Experimental Investigation of Metal Matrix Composite using EDM

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Abstract— The aim of this work is to investigate the mechanical behavior and its relation with hardness and surface hardness of the silicon carbide particulate (SiC) reinforced aluminium matrix composite. Aluminium 7075 alloy is chosen as matrix alloy, in which zinc is the main alloying element. Three different additions of Si C were used and the weight fractions were 5%, 10% and 15%. Finally testing for the material is taken out with the necessary features such as chemical composition testing and Vickers hardness measurements. The surface roughness values for the EDM machined surface and casted surface is measured and shown by means of their graphical representation. At the end a metal matrix composite of aluminium 7075 and silicon carbide particulate is found out with their specific improvement in their surface roughness values.

Key words: Si C, EDM, Matrix composite etc

I. Introduction

Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high module.Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements [1]. The strength-to-weight ratios of resulting composites can be higher than most alloys.

II. Introduction to Reinforcements

Reinforcements for the composites can be fibres, fabrics particles or whiskers. Fibres are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape.

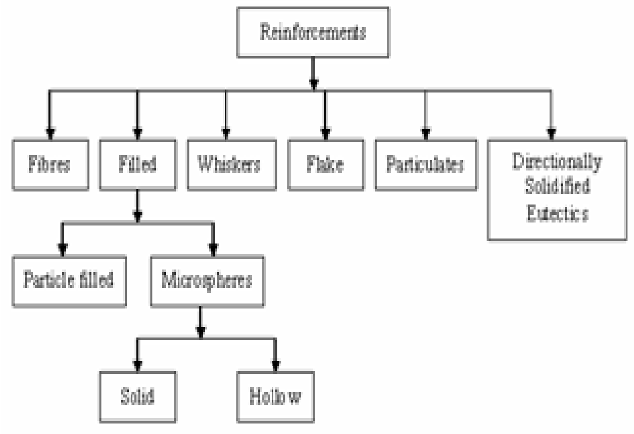

Fig. 1: Classification based on reinforcement

Whiskers have a preferred shape but are small both in diameter and length as compared to fibres. Figure 1.1 shows types of reinforcements in composites. Reinforcing constituents in composites, as the word indicates, provide the strength that makes the composite what it is. But they also serve certain additional purposes of heat resistance or conduction, resistance to corrosion and provide rigidity. Reinforcement can be made to perform all or one of these functions as per the requirements. A reinforcement that embellishes the matrix strength must be stronger and stiffer than the matrix and capable of changing failure mechanism to the advantage of the composite. This means that the ductility should be minimal or even nil the composite must behave as brittle as possible. The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites [2]. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials.

III. Particulate Reinforced Composites (PRC)

Microstructures of metal and ceramics composites, which show particles of one phase strewn in the other, are known as particle reinforced composites. Square, triangular and round shapes of reinforcement are known, but the dimensions of all their sides are observed to be more or less equal. The size and volume concentration of the dispersion distinguishes it from dispersion hardened materials. The dispersed size in particulate composites is of the order of a few microns and volume concentration is greater than 28%. The difference between particulate composite and dispersion strengthened ones is, thus, oblivious. The mechanism used to strengthen each of them is also different. The dispersed in the dispersion-strengthen materials reinforces the matrix alloy by arresting motion of dislocations and needs large forces to fracture the restriction created by dispersion. In particulate composites, the particles strengthen the system by the hydrostatic coercion of fillers in matrices and by their hardness relative to the matrix. Three-dimensional reinforcement in composites offers isotropic properties, because of the three systematically orthogonal planes. Since it is not homogeneous, the material properties acquire sensitivity to the constituent properties, as well as the interfacial properties and geometric shapes of the array. The composite's strength usually depends on the diameter of the particles, the inter-particle spacing, and the volume fraction of the reinforcement. The matrix properties influence the behaviour of particulate composite too.

IV. LITERATURE SURVEY

M. Kobashi and T. Choh made a study to find the wettability and the reaction for silicon carbide particle and aluminum alloy system. A total amount of 60galuminum or alloy was melted in an Mg O crucible in an induction furnace. After the melt been held at 1023 K silicon carbide particles wrapped in an aluminum foil were preheated above the melt for 600s. Then the silicon carbide particles (dav=14µm) were added to the liquid aluminum and melt stirring had been startedby an alumina rod. T. Choh and T. Oki have analyzed the wetting process of aluminum alloy by SiC bydip coverage method and found that alloying element addition decreased the incubation period. T.J.A. Doel and P. Bowen made a study about the effect of particulate size on thermo mechanical properties of silicon carbide reinforced metal matrix composites. As matrix alloy, aluminum 7075 (nominally 5,6wt% Zn – 2,5wt% Mg – 1,6wt%Cu) ischosen. Three grades of silicon carbide are used; F1000 (nominal average particle size d= 5µm), F600 (d=13 µm) and F230 (d=60 µm). The nominal volume fraction of all of the materials used is 15%. Three aging conditions are selected; under-aged, peak-aged and over-aged. It is generally found that, 0.2% proof stress, tensile strength and ductility tend to improve with decreasing particle size for a given volume fraction of reinforcement. David L McDaniel's evaluated mechanical properties and stress-strain behaviour for several fabricated aluminum matrix composites containing up to 40 vol. %discontinuous silicon carbide whisker, nodule or particulate reinforcement. Four types of aluminum matrices are used: 6061, 2024/2124, 7075 and 5083. Types ofsilicon carbide reinforcements are: discontinuous whisker, nodule and particulate reinforcement. The modulus of elasticity increased with increasing reinforcement content. The reinforcement content has been the dominant factor in the improvement of modulus of elasticity in these SiC/Al composites. When the factors influencing strength are considered, the effect of the matrix types found to be the most important. [3].

(Al) (%)	(Cr) (%)	(cu) (%)	(Fe) (%)	(Mg) (%)	(Mn) (%)	(Si) (%)	(Ti) (%)	(Zn) (%)
88.92	0.2	1.6	0.5	2.5	0.3	0.4	0.2	5.35

Table 1. Composition (wt %) of Aluminum 7075

V. REINFORCEMENT MATERIAL

Silicon carbide particulates are used as reinforcement material. The powder was obtained from Hindustan traders. The type of the silicon carbide is F320. Density of silicon carbide is between 3.21 g/cm3 and the mesh size is 20µm. Surfacechemical values are given in Table 2. SiC grain size = 300ppi

SiC	Al	Fe	Ca	K	Mn
73%	3.7%	3.5%	1.12%	2.45%	1.7%

Table 2. Surface chemical values of silicon carbide

The structure ofthe silicon carbide is hexagonal 6H with some rhombohedra 15R and sometime some hexagonal 4H. The silicon carbide is a chemical compound of carbon and silicon. They are produced by a high temperature electrochemical reaction of sand and carbon. These materials have excellent abrasive and heat resistance. They are not attacked by acids or alkalies are molten salts upto 800degC (resistance to chemical attack). SiC can be able to use upto 1600degC.

VI. PROPERTIES OF SIC

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IX. EDM PROCESS

EDM spark erosion is the same as having an electrical short that burns a small hole in a piece of metal it contacts. With the EDM process both the workpiece material and the electrode material must be conductors of electricity. The EDM process can be used in two different ways: 1. A pre-shaped or formed electrode (tool),usually made from graphite or copper, is shaped to the form of the cavity it is to reproduce. The formed electrode is fed vertically down and the reverse shape of the electrode is eroded (burned) into the solid work piece. 2. A continuous-travelling vertical-wire electrode, the diameter of a small needle or less, is controlled by the computer to follow a programmed path to erode or cut a narrow slot through the work piece to produce the required shape. Process parameters in EDM: Based on Yussni (2008), the variables parameters are have great effects to the machining performances results especially to the material removal rate (MRR), electrode wear rate and surface quality. There are two major groups of parameters that have been discovered and categorized

A. Non-electrical Parameters

- Injection flushing pressure
- Rotational of speed electrode

B. Electrical Parameters

- Peak current
- Polarity
- Pulse duration
- Power supply voltage

In the other hand, Van Tri (2002) categorized the parameters into five groups:

1) Dielectric Fluid

Type of dielectric, temperature, pressure, flushing system [6].

2) Machine Characteristics

Servo system and stability stiffness, thermal stability and accuracy Tool, material, shape, accuracy Work piece Adjustable parameters: Discharge current, gap voltage, pulse duration, polarity, charge frequency, capacitance and tool materials. Some of the most important parameters implicated in the EDM manufacturing process are the following ones.

3) On-Time (Pulse Time Or Ti)

The duration of time (μs) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on-time. This energy is really controlled by the peak current and the length of the on-time [7-8].

4) Off-Time (Pause Time Or T0)

It is the duration of time (μs) between the sparks (that is to this time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable.

5) Arc Gap (Or Gap):

It is the distance between the electrode and the part during the process of EDM. It may be called as spark gap [9].

6) EDM Performance Features

EDM performance, regardless of the type of the electrode material and dielectric fluid, is measured usually by the following criteria:

7) Metal Removal Rate (MRR)

Maximum of MRR is an important indicator of the efficiency and cost effectiveness of the EDM process, however increasing MRR is not always desirable for all applications since this may scarify the surface integrity of the workpiece. A rough surface finish is the outcome of fast removal rates.

8) Resistance To Wear Or Electrode Wear (EW)

The electrode wear also depends on the dielectric flow in the machining zone. If the flow is too turbulent, it results in an increase in electrode wear. Pulsed injection of the dielectric has enable reduction of wear due to dielectric flow [10].

9) Surface Roughness (Ra) Of Work Piece

The surface produced by EDM process consists of a large number of craters that are formed from the discharge energy. The quality of surface mainly depends upon the energy per spark.

Photographical view of polished material

Fig. 2: Material after polishing the casted surface

Fig. 3: 7.5 3D view of AMC

X. PROCESSING OF EDM IN THIS PROJECT

In this work, conductive metal matrix composite Al/SiC was selected as the work piece material. Three different volume fraction percentages (5, 10, and 15) of silicon carbide in the aluminium matrix were chosen. Also, for studying the effect of SiC percentage in EDM performance aluminium work pieces without any percentage of SiC particles were selected for this work. The present experiments have been performed using copper electrodes (99.7% Cu, 0.12% Zn, 0.02% Pb, and 0.02% Sn) with positive polarity. The electrode used is 12 mm in diameter and 50 mm in height. Commercial kerosene was used as a dielectric fluid. The machining was generally carried out for a fixed time interval and the amount of metal removed was measured by taking the difference in weights of the work piece before and after electrical discharge machining.

A. Readings Taken Under Edm Process

Plate 1: Al-95% SiC-5% (by volume)

Machining parameters	Symbol	Unit	1	2	3	4	5
Current	I	A	5	5	5	3	9
Pulse on time	T	μs	200	300	400	200	400
Voltage	V	V	30	40	50	30	50

Flushing pressure	P	Psi	1	2	3	2	2
Machining time	T	Min	17.58	15.28	12.43	15.28	9.1

Table 2. Readings of EDM on plate 1

Plate 2 : Al-90% SiC-10% (by volume)

Machining parameters	Symbol	Unit	1	2	3	4	5
Current	I	A	5	5	5	3	9
Pulse on time	T	µs	200	300	400	200	400
Voltage	V	V	30	40	50	30	50
Flushing pressure	P	Psi	1	2	3	2	2
Machining time	T	Min	15.32	13.26	10.13	12.17	6.18

Table 3. Readings of EDM on plate 2

Plate 3: Al85% SiC-15% (by volume)

Machining parameters	symbol	Unit	1	2	3	4	5
Current	I	A	5	5	5	3	9
Pulse on time	T	µs	200	300	400	200	400
Voltage	V	V	30	40	50	30	50
Flushing pressure	P	Psi	1	2	3	2	2
Machining time	T	Min	10.16	8.28	4.30	9.52	3.14

Table 4. Readings of EDM on plate 3

XI. RESULTS

It was manifested that micro and macro hardness of the composites were increased from 69.53 HV to 78.8 HV and 49.4 BHN to 57.21 BHN with respect to addition of weight percentage of SiC and constant weight percentage of FA particles. The reinforcement of particles has enhanced the tensile strength of aluminium matrix composites from 173 Mpa to 213 Mpa. Also results revealed that the severity of surface effects increases with EDM material removal rate. They also observed that the yield and ultimate strength of 15% SiC/Al were found to be 141 and 237 MPa, respectively. The amount of reduction in strength increases with EDM material removal rate. Vickers hardness tests showed that the EDM process induced softening of the material up to a depth of approximately 200µm below the recast layer. EDM also produces a rougher surface than polishing. It shows considerable improvement in the process and it also simplifies the optimization procedure.

XII. CONCLUSION

With this work, a metal matrix composite was formed from mixtures of aluminium and silicon carbide. Composites of different composition were formed, by adding silicon carbide to aluminium7075. Various tests are carried out of all these specimens. From our project we have shown that the hardness of the material increased compared to aluminium and surface roughness have steadily been increased on the holes were electrical discharge machining was done. From the results obtained, we can observe that Al7075/SiC has satisfied the condition given from literature review. This is a new material fabricated by us and this project can be extended for research purpose where several other performance measures can be taken out. From our project the following conclusions have been made, that includes. There is consistent increase in the surface roughness at the surface where EDM is done compared to the casted surface from the graphs showing the values. The values of surface roughness increases nearly upto 10%. The hardness of the AMC also increases compared to the aluminium metal. This is a suitable new material with low weight and having higher strength with a greater surface roughness value, since it is machined with EDM.

REFERENCES

[1] A. Al-Rashed, S. Holecek, M. PrazAk, M. Procio. “Powder metallurgy route in production of aluminium alloy matrix particulate composites”, Journal de Physique IV, (C7), pp.C7-1821-C7-1823, 1993, 03.

[2] J. M. Martin, T.omezacebo,And F. Castro , “Sintering behaviour and mechanical properties of PM Al–Zn–Mg–Cu alloy containing elemental Mg additions” Article in Powder Metallurgy· pp.173-180, July 2002.

[3] ChinawadDhadsanadhepl, TachaiLuangvaranunt, Junko Umeda and Katsuyoshi Kondoh. “Fabrication of Al/Al2O3 Composite by Powder Metallurgy Method from Aluminum and Rice Husk Ash” Journal of Metals, Materials and Minerals. Vol.18 No.2, pp.99-102, 2008.

[4] MortezaEslamian, Joel Rak, Nasser Ashgriz, “Preparation of aluminium /silicon carbide metal matrix composites using centrifugal atomization”, Powder Technology, Volume 184, Issue 1, pp 11-20, May 2008.

[5] M. Muratoglu, O. Yilmaz, M. Aksoy, “Investigation on diffusion bonding characteristics of aluminium metal matrix composites (Al/SiCp) with pure aluminum fordifferent heat treatments”, Journal of Materials Processing Technology, pp 211-217, (2006)

[6] M. Rosso, “Ceramic and metal matrix composites: Routes and properties”, Journal of material Processing Technology, pp364-375, June 2006.

[7] Javier Segurado, “Computational micromechanics of composites, the effect of particle spatial distribution” Mechanics of Materials, Vol 38, Issue 8-10, pp 873-883, Oct 2006.

[8] Dolata-Grosz a, J. Sleziona, “Structure and properties of aluminium cast compositesstrengthened by dispersion phases” Journal of material Processing Technology, Vol 175, Issue 1-3, pp 192-197, June 2006.

[9] J.DuttaMajumdar, B. Ramesh Chandra, I. Manna, “Friction and wear behavior of laser composite surfacedaluminium with silicon carbide” Wear, Vol 262 , Issue 5-6, pp 641-648,Feb 2007.

[10] Barbara Previtalia,DantePocci b, Cataldo Taccardo. “Application of traditional investment casting processto aluminium matrix composites” Composites Part-A, Vol 39 , Issue 10, pp 1606-1617, Oct 2008.