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Experimental Analysis of Aluminium Metal Matrix Composites Using Electrochemical Micromachining

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Abstract: Extravagant application of AMMC (Aluminium Metal Matrix Composites) in various fields of engineering has a unique property. Though there are vast combinations of metal composites, aluminium is a significant and readily combinable metal. In this research paper reinforcement of aluminium with Fly ash and magnesium oxide is proposed and fabricated AMMC by stir casting method and tested in EMM (Electrochemical Micromachining) using Taguchi's quality technique.

Keywords: Stir casting method, Electrochemical Micromachining, Taguchi, L9, Metal Matrix Composite, Material removal rate, Overcut.

Introduction

Nowadays, Aluminium composites are the demanding one in various fields like Aerospace, Mechanical etc. Everyday new combinations of composites have been developed by many researchers. In this paper a typical combination of AMMC (Aluminium Metal Matrix Composite) is fabricated & its properties are founded. To find a material application it is essential to identify its process parameters and the same is founded by experimenting in EMM (Electrochemical Micromachining).

Literature review

Aluminium Metal Matrix Composites is a widely applicable one. Many investigations have been carried out to bring out the uses of it since 19th century. K.L. S.Kumar reported that Inclusion of silicon carbide particle has a significant influence on MRR [K.L.S.Kumar et al]. Basavarajappa gave a report on drilling of Sicp, Sicp-graphitic reinforced composites and concluded that feed rate is the main factor which influences the thrust force in composites. The surface finish increases with increase in cutting speed but decreases with increase in feed rate [S.Basavarajappa et al]. Based on the Al-Sic (15p) study done by Ramanujam, the desirability function analysis of the experimental results of surface roughness and power consumption can convert optimization of the multiple performance characteristics into optimization of the single performance characteristic called composite desirability value [Ramanujam et al]. Experimenting AL/Sic b , Noorul concluded that Grey relational analysis in the Taguchi method for the optimization of the multi response problems is a very useful tool for predicting the surface roughness , cutting force and torque. From this analysis, it is revealed that point angle cutting speed and feed rate are prominent factors which affect drilling. In addition to that they gave an information that the best performance characteristics was obtained with Tin coated Hss drill with the lower cutting point angle of 90^0, higher feed of 0.2 mm/rev and higher cutting speed of 87.96m/min [NoorulHaq et al].

Thanigaivelan in his research derived a conclusion that electrolyte concentration influences the overcut and MRR [Thanigaivelan et al].Abrasive and adhesive wear are found to be predominant during machining the composite Al/Sic/B_4c [Riaz et

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al]. Joardar reported that linear, quadratic and interaction terms are all significant for the estimation of surface roughness [Joardar et al].Electrochemical machining over the EDM is high material removal rate and the big machining surface [S.SureshKumar et al].Metal removal rate increases with voltage, feed rate and electrolyte concentration in electrochemical machining [S.Rama Rao et al].The optimum fabrication parameters for maximum values of tensile strength and impact strength and minimum value of abrasion loss were determined using response surface methodology [S.Sathiyamurthy et al].Composites with higher concentrations of reinforcements are failed prior to 50% deformation [S.Mathusudan et al].Squeeze pressure plays a dominant role in improving surface finish [P.Vijayan et al]. Thus on reviewing the above reports Aluminium is ready to combine with many varieties of metal combinations. In this paper Aluminium is combined with unique combinations of metals and parameters like overcut, MRR, electrolyte concentration, frequency are studied using EMM (Electrochemical Micromachining).

Experimental Details: Preparation of AL/Flyash/Mgo Composite.

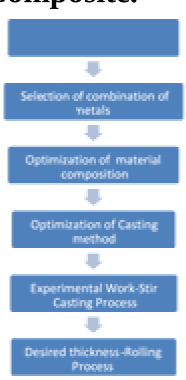

Figure 2. Flowchart showing the steps in forming metal matrix composites

This new combination of low cost composite is mainly aimed to achieve high hardness and high temperature withstanding capability. This MMC (Metal Matrix Composite) is aimed to use in high temperature conditions like engine (internal parts –combustion chamber) or anywhere according to its strength and process parameters.

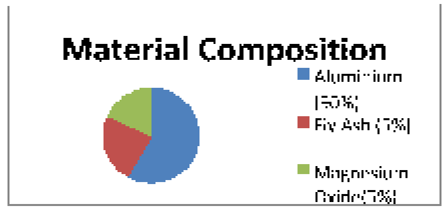

Figure:3: Chart showing the material composition

In this new composite combination of Aluminium alloy (LH6), Magnesium oxide and Flyash is proposed. Mgo gives high temperature withstanding capability to heat. Fly ash is used as a good hardener and gives strength to the composite. If this combination is combined desired objective of the new composite can be achieved. This is a trial and Error method. To select the material composition in a composite combination the base metal- here aluminium is to be used in large quantity. The adders like Mgo and flyash is used 5% each.

Figure: 4 Furnace set up

Based on the cost, processing method and permanent moulding, stir casting method is

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chosed.StirCastingis a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The aluminium alloy was melted in an electric resistance furnace shown in fig.3.3 having a clay graphite crucible. The melt was mechanically stirred by an impeller after addition of pre-heated Magnesium oxide particles (pre heat temperature=9000C average particle size =37µm). The processing of the composite was carried out at a temperature of 7500C with a stirring speed of 500 rpm. The melt was poured at a temperature of 7450C into die. The material of desired thickness can be achieved by using rolling process. This is done to decrease the material thickness to 0.2mm (if needed).This will be helpful to find the performance parameters of the material to test in EMM (electro chemical micromachining).

Figure: 5 Model

Table 1: Chemical composition of Al LM6

Component	Cu	Mg	Si	Mn	Fe	Ni	Pb	Zn	Sn	Ti
Wt %	0.1	0.1	10-13	0.5	0.6	0.1	0.1	0.1	0.05	0.2

Figure: 6EMM setup and working

The Electrochemical Micromachining shown in fig.3.5 consists of the following subsystemsMechanical Machining Unit, Tool Electrode Feeding System, Electrolyte Supply System and Pulsed Power Supply System. The electrolyte supply and cleaning system consist of a pump and a filter. A pulsed power supply stainless steel electrode, sodium nitrate of varying concentrations used as electrolytes of 20 V and 30 A with the capability for varying voltage, current. The experiments were conducted using

3.3. EMM Test Procedure

The AMMC (of reduced thickness) is cut to 50x50mm.The initial weight of AMMC sheet is noted. According to Taguchi technique (Optimization technique to find the material process parameters) –L9, L27.Before starting drilling the following factors are fixed,

Table 2: Machining Parameters

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Trial No.	A	B	C	MRR mg/min	Over cut (µ m)	S/N Ratio for MRR	S/N ratio for Over cut
1	5	18	30	0.254	201.36	-11.903	-46.079
2	5	18	40	0.277	144.12	-11.150 -	-43.174
3	5	18	50	0.376	142.20	8.496	-43.058
4	5	24	30	0.286	158.70	-10.873	-44.012
5	5	24	40	0.309	163.26	-10.201 -	-44.258
6	5	24	50	0.407	97.20	7.808	-39.753
7	5	30	30	0.263	185.64	-11.601	-45.373
8	5	30	40	0.286	195.90	-10.873	-45.841
9	5	30	50	0.385	219.24	-8.291	-46.818
10	7	18	30	0.263	87.06	-11.601	-38.796
11	7	18	40	0.285	91.56	-10.903	-39.234
12	7	18	50	0.384	94.86	-8.313	-39.542
13	7	24	30	0.310	105.06	-10.173	-40.429
14	7	24	40	0.333	95.46	-9.551	-39.596
15	7	24	50	0.431	108.48	-7.310	-40.707
16	7	30	30	0.254	192.18	-11.903	-45.674
17	7	30	40	0.276	180.72	-11.182	-45.140
18	7	30	50	0.375	192.48	-8.519	-45.688
19	9	18	30	0.252	75.42	-11.972	-37.550
20	9	18	40	0.275	76.98	-11.213	-37.728
21	9	18	50	0.374	75.90	-8.543	-37.605
22	9	24	30	0.245	88.08	-12.217	-38.898
23	9	24	40	0.268	87.42	-11.437	-38.832
24	9	24	50	0.367	81.90	-8.707	-38.266
25	9	30	30	0.241	138.48	-12.360	-42.828
26	9	30	40	0.263	147.00	-11.601	-43.346
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The initial weight & final weight of the Work piece after drilling is noted. The radius of the drill is founded by viewing the drilled work piece in computer through microscope. The Overcut can be founded by using the formula,

Overcut = Tool radius – Actual drill radius

The Material removal rate (MRR) can be founded by using the formula,

MRR= (F.W. – I.W.) / (Machining time).

This step is repeated for 27 experimental times of 3x3 fixed levels of factors, to get better results. The fig.3.6. below show the Al-FlyashMgo composite after L27orthogonal array of experimental runs. The

Figure: 7 Drilled Work piece

Microholes drilled using electrochemical micromachining is viewed largely using a computer-microscope set up which is shown in fig.3.7&3.8. This is used to find the radius of the each microhole, which would help in calculating the overcut.

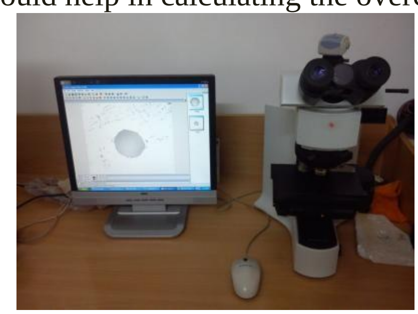

Figure: 8 Microscope & Computer view

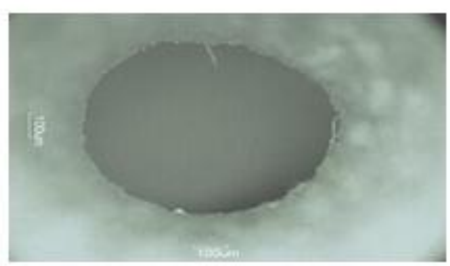

Figure: 9 Drilled Microholes

Graphical Analysis

S/N Curves for Overcut

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In terms of process parameters like Overcut – smaller is better. Hence the minimum values are chosen.The optimal values for **minimum overcut** were machining voltage of **9 V** ,electrolyte concentration of **18 g/l,** and frequency of **50 Hz**.The following S/N ratio curve in fig.4.1. shows the machining parameters for the minimum overcut,

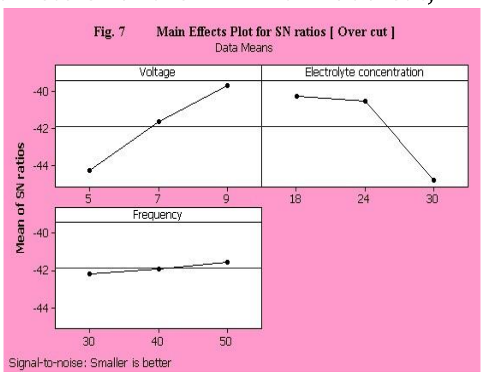

Figure: 10: S/N curves for Overcut

S/N Curves for MRR

In terms of process parameters like Metal Removal Rate – Larger is better. Hence the maximum values are chosen. The optimal values for **maximum MRR** were machining voltage of **7 V**, electrolyte concentration of **24 g/l**, and frequency of **50 Hz**. The following S/N ratio curve shows the machining parameters for the maximum MRR,

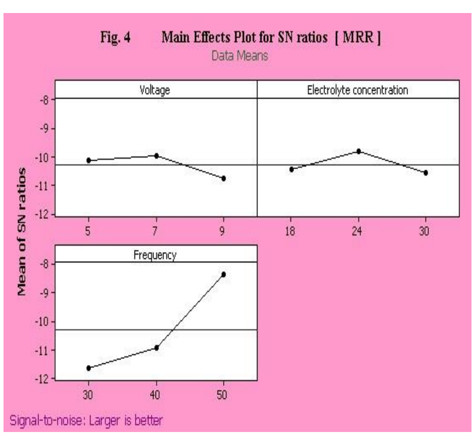

Figure: 11: S/N curves for Material Removal Rate

Verification Test

Table3: Predicted value and the repeated experimental value to verify, it.

For Material Removal Rate(MRR)			
Level	A1B1C1 **(Initial level)**	A2B2C3 **(Prediction & Experiment)**	**Improvement**
S/N ratio	-11.903	-7.731	35.5.%
For Overcut			
Level	A1B1C1 **(Initial level)**	A3B1C3 **(Prediction & Experiment)**	**Improvement**
S/N ratio	-46.079	-37.605	18.04%

Conclusion

From the S/N graph and the verification table it is shown that,

1. The optimal values for **maximum MRR** were machining voltage of **7 V**, electrolyte concentration of **24 g/l**, and frequency of **50 Hz**.

2. The optimal values for **minimum overcut** were machining voltage of **9 V**, electrolyte concentration of **18 g/l,** and frequency of **50 Hz.**

3. Based on the Verification test, the improvements of the MRR from the initial machining parameters to the optimal machining parameters are about **35.5 %** and the Overcut is improved by **18.04 %**

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