

(iii) Effect of increasing sliding speed

With the increased load wear rate coefficient of friction deceased. It can also be observed from the graphs that wear loss is decreased with the increased sliding speed. Hence it is very much clear that shows in figure-4 (a) and (b) can be concluded that wear resistance increased and friction decreased of hybrid composites with the increasing sliding distance.



(a)



(b)

Figure 4 : Effect of Sliding speed on (a) Wear Rate (b) Coefficient of Friction.

B. Taguchi Method

TABLE-II. TAGUCHI ANALYSIS DATA OF RESPONSE PARAMETERS

Load (N)	Sliding Speed (m/s)	Sliding distance (m)	Wear Rate x 10^-3 (mm3/m)	S/N Ratio for Wear rate (-10LogWi)	Coefficient of Friction	S/N Ratio for Coefficient of Friction (-10LogWi)
10	0.42	500	5.907	-17.1469	0.62	5.05242
20	0.84	1000	7.582	-16.2991	0.498	5.81218
30	1.68	2000	8.6408	-18.3082	0.41	7.08730
10	0.42	1000	4.113	-11.8603	0.47	5.90102
20	0.84	2000	5.764	-16.9340	0.469	7.47680
30	1.68	500	7.659	-16.3868	0.401	7.69388
10	0.42	2000	5.04	-12.7520	0.413	7.43777
20	0.84	500	6.09	-15.2694	0.371	7.95550
30	1.68	1000	3.033	-11.3570	0.421	8.41461

The pin on disc wear analysis was carried out as per the experimental design in Table-II and the results are analysed by using Taguchi method. The different combination effect of factors gave different wear rate and resistance. The minimum wear rate was observed for specimen have 5% and 13% bagasse ash hybrid composites for the conditions 10N load, 0.42 m/s speed and 1000m sliding distance, while maximum wear rate was observed for 5% of bagasse ash composites for conditions 30N load, 1.68 m/s sliding speed and 1000m sliding distance. Figure.5 shows the wear rate for various combinations of levels of factors for smaller-the-better,

η = -10log(mean of sum of squares of measured data).

Taguchi analysis of wear rate x 10^3 (mm^3/m) versus L, S, D response of wear rate has signal to noise (S/N) ratios for smaller is better parameter selection are tabulated in table-III.

TABLE-III. WEAR RATE RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS

Level	L	S	D
1	-17.25	-13.92	-16.27
2	-15.06	-16.17	-13.17
3	-13.13	-15.35	-16.00
Delta	4.13	2.25	3.10
Rank	1	3	2

The individual effects of factors are shown in Table-III. 46.29% Load is the most dominant factor for wear rate as the load increases and contact area increases which causes increase in wear rate. sliding distance 29.36% was the 2nd dominant factor as the sliding speed increases the sliding distance also increases.

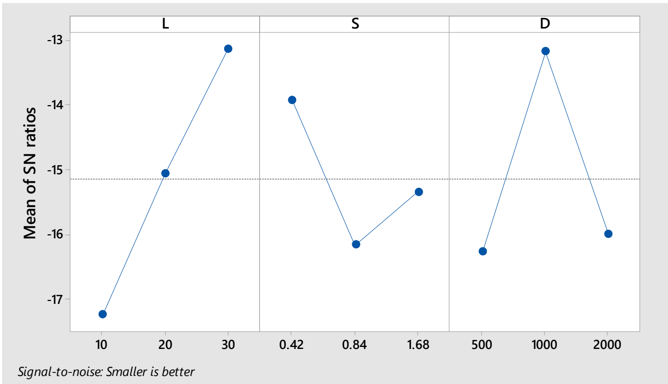


Figure-5 : Wear rate verses S/N ratio

The pin on disc coefficient of friction analysis was carried out as per the experimental design in Table-II and the results are analysed by using Taguchi method. The different combination effect of factors gave different coefficient of friction. The minimum coefficient of friction was observed for specimen have 5%

and 13% bagasse ash hybrid composites for the conditions 10N load, 0.42 m/s speed and 1000m sliding distance, while maximum coefficient of friction was observed for 5% of bagasse ash composites for conditions 30N load, 1.68 m/s sliding speed and 1000m sliding distance. Figure.5 shows the coefficient of friction for various combinations of levels of factors for smaller-the-better,

η = -10log(mean of sum of squares of measured data).

Taguchi analysis of coefficient of friction versus Load, Sliding speed and sliding distance response of coefficient of friction has signal to noise (S/N) ratios for smaller is better parameter selection are tabulated in table-IV.

TABLE-IV. COEFFICIENT OF FRICTION RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS

Level	L	S	D
1	5.984	6.130	6.901
2	7.024	7.081	6.709
3	7.936	7.732	7.334
Delta	1.952	1.602	0.625
Rank	1	2	3

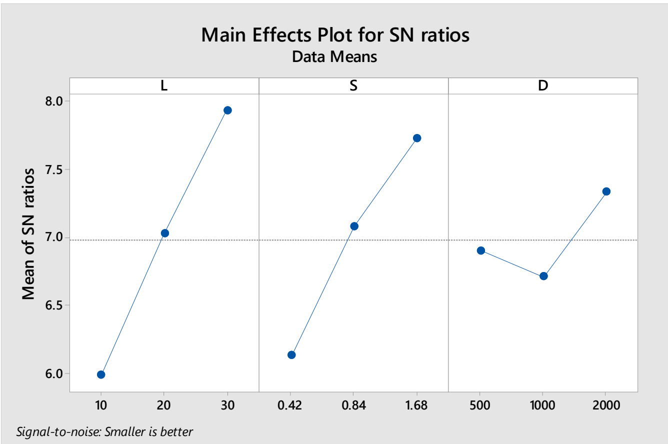


Figure-6 : Wear rate verses S/N ratio

IV. Discussion

The reciprocal significance wear rate value is known as wear resistance. It is evident from the resultant graphs obtained by experimental conduction of wear test, with the fractions of reinforcement in the composites significantly improved wear resistance. The wear resistance of composites obtained is higher than that of the base matrix alloy also wear resistance of hybrid composites are very much higher than both composites and base metal. Here, Gr powder forms on worn surface of specimens in hybrid composites which acts as solid lubrication element and reduces the wear rate. Wear resistance have improved by 61.43%. Further it can also be observed that the by using Taguchi method the experimental and analysis results does not have much error that is 3.78-7.02% which is acceptable for the selection material to preferable applications.

V. CONCLUSION

In this wear and coefficient of friction analysis on Al7075 and its composite specimens prepared by liquid metallurgical manufacturing technique, Based on the investigation carried out to study the wear behaviour of Al7075 reinforced with bagasse ash and Gr, the following conclusions were observed as,

- Cast Al7075 matrix hybrid composites has been prepared satisfactorily by stir casting process.
- The Gr particles deposit on pin surface on the disc track and cause reduction in wear by reducing the roughness of the pin with lubricating effect.
- Wear rate increases with increased sliding distance and With the increased reinforcement weight fractions wear rate decrease in composites. The stable value of sliding distance decreases with the increasing % of reinforcement.
- Wear resistance increased about 61.43% with increased % of reinforcement and it is dependent on the hardness of the composites.
- The Bagasse ash particulates much contribute in increasing the wear resistance of the composites while particle Gr contributes by providing lubricating layer between pin and disc, because it has less friction exhibits good coefficient of friction of composite may be used in automobile application for the production of composites.
- The generated Taguchi design can be used to predict the wear behaviour under the minimum and maximum wear conditions for the optimization of experimental conductions.
- The optimal combination is has minimum wear rate was observed for specimen have 5% and 13%

bagasse ash hybrid composites for the conditions 10N load, 0.42 m/s speed and 1000m sliding distance.

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