Synthesis and Characterization of Al-Al2o3 Composites

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Abstract- Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste byproduct during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of fly ash particles in aluminum alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminum and thereby, reducing the cost of aluminum products. Now a days the particulate reinforced aluminum matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. The present investigation has been focused on the utilization of abundantly available industrial waste Al2O3 in useful manner by dispersing it into aluminum to produce composites by stir casting method.

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

I. INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersoids used, fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product during combustion of coal in thermal power plants. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. It is therefore expected that the incorporation of fly ash particles in aluminum alloy will promote yet another use of this low-cost waste by-product and, at the same time, has the potential for conserving energy intensive aluminum and thereby, reducing the cost of aluminum products .

Now a days the particulate reinforced aluminum matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminum matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys. While investigating the opportunity of using fly-ash as reinforcing element in the aluminum melt, R.Q.Guo and P.K.Rohatagi observed that the high electrical resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight insulating composites. The particulate composite can be prepared by injecting the reinforcing particles into liquid matrix through liquid metallurgy route by casting. Casting route is preferred as it is less expensive and amenable to mass production. Among the entire liquid state production routes, stir casting is the simplest and cheapest one. The only problem associated with this process is the non uniform distribution of the particulate due to poor wet ability and gravity regulated segregation. Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement, matrix material and reaction at the interface. These aspects have been discussed by many researchers.

Aghajanian et al. have studied the Al2O3 particle reinforced Al MMCs, with varying particulate volume percentages (25, 36, 46, 52 and 56) and report improvement in elastic modulus, tensile strength, compressive strength and fracture properties with an increase in the reinforcement content. The interface between the matrix and reinforcement plays a critical role in determining the properties of MMCs. Stiffening and strengthening rely on load transfer across the interface. Toughness is influenced by the crack deflection at the interface and ductility is affected by the relaxation of peak stress near the interface. Extensive studies on the tribological characteristics of Al MMCs containing reinforcements such as Sic and Al2O3 is available in the literatures. However, reports on friction and wear characteristics of fly ash reinforced AMCs are very limited. Rohatgi has reported that the addition of fly ash particles to the aluminum alloy significantly increases its abrasive wear resistance. He attributed the improvement in wear resistance to the hard aluminosilicate constituent present in fly ash particles.

II. FABRICATION TEST

2.1 FURNACE AND CRUCIBLE

The term furnace can also refer to a direct fired heater, used in boiler applications in chemical industries or for providing heat to chemical a reaction for processes like cracking, and is part of the Standard English names for many metallurgical furnaces worldwide.
The heat energy to fuel a furnace may be supplied directly by fuel combustion, by electricity such as the electric arc furnace, or through induction heating in induction furnaces.

FIG-1 Furnace that have been used for melting purpose

Fig : furnace and crucible

FIG-2 The crucible that have been placed in the furnace is ready to melt the metal(in our project we have used the material aluminum).

FIG-3The aluminum placed in the crucible is ready to melt. the coal placed between the crucible and furnace is used for heating.

III. FABRICATION

Metal fabrication is a value added process that involves the construction of machines and structures from various raw materials. A fab shop will bid on a job, usually based on the engineering drawings, and if awarded the contract will build the product. Large fab shops will employee a multitude of value added processes in one plant or facility. These large fab shops offer additional value to their customers by limiting the need for purchasing personal to locate multiple vendors for different services.

Fabrication shops are employed by Contractors, OEMs and VARs. Typical projects include; loose parts, structural frames for buildings and heavy equipment, and hand railings and stairs for buildings.

IV. OPERATION FOR FURNACE

The furnace transfers heat to the living space of the building through an intermediary distribution system. If the distribution is through hot water (or other fluid) or through steam, then the furnace is more commonly called a boiler. One advantage of a boiler is that the furnace can provide hot water for bathing and washing dishes, rather than requiring a separate water heater. One disadvantage to this type of application is when the boiler breaks down, neither heating nor domestic hot water are available.

Air convection heating systems have been in use for over a century, but the older systems relied on a passive air circulation system where the greater density of cooler air caused it to sink into the furnace, and the lesser density of the warmed air caused it to rise in the ductwork, the two forces acting together to drive air circulation in a system termed "gravity-feed; the layout of the ducts and furnace was optimized for short, large ducts. This caused the furnace to be referred to as an "octopus" furnace.

By comparison, most modern "warm air" furnaces typically use a fan to circulate air to the rooms of house and pull cooler air back to the furnace for reheating; this is called forced-air heat. Because the fan easily overcomes the resistance of the ductwork, the arrangement of ducts can be far more flexible than the octopus of old. In American practice, separate ducts collect cool air to be returned to the furnace. At the furnace, cool air passes into the furnace, usually through an air filter, through the blower, then through the heat exchanger of the furnace, whence it is blown throughout the building. One major advantage of this type of system is that it also enables easy installation of central air conditioning, simply by adding a cooling coil at the outlet of the furnace.

V. OPERATION FOR FABRICATION

The raw material has to be cut to size. This is done with a variety of tools. The most common way to cut material is by Shearing (metalworking); Special band saws designed for cutting metal have hardened blades and a feed mechanism for even cutting. Abrasive cut-off saws, also known as chop saws, are similar to miter saws but with a steel cutting abrasive disk. Cutting torches can cut very large sections of steel with little effort.
Burn tables are CNC cutting torches, usually natural gas powered. Plasma and laser cutting tables, and Water jet cutters, are also common. Plate steel is loaded on a table and the parts are cut out as programmed. The support table is made of a grid of bars that can be replaced. Some very expensive burn tables also include CNC punch capability, with a carousel of different punches and taps. Fabrication of structural steel by plasma and laser cutting introduces robots to move the cutting head in three dimensions around the material to be cut.

VI. PERFORMANCE TEST

6.1 ELECTROCHEMICAL MACHINING

Electrochemical machining (ECM) is among the well recognized non-traditional manufacturing processes in industry. It is the controlled removal of metal by anodic dissolution in an electrolytic medium in which the work piece is the anode & the tool is the cathode. Different from the other machining processes, in ECM there is no contact between tool and work-piece. The main components of ECM system are a low voltage and high current power supply and an electrolyte. The electrolyte is normally solutions of inorganic salts, like sodium chloride ($NaCl$) or sodium nitrate ($NaNO_3$). The
chemical reaction between an electrode and the electrolyte leads to electrons being added, or removed from the electrode metal. This addition/subtraction leads to a voltage potential.

The main purpose of this work is to show the process characteristics of ECM and how it is affected by the process parameters. This work shows a study of the intervening variables in electrochemical machining (ECM) of mild steel (C=0.08%, Mn=0.35%, P=0.014%, S=0.018%, Si=0.017%, Fe= rest). The material removal rate (MRR) was studied. Two parameters were changed during the experiments: feed rate and voltage. Sodium chloride solution was taken as electrolyte (100gm/l). The results show that feed rate was the main parameter affecting the MRR.

6.2 EQUIPMENT

The electrochemical machining system has the following modules:
- Power supply
- Electrolyte filtration and delivery system
- Tool feed system
- Working tank

The main components of ECM system are a low voltage and high current power supply and an electrolyte. The electrolyte is normally solutions of inorganic salts, like sodium chloride ($NaCl$) or sodium nitrate ($NaNO_3$).

VII. ELECTROCHEMICAL MACHINING SET UP

FIG-4 ECM SETUP

VIII. ECMPROCESSCHARACTERISTICS

8.1Material removal rate:

It depends chiefly on feed rates. The feed rate determines the current passed between the work & the tool. As the tool approaches the work, the length of the conductive current path decreases & the magnitude of current increases. This continues until the current is just sufficient to remove the metal at a rate corresponding to the rate of tool advance. A stable cut is then made with a fixed spacing between the

work and the tool, termed as the equilibrium-machining gap. If the tool feed rate is reduced, the tool advance will momentarily lag behind, increasing the gap and thus resulting in a reduction of current. This happens until a stable gap is once again established.

8.2 Accuracy:

Under ideal conditions & with properly designed tooling, ECM is capable of holding tolerance of the order of .02 mm & less. Repeatability of the ECM process is also very good. This is largely due to the fact that the tool wear is virtually non-existent on a good machine; tolerance can be maintained on a production basis in the region of .02-.04 mm. As a general rule, the more complex the shape of the work, the more difficult is to hold tight tolerances and the greater is the attention required for developing a proper tooling and electrode shape.

8.3 Surface Finish:

Ecm under certain condition can produce surface finishes of the order of 0.4m can be obtained by the frontal cut or the rotation of the tool or the work. The important variables affecting the surface finish are feed rate, gap dimension, electrolyte composition, viscosity, temperature & flow. Any defect on the tool will cause machining defects on the surface of the work.

The main manufacturing characteristics (attributes, indicators) of ECM are:

l. The rate of material machining does not depend on the mechanical properties of the metal and approximately depend on work piece material, is equal from 1200 to 2500 mm3 for each 1000A of power supply;

2. The accuracy of ECM is depend on shape and dimensions of machining work piece and approximately

is from 0.05 mm to 0.3 mm at using continuous current, and from 0.02 mm to 0.05

3. The surface roughness of machined surface is decreasing with increasing machining rate (for typical materials) and approximately is equal from Ra=0.1 mm to Ra= 2.5 mm;

4. The electrochemical machining generates no residual stress into material of work piece;

5. There is no tool wear;

6. The energy consumption of ECM is relative high and equal from 200 J/mm3 to

600J/mm3, depend on voltage and electrochemical properties of work piece material,

7. The application of ECM in industry is connected with finding solutions to environmental problems. mm at using pulse ECM;

IX. EXPERIMENTAL PROCEDURE

1. Commercially pure Al was melted and casted.
2. Al-(5%, 10%, 15%, 20%) Al_2O_3 composite was fabricated by stir casting method.
3. We have made micro holes on the plate using ECM set up.
4. The size of micro holes has been measured by the scanning micro scope.
5. Hardness measurement was carried out for Al- Al_2O_3 composite samples.
6. The wear characteristics of Al- Al_2O_3 ash composite samples were evaluated and compared.

FIG-5 MICRO HOLES USING ECM MACHINE

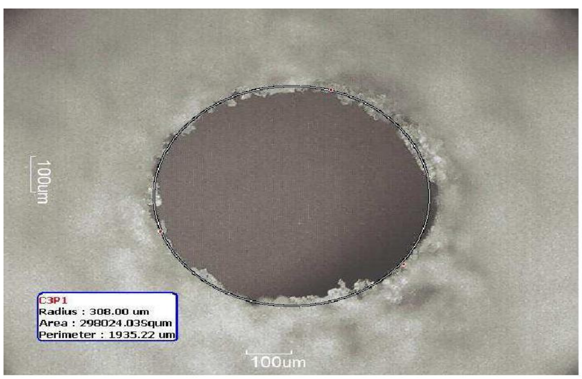
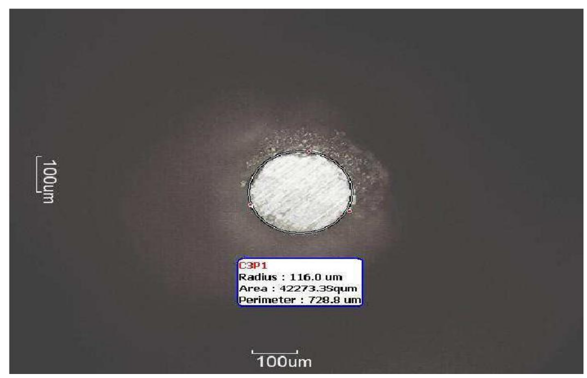
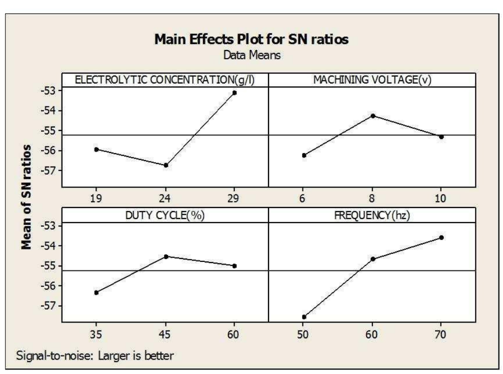


FIG-6 TOOL USED FOR DRILLING IN ECM

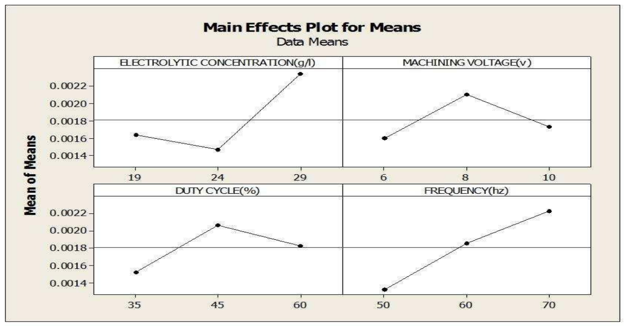


X. RESULTS AND DISCUSSIONS

10.1 ANALYSIS OF MATERIAL REMOVAL RATE:



The graph indicates that the material removal rate is to be larger in order to get the betterment Of making holes. In the value of SN ratio with respect to electrolytic concentration decreases initially and there is sudden increase in its value. Machining voltage the SN ratio is increases and then gradually decreases.



The value of duty cycle increases with respect to MOM and then decreases finally. But the value of frequency does not decrease. The graph indicates that the value of MOM increases at all values of frequency.

10.2 ANALYSIS OF OVERCUT

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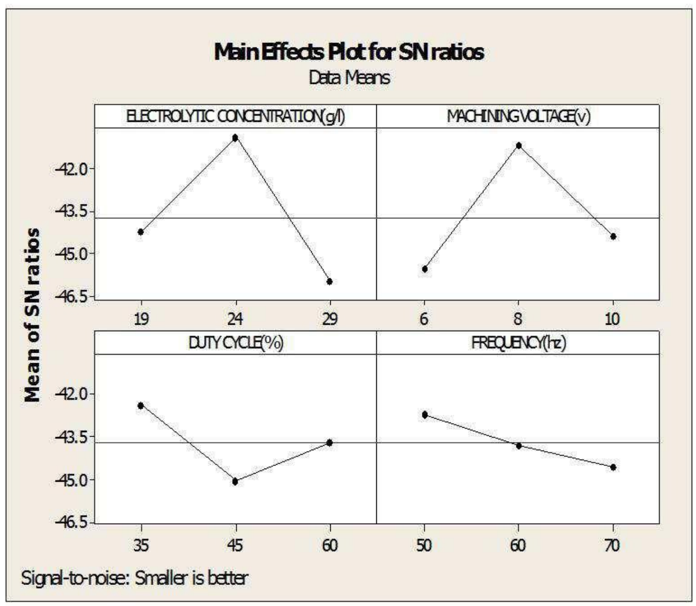
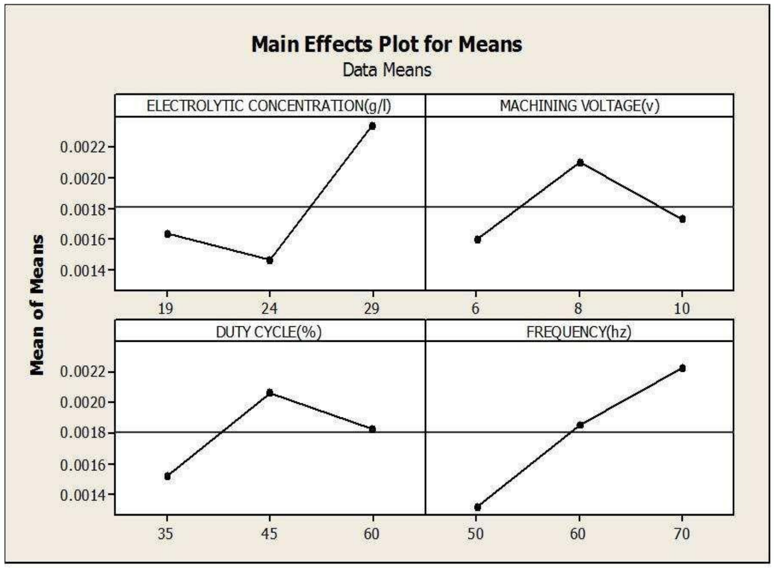


In order to get the better holes the overcut has to reduced so smaller is better.
Both the values of electrolytic concentration and machining voltage increases initially and the sudden decrease with respect to the SN ratio.



The value of duty cycle increases with respect to MOM and then decreases.
But the value of frequency does not decrease in its value the graph indicates that the frequency always increases in its value with respect to MOM.

ELECTROLYTIC CONCENTRATION(g/l)	MACHINING VOLTAGE(v)	DUTY CYCLE(%)	FREQUENCY(hz)	OVER CUT(um)	SNRA1	MEAN1	MRR(mg/min	SNRA2	MEAN2
19	6	45	50	210	-46.4444	210	0.0012	-58.4164	0.0015
19	8	35	60	106	-40.5061	106	0.0017	-55.391	0.0015
19	10	60	70	194	-45.756	194	0.002	-53.9794	0.0015
24	6	35	70	130	-42.2789	130	0.0014	-57.0774	0.0015
24	8	60	50	74	-37.3846	74	0.0013	-57.7211	0.0015
24	10	45	60	142	-43.0458	142	0.0017	-55.391	0.0015
29	6	60	60	250	-47.9588	250	0.0022	-53.1515	0.0015
29	8	45	70	192	-45.666	192	0.0033	-49.6297	0.0015
29	10	35	50	166	-44.4022	166	0.0015	-56.4782	0.0015

This is the table which is used to plot the above graphs. the value of duty cycle,frequency,machining voltage and electrolytic concentration are tabulated and the value of SN ratio and the mean values for both MRR and overcut has been obtained.

XI. CONCLUSION

Both presented methods of aluminum matrix composite materials reinforced by ceramic particles manufacturing ensures required structure and can be applied in practice. Undoubtedly advantageous of powder metallurgy method is possibility of manufacturing small elements near net shape while pressure infiltration method allow to manufacture locally reinforced elements from composite materials with good surface quality, but is more energy consuming than powder metallurgy and this is the main restriction of its application. The composites were fabricated for the assessment of their mechanical performance.
For instance, in view of being used for discarding sabots as a substitution of Al-alloy.

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