ISSN XXXX XXXX © 2017 IJESC

Research Article Volume 7 Issue No.7

A Comprehensive Study of Electro Discharge Machining of Al/Al_2O_3 Composite and it's Optimization

Shubham Dubey[1], Pankaj Agrawal[2], Abhishek Jha[3]
M.Tech student[1], Assistant professor[2, 3]
Department of Mechanical Engineering
Shri Shankaracharya Institute of Engineering & Technology, Durg, C.G, India

Abstract:
World is as of now concentrating on alternate material sources that are apart from conventional material such as composites. In recent years, Al and Al2O3 metal matrix composites are gaining more attention in manufacturing industries particularly in aerospace and automobile industries due to their excellent mechanical properties. So, it became necessary for manufacturers to study the machining behavior of these composites. Addition of Al2O3 as a reinforcing material helps in improving the mechanical properties of composite. In the present research work the Al and Al2O3 composite was prepared by powder metallurgy method and then non convention machining process mainly electro discharge machining (EDM) is used for machining of metal matrix composites. In this study, three machining parameters such as pulse duration (Ton), discharge current (Ip) and duty cycle (τ) have been taken to assess their influence on material removal rate (MRR), surface roughness (Ra) and tool wear rate (TWR). The study also utilizes the desirability function approach integrated with Taguchi has been used to generate the optimal machining condition.

Keywords: composites, machining, Al/Al2O3, EDM, Desirability, Taguchi method.

I. INTRODUCTION

Composites are combinations of two materials in which one of the materials, called the reinforcing phase, is in the form of fiber sheets or particles and are embedded in the other material called the matrix phase. The primary functions of the matrix are to transfer stresses between the reinforcing fibers/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibers/particles in a composite improves its mechanical properties such as strength, stiffness etc. A composite is therefore a synergistic combination of two or more micro-constituents that differ in physical form and chemical composition and which are insoluble in each other. The objective is to take advantage of the superior properties of both materials without compromising on the weakness of either. Composite materials have successfully substituted the traditional materials in several light weight and high strength applications. The reasons why composites are selected for such applications are mainly their high strength-to-weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness. Typically, in a composite, the reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material. The strength of the composites depends primarily on the amount, arrangement and type of fiber and /or particle reinforcement in the resin. Composite materials has an significant role in the areas of industrial as well as advance manufacturing, due to increased demands from technology as there is rapid growth and advance activities in aircrafts, aviation and automobile industries. These materials possess low specific gravity that helps in making their properties enhanced particularly in mechanical strength and modulus to various traditional engineering materials such as metals. The term "composite" mainly specify those material systems which consist of a discrete constituent i.e. the reinforcement, diffused in a continuous phase i.e. the matrix, and which derives its unique characteristics from the properties, architecture and geometry of the constituents, and from the properties of the boundaries or interfaces between different constituents. A composite material composes of two or more chemically and/or physically apparent phases. Composite materials are engineered or naturally appearing materials produced from two or more composing materials having considerably different chemical or physical properties which possess distinct and separate within the finished structure. The constituent elements, mainly comprises of a reinforcing material, fillers, and a composite matrix binder which differ in form or composition on a macro-scale. The constituent elements retain their own characters i.e. they do not fuse completely into one another although they act in concert. Normally, the constituent material exhibits an interface between one another and can be identified physically. Composites having heterogeneous structures accommodate the importance of specific function and design, infused with properties which limit the scope for classification. However, the new varieties of composites are being invented, each with their own specific purpose and characteristics like the particulate, laminar, flake and filled composites. Particles or fibers reinforced in matrix of another material are the most suitable example of day to day composite materials, which are mostly structural. The present study deals with mach inability and machining aspects of Metal Matrix Composites (MMCs) focuses on parametric appraisal and multi-objective optimization in relation to machining performance features. The following sections gather basic knowledge on MMCs. The major advantages of aluminium alloy based metal matrix composites are as follows:

- High strength
- Enhanced stiffness
- Reduced density

- Enhanced high temperature properties
- Thermal expansion coefficient is controlled
- Thermal or heat management

II. LITERATURE REVIEW

The main purpose of this chapter is to provide the brief information about the proposed study from an extensive literature survey. From this literature review a planning and understanding of present work has been accomplished. Selection of material, their day-to-day applications, brief information about the processes utilized in fabrication and development of metal matrix composites, recent advancement or improvements in processing and machining, evolution and efficient use of different optimization technique have been surveyed in this chapter. Many researches and investigations have been carried out to analyze the efficient way for fabrication and effective machining of Al/Al2O3 reinforced composite. Surappa [1] presents an overview of Aluminium matrix composite material systems on aspects which are related to processing, study of microstructure, variation in properties and its applications. Rosso [2] studied the nature of advanced metal matrix and ceramic matrix composites. The study mainly focusses on the processes involved in the manufacturing of composite, its application in various fields and the future scope of this potential material. Lindroos and Talvitie [3] studied advances which were made in processing, properties and utilization of metal matrix composites is reviewed. Dasgupta et al. [4] has made an attempt to show the effect of scattering SiC in base alloy where the liquid metallurgy route was adopted and studied its effect on different wear modes like sliding, erosion, abrasion, and combinations of wear modes like cavitation erosion, sliding abrasion, erosion abrasion, sliding and the results which were obtained were compared with the base alloy. Dewangan and Prabhkar [5] have studied the EDM of stainless steel in which the best process environment was determined. Nanimina et al. [6] investigated the effects of EDM on Al606130%Al2O3 metal matrix composites. Pulse on time, pulse off time, and peak current, were selected as the machining parameter and performance parameter were mainly tool wear rate and material removal rate. Kumar et al. [7] emphasized on the potential of EDM process. Experiments were performed on Die sink EDM in which Material removal rate (MRR), tool wear rate (TWR), circularity, overcut, surface roughness (SR) etc. were considered to be the most important performance parameters. Many researchers carried out investigation for enhancing or improving the process performance. Kiyak and Akır [8] observed that surface roughness of work piece and electrode were mainly affected by pulsed current and pulse on time, and it is observed that surface roughness was increased if the values of these parameters were high. Chen and Mahdivian [9] showed that sparks are generated by electrical circuits of several types and of different wave form of current and voltage of its own and observed that the material removal is a function of discharge energy. Hocheng et al. [10] studied the correlation between the major machining parameters which are pulse on time and electrical current, and the crater size produced by a single spark for the representative material SiC/Al. Leão and Pashby [11] focused their study on the use hydrocarbon oil which can be considered to be one of the alternative to dielectric fluids. Yang et. al. [12] suggested a multiple attribute decision making (MADM) method, grey relational analysis (GRA), for solving this kind of problem. Jong et al [13] attempted to find the optimal machining parameter conditions. The Taguchi method was utilized to find the relations between process characteristics and machining parameter. Raj et al. [14] studied the optimization of electric discharge machining (EDM) process parameters are mainly based on the Taguchi technique. Also the effect of peak current, pulse off time, pulse on time, and Tool lift time on the EDM output responses has been studied. Aliakbari and Baseri [15] studied the rotary EDM and optimal setting of its process parameters. Most publications which are made on the EDM process are mainly focused towards non-rotational tools, but rotation of the tool helps in providing a good flushing in the machining area. Singh et al. [16] carried out the EDM of Al/10%SiCp as metal matrix composites utilizing orthogonal array (OA) combined with grey relational analysis. They studied the multi-response optimization of the process parameters which are, metal removal rate (MRR), tool wear rate (TWR), taper (T), radial overcut (ROC), and surface roughness (SR). Velmurgan et al. [17] investigated the effect of some important parameters like Pulse on time(T), Current(I), Voltage(V) and Flushing pressure(P), Tool wear rate(TWR), metal removal rate (MRR), as well as surface roughness(SR) in the electro discharge machining of Al6061 metal matrix composites with 10% SiC and 4%graphite particles were reinforced. The least squares technique was used to compute the regression coefficients and Analysis of Variance (ANOVA) technique was utilized to check the importance of the models developed. Lin and Lin [18] suggested a different approach for the optimization of the electrical discharge machining (EDM) process with multiple performance characteristics was studied which is based on the orthogonal array with the help of grey relational analysis (GRA). The grey relational analysis gave some grey relational grade which is utilized to solve the EDM process with the multiple performance characteristics. Then determining the optimal machining parameter by the use of grey relational grade as the performance index. Purohit and Sahu [19] reported the effect of pulse-on time (Ton), pulse current (Ip), and gap voltage (Vg) on metal removal rate (MRR), tool wear rate (TWR) during ECM of Al-alloy reinforced with 20% by wt. SiCp composites in which a three level and three factor full factorial design of experiment was utilized. Chung et al [20] studied the blind-hole drilling of Al2O3/6061Al composite and its optimization, using rotary electrical discharge machining. Taguchi method was applied for experimental design. German et al. [21] investigated the microstructure and mechanical properties of Al-alloy powder containing Mg and Si and also die compaction and sintering response were studied in order to determine the optimum press sinter processing conditions.

III . EXPERIMENTATION

The most important task was the fabrication of composite material. The uniform distribution of reinforcement and metal matrix is necessary for the fabrication of composite. Our main aim is to achieve the better physical and mechanical properties through proper bonding between reinforcement and metal matrix. Various routes available for the fabrication of Al based MMCs are thixo forming, spray deposition, casting and powder metallurgy methods. Spray deposition method helps in improving the material and low segregation property of Al based metal matrix composite but this method is found to be costly, difficulty in acquiring the net shape and also the reinforcement quantity is not uniform and hence this method is not widely used. Casting method involved the difficulty like poor interfacial bonding, segregation, reinforcement clustering etc. are observed in casting method. The Powder Metallurgy is most versatile method for the fabrication of the metal matrix composites due to various reasons which include wide range of variation in volume of reinforcement in matrix, short fibre and long fibre form. It also results in high increament in hardness, indirect strength, and compressive strength of composites. This method is carried out at low temperature and hence offer better control of interface kinetics. . This process employs micro-structural control of the phases which is not present in the liquid phase route. The proper bonding between the reinforcement and metal matrix is achieved through the use of powder metallurgy technique. From literature survey it is found that the percent weight of Al2O3 affects the property of composite. When the weight percent of Al2O3 is more than 5%, the tensile strength, hardness, compressive strength increases. And when the weight percent is more than 20% the strength, hardness reach to maximum value after that they decrease gradually. So from papers it has been that for automobile and aerospace applications generally 10-15% weight of Al2O3 reinforcement is employed to get the best properties. Proper mixing of the sample is carried out in Ball planetary mill machine (Model-PULVERISETTE5, Make-FRITSCH, Germany). It comprise of three cylindrical container of chrome steel within which 6 balls made up of chrome steel of sizes 10 mm. To achieve the homogeneous distribution of reinforcement in the mixture, the blending machine continues 2 lakh revolutions. Compaction of sample is carried out in Cold Uniaxial press machine (Make-SOILLAB, Type-Hydraulic with maximum load: 20 tonnes). For this purpose, a stainless steel die of 25 mm internal diameter was used. To fabricate the green circular test samples of 25 mm outer diameter a load of 18 ton was applied. Sintering is carried out in horizontal tubular furnace in the atmosphere of argon and pressure of 1 bar. Nine green samples were sintered at the temperature of 610 0C just below the melting point of aluminium for holding time of 1 hour. Then furnace is left to cool to room temperature for a time span of 24 hours. After the material is sintered and achieved sufficient strength. The samples are ready to carry out EDM process. The electro discharge machining was carried out in all the nine samples taking into consideration the process parameters that are voltage, current, and duty factor and thereby calculating metal removal rate, tool wear rate, surface roughness. And after getting these results we will be going to perform optimization using Desirability and Taguchi method.

Density calculation for composite:

The density of the composite is found by following method. First the actual density then theoretical density is calculated as shown below:-

□ Actual density of composite sample:-

$$\rho_C = M_C/V_C \quad (1)$$

Mc = Mass of composite (4.5 gm)
Vc = Volume of composite
$Vc = \pi/4 * d^2 * t$
d = dia. of sample = 25 mm, t = Thickness of sample = 4mm
After calculation we get ρ_c = 2.290x10-3 gm/ mm3
Theoretical density of composite sample:

$$\rho_C = \frac{1}{\left(\frac{X_{Al}}{\rho_{Al}} + \frac{X_{Al_2O_3}}{\rho_{Al_2O_3}}\right)} \quad (2)$$

The actual density comes out to be 2.290x10-3 gm/ mm3 and the theoretical density is found to be 2.780x10-3 gm/ mm3 as calculated using above formula.

Electro discharge machining

This work mainly focuses to study the effect of major process parameters of EDM on different performance parameters of electro discharge machining (EDM) process. Experiments on samples are carried out in an Electronica Electraplus PS 50ZNC Die Sinking Fuzzy Logic based EDM (specification described in below) as shown in Fig.3.10. A sideways flushing system is employed for efficient cooling purpose and flushing of debris after machining from the electrode gap region. EDM oil (specific gravity = 0.763, freezing point= 94°C) is used as dielectric fluid. The work piece material used is Al, 10%Al2O3 metal matrix composite (MMC). A cylindrical shaped tool made of copper having a diameter of 10 mm is used for machining. Density of copper tool taken having a density 8.96x10-3gm/mm3 shown in Fig. 13. Each run of experiment is performed for ten minutes. The tool was taken as anode i.e negative polarity and work piece was taken as cathode i.e positive polarity. The images of the Al, 10%Al2O3 composite after machining.

Figure.1. Sample after machining

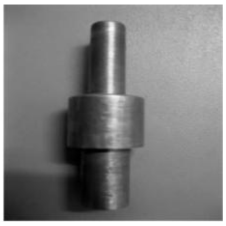

Figure.2. Copper tool

IV. DATA ANALYSIS

We have to determine the individual desirability index (Di), for the corresponding response with the help of the formula given by Derringer et al, In Desirability function there are mainly three types of formula based on response characteristic.

Table.1. Experimental data

Sl.No.	MRR (mm^3/min)	TWR (mm^3/min)	Ra (µm)
1.	4.556	0.0669	7.272
2.	3.905	0.0950	6.072
3.	1.6187	0.0550	8.193
4.	1.546	0.0446	7.345
5.	6.1151	0.0223	6.576
6.	3.3453	0.0446	6.027
7.	7.0502	0.0334	8.243
8.	4.7841	0.0233	6.836
9.	8.2733	0.0111	7.671

Table.2. Experimental data with higher and lower limit

Sl. No.	MRR	TWR	Ra
Upper limit	8.28	0.096	8.3
Lower Limit	1.55	0.012	6.028

V. CONCLUSIONS

Taguchi method is mainly related with the optimization of single response only. Therefore, in this research work a multi-objective optimization technique combining Desirability integrated with Taguchi method is used effectively for optimizing the performance parameters of EDM thereby getting an optimal parameter setting so that machining of advanced materials like Al, 10%Al2O3 MMCs can be done. In a production system if we require improvement in product quality and process performance then these integrated approaches can be applied which include multiple response characteristic and can be considered as one of the efficient tool for process improvement and off-line quality control.

VI. REFRENCES

[1]. Surappa M. K. (2003), Aluminium matrix composites: Challenges and opportunities. Sadhana, 28(1-2): 319-334.

[2]. Rosso M. (2006), ceramic and metal matrix composites: Routes and properties. Journal of Materials Processing Technology, 175(1): 364-375.

[3]. Lindroos V. K. and Talvitie M. J. (1995), Recent advances in metal matrix composites. Journal of Materials Processing Technology, 53(1): 273-284

[4]. Dasgupta R. (2012), Aluminium Alloy-Based Metal Matrix Composites: A Potential Material for Wear Resistant Applications. ISRN Metallurgy, 2012.

[5]. Dalai H., Dewangan S., Datta S., Patel S. K. and Mahapatra S. S. (2012), A case study on quality and productivity optimization in electric discharge machining (EDM). Advanced Materials Research, 445: 27-32.

[6]. Rani A, Nanimina A. M., and Ahmed F. (2009), Non-conventional machining of Aluminium metal matrix composites. International Conference on Electrical Engineering, 26-31.

[7]. Kumar S., Singh R., Singh T. P. and Sethi B. L. (2009), Surface modification by electrical discharge machining: A review. Journal of Materials Processing Technology, 209(8): 3675-3687.

[8]. Kiyak M. and Cakır O. (2007), Examination of machining parameters on surface roughness in EDM of tool steel. Journal of Materials Processing Technology, 191(1): 141-144.

[9]. Chen Y. and Mahdivian S. M. (2000), Analysis of electro-discharge machining process and its comparison with experiments. Journal of Materials Processing Technology, 104(1): 150-157.

[10]. Hocheng H., Lei W. T. and Hsu H. S. (1997), Preliminary study of material removal in electrical-discharge machining of SiC/Al. Journal of Materials Processing Technology, 63(1): 813-818.

[11]. Leão F. N., and Pashby I. R. (2004), A review on the use of environmentally-friendly dielectric fluids in electrical discharge machining. Journal of Materials Processing Technology, 149(1): 341-346.

[12]. Kuo Y., Yang T. and Huang G. W. (2008), The use of grey relational analysis in solving multiple attribute decision-making problems. Computers & Industrial Engineering, 55(1): 80-93.

[13]. Jung J. H. and Kwon W. T. (2010), Optimization of EDM process for multiple performance characteristics using Taguchi method and Grey relational analysis. Journal of Mechanical Science and Technology, 24(5): 1083-1090.

[14]. Laxman J. and Raj K. G. (2001), Optimization of Electric Discharge Machining Process Parameters Using Taguchi Technique.

[15]. Aliakbari E. and Baseri H. (2012), Optimization of machining parameters in rotary EDM process by using the Taguchi method. The International Journal of Advanced Manufacturing Technology, 62(9-12): 1041-1053.

[16].Singh S., Maheshwari, S. and Pandey P. C. (2004), Some investigations into the electric discharge machining of hardened tool steel using different electrode materials. Journal of materials processing technology, 149(1): 272-277.

[17]. Velmurugan C., Subramanian R., Thirugnanam, S. and Ananadavel, B. (2011), Experimental investigations on machining characteristics of Al 6061 hybrid metal matrix composites processed by electrical discharge machining. International Journal of Engineering, Science and Technology, 3(8): 87-101.

[18]. Lin C. L., Lin J. L. and Ko T. C. (2002), Optimisation of the EDM process based on the orthogonal array with fuzzy logic and grey relational analysis method. The International Journal of Advanced Manufacturing Technology, 19(4): 271-277.

[19]. Purohit R. and Sahu P. (2012). Electric Discharge Machining and Mathematical Modeling of Al-Alloy-20% SiC Composites Using Copper Electrode. International. Journal of Mechanical and Production Engineering Research and Development, 2: 37-46.

[20]. D.D.L. Chung (2010) Composite Materials, Science and Applications, Second edition.

[21]. Arockiasamy A., German R. M., Wang P. T., Horstemeyer M. F., Morgan W., Park S. J., and Otsuka I. (2011), Sintering behaviour of Al-6061 powder produced by rapid solidification process. Powder Metallurgy, 54(3): 354-359.