Study of Hardness and Optimization of Wear Properties of AL 7075 Hybrid Composite

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***Abstract*— Waste sugarcane Bagasse-ash and graphite with different percentages are utilizing as reinforcing material along with Aluminium 7075 matrix material. The selection of bagasse-ash as reinforcement has one of the most significant criteria for the fabrication of Aluminium matrix hybrid composites. Stir casting technique is one of the liquid metallurgical route is used for fabricating the Aluminium 7075 at 800°C. The effect of reinforcement on hardness was measured. Experimentation have been carried out based on standard L9 orthogonal array design with three process parameters namely type of material, load, speed. Optimum parameters were noted for attaining the minimum wear rate of hybrid composites by the application of Taguchi's technique.**

Keywords*— Al 7075, Bagasse-Ash, Graphite, Taguchi, Wear, Hardness

I. INTRODUCTION

Mechanical properties of Al 7075 alloy with graphite (Gr) reinforced composites were investigated. The effect of reinforcement was analyzed on added reinforcement content of graphite and bagasse with varying percentages by weight. It was observed that the hardness of the composites increased with increasing the reinforcement in the base alloy and the ductility decreases with increasing content of reinforcement in the matrix alloy [1]. Studies were carried out to understand the influence of bagasse ash and graphite as reinforcing materials in different percentages with Al7075 found that the increase in bagasse ash percentage increases the ultimate tensile strength and yield strength whereas the percentage elongation decreases [2]. L. Arulmani et al.[3] presented the study on ultimate tensile strength and hardness influenced by bagasse ash and graphite as reinforcing materials with aluminium 7075. Study emphasized that the dry sliding wear behaviour of Al 7075 reinforced with graphite in weight percentages of 5,10,15 and 20 hybrid composites by using pin on disc[4]. A. Baradeswaran et al.[5] Studied on mechanical and tribological behavior of Aluminium 7075 hybrid composites with 2–8 percentages by weight of Al_2O_3 particles and 5 percent by weight of graphite and found that hardness and tensile strength of composites increased with increasing Al_2O_3 content. Some works have been carried out to study the characterization of Al 7075 MMC [6]. The various specimens of the composite with varying weight percentages of reinforced material were made and experiments were conducted using L9 orthogonal array and the properties of the composite and their significant changes were evaluated [7]. A. Baradeswaran et.al. [9] adopted Taguchi's optimization methodology to optimize the wear rate of Al-Al_2O_3 composites.

II. MATERIALS

A. Matrix alloy

In the present work, aluminium alloy 7075 is considered as matrix metal, bagasse and graphite as reinforcing materials and test specimens were cast using stir casting process. Table 1 shows the chemical composition of Al 7075 alloy used in this investigation which has been supplied by the Venuka Engineering, Jeedimetla, Hyderabad.

TABLE I. CHEMICAL COMPOSITION OF ALUMINIUM 7075 ALLOY

Chemical Composition (%)									
Weight %	Al	Si	Fe	Cu	Ti	Mg	Mn	Zn	Cr
7075 Alloy	Balance	0.08	0.16	1.56	0	2.64	0.01	5.72	0.22

B. Graphite

Graphite(Gr) possesses high thermal stability, wear resistance, low density, low friction, good electrical and thermal conductivity facilitating its widespread use in engineering applications. The graphite powder of grain size of 30-70 micron meters has also been supplied by the Venuka engineering, Jeedimetla, Hyderabad.

C. Bagasse Ash

Bagasse was packed in graphite crucible and placed inside electric control furnace. It was burnt to obtain black ash. This carbonated bagasse was collected and burned at temperature of 1200°C for 3hrs [8]. After burning, a heterogeneous composition of light colored and black colored ash consisting of leftovers of the unburnt sugarcane bagasse along with charcoal particles was observed on the surface. Then the further processing was to make the amorphous shape through

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grinding for long time. It was done using a mill with steel balls for 120 minutes and the speed of revolution was chosen appropriately so that the impact force can break silica crystal existed in ash. 100grams of the dried ash was taken into sieves to obtain the required grain size of the bagasse ash. In this present investigation 75 micro meters grain size was chosen. Required grain sized sieves are used to retain the bagasse ash(BA) grain size.

III. COMPOSITE PREPARATION

Hybrid Al7075-Gr-Bagasse ash composites were fabricated by stir casting technique using electrical resistance furnace. Aluminum 7075 is maintained at 800°C in the stir casting equipment until it is completely converted into molten state. Figure 1 shows the aluminium 7075 alloys being melted in the crucible of stir casting equipment. According to the required percentage level of composition by weight bagasse ash and the graphite are taken and preheated separately. The compositions of samples that are to be made are as per the Table 2.

Fig 1. Crucible with composite material

TABLE II. SAMPLES PERCENTAGE BY WEIGHT

Sample	Composition
M1	Al7075 alloy + 2%BA + 2%Gr
M2	Al7075 alloy + 2%BA + 4%Gr
M3	Al7075 alloy + 2%BA + 6%Gr
M4	Al7075 alloy + 0%BA + 2%Gr

It is then mixed with the molten aluminum 7075 and is stirred with the stirrer at 300rpm for 2 minutes. Then it is poured into graphite die of cylindrical shape as shown in Figure 2.

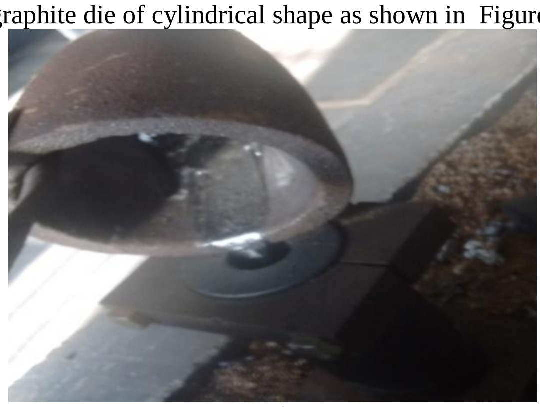


Fig 2. Pouring of Molten Metal

IV. HARDNESS TEST

The values of the Hardness Rockwell value (HRV) are shown in Table 3.

TABLE III. ROCKWELL HARDNESS VALUES FOR SAMPLES

Samples	HRV
M1	46
M2	40
M3	36.25
M4	33

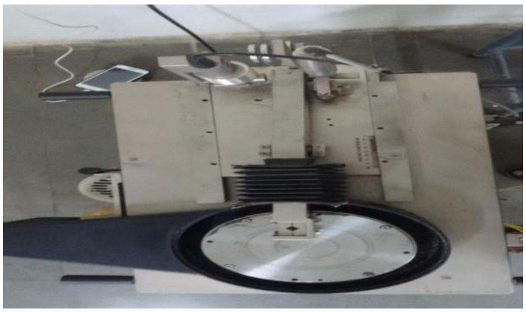
It can be observed that as the graphite increases the hardness are reduced. These results are verified with the sample M4. Hardness increases as baggase ash is mixed with the Al7075 material as compared with aluminum and graphite content. The confidence interval has shown the hardness decreased with increasing in graphite reinforcement.

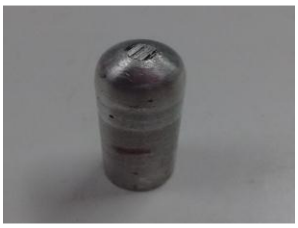
V. WEAR TEST

Loss of material from a surface by means of some mechanical action is termed as wear. Wear is due to hard particles or hard protuberances forced against and moving along a solid surface. The resistance offered against such a force is called as wear resistance. The wear resistance of the material is tested on a pin on disk wear testing machine.

The pin on disk machine is as shown in the Figure 3. It consists of a flat circular disc positioned horizontally, which can be rotated at a desired speed. The specimen is held perpendicular to the disc in a small holder. The force with which the specimen is forced on to the disc and the circumferential distance from the specimen to the centre of the disc can be changed. The specimen is prepared as per standard dimensions as shown in Figure3. Three specimens are prepared each made with a specific composition as shown in the Table 2.

Once the combination of load, specimen, sliding distance are given to the machine, the wear rate and frictional can be directly obtained from the digital meter provided.





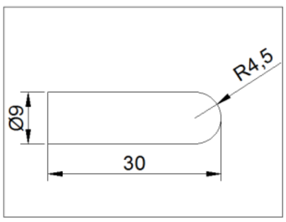


Fig 3. Pin on disc apparatus and Specimen for wear testing

VI. OPTIMIZATION

Taguchi method is one of the widely used technique for the purpose of single objective optimization accompanied by an advantage of conducting lesser number of experiments without affecting the quality of experimentation. The application of the technique involves deciding the process parameters and response variables, choosing the suitable orthogonal array, conducting the experimentation and analysis of the obtained responses.

In this work, the type of material, speed and load were taken as the process parameters. Wear resistance and frictional force are the response variables. The three parameters are varied each at three levels as shown in the Table IV and L9 orthogonal array is chosen for the experimentation depending on the factor and their levels.

TABLE IV. FACTORS AND LEVELS

Process Parameters	Level1	Level2	Level3
Material	M1	M2	M3
Speed (rpm)	100(1.57 m/s)	150(2.09m/s)	200(2.61m/s)
Load (N)	10	15	20

TABLE V. CRITERIA AND EXPRESSIONS FOR CALCULATING S/N RATIO

Criteria	Expression
Lower the better	$S/_N = -10\log\left(\frac{1}{r}\sum_{i=1}^{r} y_i^2\right)$
Higher the better	$S/_N = -10\log\left(\left(\frac{1}{r}\right)\sum_{i=1}^{r}\frac{1}{y_i^2}\right)$

The experiment was conducted using L9 orthogonal array and the corresponding observations of the responses were tabulated and given in Table VI. Wear rate and frictional forces are considered as the responses as mentioned earlier and the same were optimized using Taguchi method.

The observations were converted to S/N ratios using the appropriate criteria and expressions as shown in the Table V. The criteria is chosen depending on the characteristic of the response. In this study, wear rate and frictional force are always needed to be minimized. Hence lower the better criteria is chosen for both wear rate and frictional force. The S/N ratios for wear rate and frictional force are also shown in the Table VI**.**

TABLE VI. OBSERVATIONS AND S/N RATIOS

Material	Speed (rpm)	Load (kgf)	Wear (µm)	Frictional force (N)	S/N ratio for Wear rate	S/N ratio for frictional force
M1	100	1.02	119	2.9	-41.5109	-9.24796
M1	150	1.53	173	4.8	-44.7609	-13.6248
M1	200	2.038	131	6.3	-42.3454	-15.9868
M2	100	1.53	220	4.7	-46.8485	-13.442
M2	150	2.038	152	6.9	-43.6369	-16.777
M2	200	1.02	211	2.8	-46.4856	-8.94316
M3	100	2.038	122	6.5	-41.7272	-16.2583
M3	150	1.02	88	2.6	-38.8897	-8.29947
M3	200	1.53	377	4.3	-51.5268	-12.6694

A. Wear Rate

The S/N ratios of wear rate for each factor at each level are shown in the Table VII. Figure 4 shows the variation of S/N ratio for the factors at their respective levels. It can be observed that all the factors i.e., material, speed and load are influencing the wear rate. The optimum combination of the factors that minimizes the wear rate is obtained by taking the levels of the factors at which the S/N ratio is maximum. Hence the optimal combination that minimizes the wear rate is material at level 1 (M1), speed at level 2 (150 rpm) and the load at level 1 (10N).The delta value is the difference between the highest and lowest of the S/N ratios for each factor. Ranks are given to the delta values from highest to lowest. Higher rank indicates higher influence of a factor on the response. Therefore wear rate is highly influenced by load followed by speed and material.

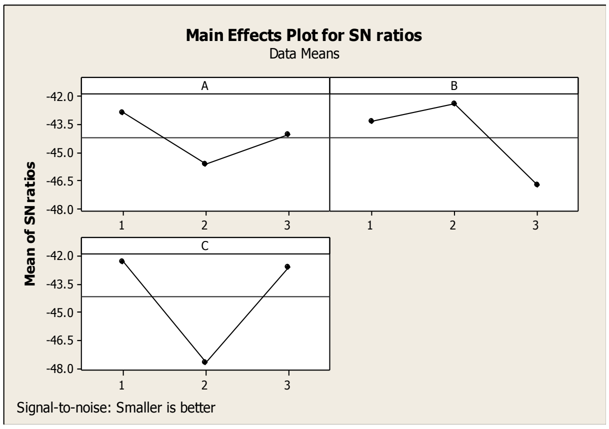


Fig 4. S/N ratio of wear rate for each factor at each level

TABLE VII. S/N RATIO FOR EACH FACTOR AT EACH LEVEL (WEAR RATE)

Level	Material	Speed	Load
1	-42.87	-43.36	-42.3
2	-45.66	-42.43	-47.71
3	-44.05	-46.79	-42.57
Delta	2.78	4.36	5.42
Rank	3	2	1

B. *Frictional Force*

The S/N ratios are calculated using the smaller the better criteria. The Figure 5 shows the variation of S/N ratio for each factor at each level for frictional force .It can be observed that the frictional force is highly influenced by load while the influence of speed and material is minimum. The S/N ratios for frictional force for each factor at each level are also shown in the Table VIII. From the table, the optimum combination of factors that minimizes the frictional force is obtained taking the level of the factor at which the S/N ratio is higher. Hence the optimal combination that minimizes the frictional force is Material at level 3 (M3), speed at level 3 (200 rpm) and the load at level 1 (10N).It can be observed from the delta values that load is given the highest rank which indicates that it is having higher influence on the frictional force.

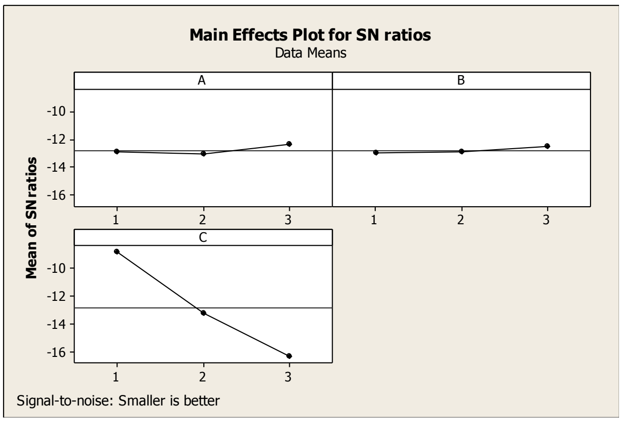


Fig 5. S/N ratio of frictional force for each factor at each level

TABLE VIII. S/N RATIO OF FRICTIONAL FORCE FOR EACH FACTOR AT EACH LEVEL

Level	Material	Speed	Load
1	-12.953	-12.983	-8.830
2	-13.054	-12.900	-13.245
3	-12.409	-12.533	-16.341
Delta	0.645	0.450	7.510
Rank	2	3	1

VII. CONCLUSION

The experimentation was conducted using Taguchi method and the following conclusions were drawn.

- Al7075– Bagasse ash–Graphite hybrid composite specimens are prepared with constant bagasse ash content by weight percentage with the variation of the graphite percentage using stir casting technique.
- Hardness of the material gets reduced with increasing the graphite content. Hardness increases as bagasse ash is mixed with the AL7075 material as compared with aluminum and graphite content.
- From Taguchi method it was concluded that for minimizing the wear rate, the optimal combination is Material at level 1 (M1), speed at level 2(150 rpm) and the load at level 1 (10N).
- For minimizing the frictional force the optimal combination is Material at level 3 (M3), speed level 3 (200 rpm) and the load at level 1 (10N).

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