Study on Mechanical and Machinability Properties of Aluminium Coconut shell ash by Taguchi Approach

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***Abstract*- In this modern era, the demand of aluminium and its composites has grown day by day due to its vast applications due to low coefficient of thermal expansion, moderate in strength, excellent ductility and light weight. So, this paper aims to study of physical, mechanical, micro structural and machinability properties of the Aluminum (Al-1100) metal with a reinforcement of Coconut Shell Ash (CSA) (15% of volume) fabricated, by liquid metallurgical route. The experiments are designed by Taguchi approach [L_9]. The effect of the machining parameters like speed, feed and depth of cut where examine in detail on MRR, Surface roughness for aluminium and surface roughness for composite, during the process of turning operation. Due to the presence of CSA particles the surface roughness of composites decreases compare to its parent metal Al. ANOVA methods have been used for obtaining the best machining parameters by increasing the MRR and decreasing the Surface roughness.**

***Index Terms*- Al MMCs, Surface roughness, Taguchi [L_9], CSAp, ANOVA.**

I. INTRODUCTION

A composite material is result of reinforcement of two or more constituent materials with different properties. The composites has improved properties compare to its parent metal. The composite materials are lighter and having high strength and these are available with a minimum cost compare to other material. The constitute material has two categories i.e. matrix and reinforcement. The matrix acts as a binder. The matrix combines the reinforcement and maintained them in their relative positions. To make a product economic and attractive we are using composites. The composites do not rust and do not directly suffer from galvanic corrosion caused by stray currents[1]–[4].

Metal matrix composites (MMCs) are the most advanced materials that consist of a parent metallic alloy which is reinforced with other metal in the form of particles, like whiskers and short fibers. This metal matrix composites has the enhanced properties than the parent metals [5]–[7]. MMCs are used in industries like automobile and different structural application. This is also used for saving the weights. So far the most common MMCs are based on aluminum, magnesium and titanium alloys reinforced with alumina (Al_2O_3) or carbon or coconut shell ash (CSA). The reinforcement increases the strength and hardness and stiffness of the matrix. Due to addition of graphite to the matrix the coefficient of friction between the composite and counter face alters which leads to prolonged wear life during sliding. The addition of hard ceramic particles enhances the property of hardness of the MMCs.\

Aluminum is used for the composite due to its low density. It has the capability to get strengthened by the process of precipitation. It has good corrosion resistance and better thermal and electrical conductivity. It has high damping capacity.

The aluminum matrix has low density and high specific mechanical properties. It is used for manufacturing of light weight parts for many types of vehicles. The wear resistance and strength of the aluminum matrix is equal to iron metal. It has 3 times the thermal conductivity and 67% lower density than iron metal.

In this paper we will concerned about the addition of coconut shell ash with aluminum. Coconut shell ash which is a waste product and it is an agro based material which is easily available. It has high strength and modulus properties with advantage of high lignin content. Due to presence of high lignin content the composite made with this are more weather resistance and more suitable for application. Coconut shell ash contain about 70-75% volatile material and moisture which can be removed by carbonization process[11]–[16].

This paper shows an experimental report on the effect on properties like hardness and MRR and power consumption of the Al-CSA composites compare to its parent material aluminum. In addition, an analysis of variance is employed to find out effective cutting parameters on surface finish. The setup for work piece (Al and Al-CSAp) and cutting tool (carbide) contact interface have shown Fig 1.

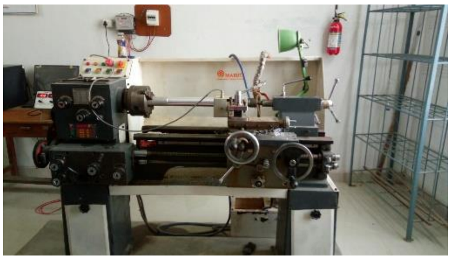

Figure 1: The work piece and tool setup

II. MATERIALS AND METHODS

2.1 Materials:

The material used for preparation of matrix composite is aluminum and the reinforced material chosen is coconut shell ash particles of size 60µm. 5-15% of coconut shell ash has been fabricated for the composite[17], [14], [18]. In order to maintain uniform distribution of reinforcement the fabrication process is done by stir casting process. The Al alloy which is initially in the form of ingot has cut into small pieces to accommodate into the graphite Crucible. At first Al alloy has been melted in an electric furnace. And then the already prepared coconut shell ash, preheated to a temperature of 900 ^{0}C and then it added to the molten metal at 700 ^{0}C and continuously stirred. This stirring process continues for 9 min with a speed of 600 rpm for uniform distribution of particles. Then to increase the wettability magnesium is added in added in small amount during stirring. Finally the melt reinforced is poured in metallic mould.

2.2 Measurement of Hardness:

Hardness is a characteristic of material. Hardness is defined as the resistance of a solid matter to different kind of shape change under the application of a compressive load. It is also representing the resistance to scratching and penetration. It also can be properties of material to resist plastic deformation. The hardness test was done by using Brinell hardness tester.

2.3 Metallography:

The microstructure of Al sample and Al-CSAp sample was found out with the help of a microscope and the record was recorded. To obtain the microstructure first the samples were rubbed on the surface of some emery paper of designation 220, 320, 600, 800, 1000, 1200, 1500 grits. This rubbing was done with a constant velocity and force with same direction against those emery papers in an orderly manner for about 10 min each. After that we did the Disc polishing to get the mirror like surface finish. During this disc polishing process some amount of alumina powder continuously fed into that disc to get better surface finish of the sample. After that the sample were etched by Keller's reagent to determine the microstructure. The composition of that solution is 95ml of H_2O, 2.5ml of HNO3, 1.5ml of HCL and 1ml of HF.

2.4 Measurement of Surface Roughness

The surface roughness were measured by using the instrument SURTRONIC 25, which is a surface roughness tester. For measuring the direction of roughness the preferred direction taken was orthogonal to the cutting velocity vector. The analysis is done by taking the average value of all measurement.

Figure 2 Surface Roughness Tester

2.5 Taguchi Method

It is a technique which is used to verify the results of a product designed and its performance, which will deliver more consistent result. This method contains system design, parameter design and tolerance design procedure for achieve an exact process and result for the best product quality. This experimental verification was done by the help of a software which is based on orthogonal array [L_9] technique. The parameters which were considered during the experiment are shown in Table 1. Optimization of process parameters has done to get better control over quality, productivity and cost aspect of the process. Analysis of variance (ANOVA) has done to study the effect of process parameters on the machining process. The Signal-noise ratio (S/N) and analysis of variance (ANOVA) has been employed to study the performance characteristics.

The considered parameters are speed, feed rate and depth of cut (DOC) and the used values of those parameters are given in the table 1.

Table 1 Process parameters

Parameters	Unit	Levels (-1)	Levels(0)	Levels(+1)
Speed (S)	rpm	116	269	525
Feed (F)	mm / rev	0.15	0.49	0.83
Depth of cut (D)	mm	0.25	0.50	0.75

The hardness result were has shown in Table 3 and it has observed that the hardness of composite is more than its parent material.

Table 2 Mechanical Properties of Composite

Sl. No.	Sample	Brinell Hardness number	Tensile strength (N/mm^2)
1	Al	17	57.8
2	Al-CSAp	46	112.8

Table 3 Composition of Coconut Shell Ash

Element	SiO_2	MgO	Al_2O_3	Fe_2O_3	MnO	ZnO	Na_2O	K_2O
%	46	18	16	14	0.5	0.6	0.9	1.2

From the composition of CSAp it can be observed that as CSAp is used as reinforcement material in Al metal, the hardness of composite will increase due to presence of hardening elements like SiO, Mgo, MnO in Coconut Shell Ash Particles (CSAp).

III. RESULTS AND DISCUSSIONS

3.1 Mechanical Properties

Table 2 represents the hardness of composite increase with increase of reinforcement due to hard face of reinforcement and uniform distribution of particle in the matrix which strength the material. Hardness also increases with the increase in sintering temperature for a particular composition of CSA. CSA consists of various hard face ceramic particulates, shown in Table 3. SiO_2, Al_2O_3 and Fe_2O_3 are in major quantities. This happens because as the sintering temperature increases the voids get reduced in number due to better bonding between the particles. Similarly, the tensile strength increase with increase of reinforcement and decrease of percentage of elongation due to the brittleness of material. Particle moment has been difficult due to reinforced material which improves the hardness and tensile strength[17], [18].

Figure 2, the microstructure of aluminium matrix indicates ductile material, contains larger in grain sizes (Fig.2a). The metallography indicates the distributions of particles are uniformly in throughout the matrix and revealed uniform grain sizes and smaller in size (Fig.2b). This indicates with decrease of grain size, increased strength in composite.

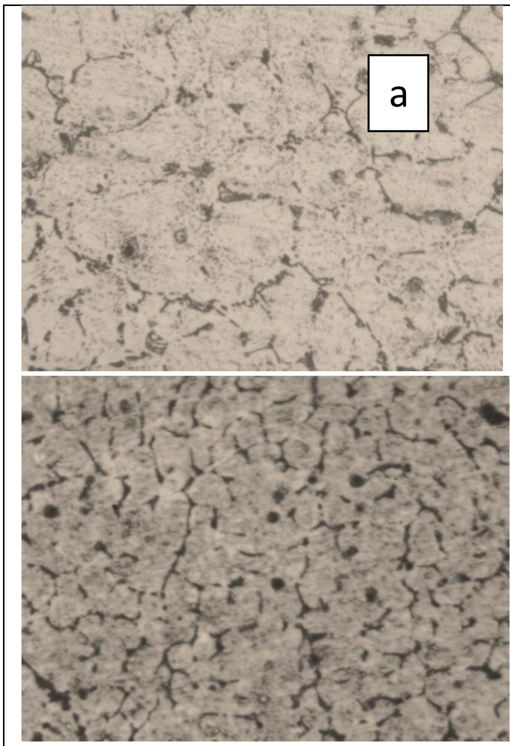

Figure 3 Microstructure of (a) Al (b) Al-CSA composite

3.1 S/N ratio results

The S/N ratio is obtained during the ANOVA. The influence of parameters such as cutting speed, feed rate, and depth of cut on the surface roughness (R_a) for Al and Al-CSAp was analyzed Table 4 and Table 5. The ranking of the parameters is presented in S/N response in Tables 6&7.

Table 4 Experimental results and corresponding S/N ratios for Al

	Parameters			Responses			Signal to noise ratio		
Sl.No.	Speed	Feed	DOC	MRR (mm3/min)	Power (KWh)	Surface Roughness (Ra)	MRR	Power	Ra
1	116	0.15	0.25	0.0006	1.152	3.918	-64.44	-1.23	-11.86
2	116	0.49	0.5	0.004	1.344	3.723	-47.96	-2.57	-11.42
3	116	0.83	0.75	0.0113	1.152	3.94	-38.94	-1.23	-11.91
4	269	0.15	0.5	0.0031	1.536	1.754	-50.17	-3.73	-4.88
5	269	0.49	0.75	0.0155	2.304	1.872	-36.19	-7.25	-5.45
6	269	0.83	0.25	0.0087	1.92	3.81	-41.21	-5.67	-11.62
7	525	0.15	0.75	0.0092	1.728	6.235	-40.72	-4.75	-15.90
8	525	0.49	0.25	0.0101	3.264	14.46	-39.91	-10.28	-23.20
9	525	0.83	0.5	0.0342	2.688	34.46	-29.32	-8.59	-30.75

Table 5 Experimental results and corresponding S/N ratios for Al-CSA

Sl.No.	Ra (Al-CSAp)	S/N Al-CSAp
1	1.19	-1.511
2	1.66	-4.402
3	2.25	-7.044
4	1.06	-0.506
5	1.39	-2.860
6	1.62	-4.190
7	0.935	0.5838
8	0.99	0.0873
9	1.36	-2.671

Table 6 Response Table for Signal to Noise Ratios for Al

Level	SPEED	FEED	DEPTH OF CUT
1	-11.73	-10.88	-15.561
2	-7.315	-13.356	-15.682
3	-23.282	-18.092	-11.084
Delta	15.967	7.212	4.597
Rank	1	2	3

Given that the process parameters with the highest S/N ratio will yield the optimum quality with minimum variance, we can determine from the response Table 6 and Fig.4, the speed is a dominant parameter on the surface roughness of tested specimens, followed by feed and depth of cut. The average S/N ratios were plotted for each parameter against each of its levels (Figs. 4). The optimum parameters are cutting speed (269 m/min), feed rate (0.15 mm/rev), and depth of cut (0.75 mm) irrespective of the machined surface of the tested materials. The optimal level is $S_2F_1D_3$.

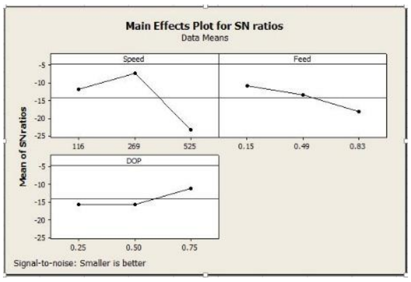

Figure 4 Means of SN ratio for Al

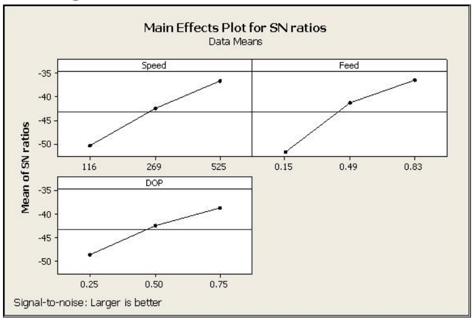

Figure 5 Means of SN ratio of MRR for Al

Figure 5 and Table 7 represents for the better optimal condition of Material removable rate (MRR). It revealed that Feed is the most influencing parameter followed by speed and depth of cut. The best optimal level for MRR for aluminium is S3 (525 rpm), F3 (0.83mm/rev) and D2 (0. 50 mm).

Table 7 Response Table for Means (MRR for Al)

Level	Speed	Feed	DOP
1	-50.44	-51.78	-48.52
2	-42.53	-41.36	-42.48

3	-36.65	-36.49	-38.62
Delta	13.79	15.29	9.9
Rank	2	1	3

Table 8 Response Table for Means (Surface Roughness for Al-CSAp)

LEVEL	SPEED	FEED	DEPTH OF CUT
1	1.7	1.062	1.267
2	1.357	1.347	1.36
3	1.095	1.743	1.525
DELTA	0.605	0.682	0.258
RANK	2	1	3

Table 8 represents mean effective plot of surface roughness for Al-CSA composite. The optimum parameters are cutting speed (525 m/min), feed rate (0.15 mm/rev), and depth of cut (0.25 mm) irrespective of the machined surface of the tested materials. The optimal level is $S_3F_1D_1$.

3.2 Analysis of variance

Analysis of Variance (ANOVA) is a statistical analysis which is done to study the effect of process parameters on the machining process. When S/N ratio will high a minimum variance and optimum quality will be yielded. So the dominant parameters can be determined from the response table for the S/N ratio. Table 9&10 shows the result of ANOVA analysis of S/N ratio of Al and Al- CSAp for surface roughness. The last column of the table shows the "percent contribution" (*P*) of each factor as the total variation, indicating its influence on the result.

Table 9 Analysis of variance for SN Ratios for Al

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	407.89	407.89	203.947	24.59	0.039
Feed	2	80.57	80.57	40.287	4.86	0.171
DOP	2	41.19	41.19	20.596	2.48	0.287
Error	2	16.59	16.59	8.293		
Total	8	546.25				
S = 2.880 R-Sq = 97.0% R-Sq(adj) = 87.9%						

From the Table 9, speed is the most influencing parameter with 74.67% of contribution followed by feed and depth of cut as 14.75 and 7.54% contribution. The ANOVA values of R^2 and R^2_{adj} is 97.0 and 87.9% for surface roughness of aluminium alloy. From the Table 10, feed is the most influencing parameter with 45.58% of contribution followed by speed and depth of cut as 35.78 and 18.60% contribution. The ANOVA values of R^2 and R^2_{adj} is 98.4 and 97.9% for MRR of Al matrix.

Table 10 Analysis of variance for MRR for Al

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Source
Speed	2	287.436	287.436	143.718	1604.58	0.001	35.79%
Feed	2	366.06	366.06	183.03	2043.49	0	45.58%
DOC	2	149.413	149.413	74.707	834.08	0.001	18.60%
Error	2	0.179	0.179	0.09			
Total	8	803.089					
S = 0.2993 R-Sq = 98.4% R-Sq(adj) = 97.9%							

From the Table 11, feed is the most influencing parameter with 53.63% of contribution followed by speed and depth of cut as 41.31 and 4.73%

contribution. The ANOVA values of R^2 and R^2_{adj} is 98.4 and 96.7% for surface roughness of Al- CSA composite.

Table 11 Analysis of variance for SN ratios Al-CSAp

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	20.0108	20.0108	10.0054	127.76	0.008
Feed	2	25.977	25.977	12.9885	165.86	0.006
Depth of cut	2	2.2922	2.2922	1.1461	14.63	0.064
Residual error	2	0.1566	0.1566	0.0783		
Total	8	48.4366				
S = 0.2798			**R^2 = 98.4%**			
R^2_{adj} = 96.7%						

IV. CONCLUSIONS

The exploration consequences explain that

- Mechanical properties (i.e. Hardness and Tensile strength) of composite have been increased with the increasing CSA.
- The speed is highest influence on surface roughness in the machining of an Al matrix followed by feed and depth of cut. The optimal condition to achieve minimum surface roughness is $S_2F_1D_3$.
- The feed is highest influence on MRR in the machining of an Al matrix followed by speed and depth of cut. The optimal condition to achieve maximum MRR is $S_3F_3D_2$.
- The feed rate has the highest influence on surface roughness in the machining of an Al- CSAp composite followed by cutting speed and depth of cut. The optimal condition to achieve minimum surface roughness is $S_3F_1D_1$.

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