Optimization of WEDM Process Parameter on Machining of Aluminium Reinforced with Fly Ash

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***Abstract* - In this present investigation aluminium composite reinforced with fly ash fabricated by stir casting process. The objective of the research work is to optimize the Wire EDM process parameters such as input current, pulse on time, pulse off time, wire feed for the surface roughness and material removal rate of aluminium matrix composites (AMCs).The experimental work has been carried out by using Taguchi L9 orthogonal array under appropriate combination of process parameter. Analysis of variance (ANOVA) used to find out the design parameter how significantly influencing the responses. To evaluate the influence of these parameter Signal to Noise(S/N) ratio analysis has been done. The result shows the optimum combination of parameter which give the maximum metal removal rate and minimum surface roughness.**

***Index Terms* - AMCs, WEDM, S/N ratio, ANOVA, Metal Removal Rate, Surface Roughness.**

INTRODUCTION

Recently the manufacturing industry has the demand for materials having higher strength, hardness and toughness. These materials pose a problem while machining with conventional machines available. The new materials available are lightweight combined with greater hardness and toughness. Sometimes their properties may create major challenges during their machining. With the technological and industrial growth, devolvement of hard to machine materials takes place, which have lots of applications in nuclear plants, missile technology, aerospace and space research equipment and other industries due to their high strength to weight ratio, heat resistance and hardness qualities. Wire EDM Machining (also known as Spark EDM) is an electro thermal production process in which a thin single-strand metal wire (usually brass) in conjunction with de-ionized water (used to conduct electricity) allows the wire to cut through metal by the use of heat from electrical sparks. A thin single-strand metal wire, usually brass, is fed through the work piece, submerged in a tank of dielectric fluid, typically deionized water. Wire-cut EDM is typically used to cut plates as thick as 300mm and to make punches, tools, and dies from hard metals that are difficult to machine with other methods.

Bibin K.T et.al studied the optimum parameter combination to obtain better micro hardness of Al6061 alloy by wire EDM process. They have concluded that least significant parameter affecting Micro hardness is pulse ON time and based on the Taguchi optimization conducted for micro hardness, the optimal combination is found to be current with 12A, pulse ON time 115µs, pulse OFF time 58µs, feed rate 5mm/min and wire tension 5N[1].

Mangesh R.Phate, Shraddha B.Toney have done their work on CNC wire electrical discharge machining (WEDM) of Al 2124 SiCp (0,15,20) Metal Matrix Composite (MMC) is analyzed by using dimensional analysis approach (DA) & artificial neural network (ANN). From the experiment they have observed that the pulse on time, thermal conductivity, coefficient of thermal expansion, wire feed rate and the wire tension are the most influencing parameters [2].

A Muniappan et.al studied the effect and advancement of machining parameters on cutting speed (CS) in wire electrical discharge machining (WEDM) . The hybrid metal matrix composite (MMC) was manufactured by stir casting process using particulates of Silicon carbide and graphite with Al6061 alloy. The analysis is done with response surface methodology. The optimized parameters are Pulse on time (Level 3), Pulse off time (Level 1), peak current (Level 2) and control speed (Level 2) are the best combination to achieve best material removal rate. Pulse off time, control speed, Pulse on time and discharge current have considerable effect and most influenced control parameters on CS [3].

Suha K. Shihib investigated the effect of wire electrical discharge machining (WEDM) process parameters such a pulse on time, pulse off time and peak current on the machining characteristics such as material removal rate, kerf width, and surface roughness during WEDM of friction-stir-welded 5754 aluminum alloy. Analysis of variance was employed to estimate the significance of WEDM process parameters. The optimization of individual and multiple responses was performed using the desirability analysis to achieve the higher material removal rate, minimum kerf width, and minimum surface roughness. The results indicated that the use of BBD can reduce the number of experiments required for optimizing WEDM process parameters [4].

M.Raja Roy et.al studied the combine effect of reinforcement on Aluminum metal matrix composite. They concluded that percentage of reinforcement is varying from 1% to 10% .Stir casting Technique is observed as one of the most effective technique for preparing the metal matrix composites. Pulse on time pulse off time and input current are to observe to be the most effective parameters in wire EDM process [5].

Dhar et al. investigate the effects of machining parameters like pulse on time and gap voltage on the response parameters like material removal rate, tool wear rate and radial over cut in WEDM of Al4 Cu-6Si alloy reinforced with 10% SiC particles. From the results, they developed the mathematical model to organize bonding among the parameters. The material removal rate and surface roughness were increased by increasing the current [6].

Liao et al. identified some of machining parameters like voltage, resistance, pulse- generating circuit and capacitance as the significant parameters affecting the surface roughness of WEDM in finishing process with the help of Taguchi quality design, ANOVA and F-test [7].

Rao et al. performed parametric analysis of Wire EDM parameters on surface roughness and material removal rate using Taguchi method. Hybrid genetic algorithm is used to develop linear regression model to optimize the performance measures such as surface roughness and material removal rate simultaneously. The results obtained are in a good agreement with experimental values [8].

Patel and Brahmankar carried out experimental studies on WEDM of the aluminium metal matrix reinforced with alumina particle and found that increased percentage of ceramic particulates reinforcement in the MMC decreases MRR. The pulse on-time and thermo-physical properties like melting point temperature, thermal diffusivity and coefficient of thermal expansion are important parameters influencing MRR [9].

Sujit K.Roy et al. studied the factors influencing the behavior of Al2O3/Al interpenetrating phase composite during wire electro discharge machining process. The responses which were compared under different machining conditions were material removal rate (MRR) and surface roughness (SR). The machining variables used in the study were Peak current, Pulse on time and Pulse off time. It was found that pulse current and pulse on time exert most considerable influence on MRR and and SR. Pulse off time was least effective. MRR was found to be higher for larger current and pulse on time at the expense of SR [10].

MATERIAL AND METHOD

The strength of the any composites material can be controlled by base metal and amount of reinforced material present in the composites. Aluminum and Titanium alloys are the two most commonly used metal matrices because of their low specific gravities and are available in different alloy forms. Al 6061 alloy is a most commonly used as a matrix material because of its high strength and which can be further increased by suitable heat treatment process. Commonly used reinforcements are silicon carbide (SiC), tungsten carbide, alumina (Al2O3), graphite, boron carbide and titanium nitride. Fly ash could be a substitute to Al2O3 and SiC due to its light in weight and inexpensive. Fly ash has properties like low density (2.61 g/cm3), high compressive strength, light weight and good chemical stability.

In this work, Al 6061 is used as a base metal and Fly ash is used as a reinforced particle (particle size 55 μm) to fabricate Fly ash metal matrix composite. The FA particles (15% of the wt. of base metal) are reinforced in the Al 6061 metal matrix through stir casting process. The chemical composition of base metal and fly ash is given in the table1&2.

TABLE I- CHEMICAL COMPOSITION OF AL6061 ALLOY

Element	Al	Mg	Si	Fe	Cu	Cr	Zn	Ti	Mn	Other
Composition in (%)	96.85	0.9	0.7	0.6	0.30	0.25	0.20	0.10	0.05	0.05

TABLE II- CHEMICAL COMPOSITION OF FLY ASH

Content	Oxides	Si	Al	Fe	Ti	K	Ca	Loss in ignition
Composition in (%)	38.38	26.43	16.73	3.8	1.4	0.99	0.5	Balance

A. Fabrication of Al 6061 metal matrix composite

Different techniques have been used by different researchers for fabricating composites. According to the different type of reinforcement particles, the fabrication method differs considerably. Among the several techniques available for aluminium alloy metal matrix composites, stir casting method is most suitable for Al MMCs because of cast ability of aluminium. This method is also highly economical for the production of MMCs. This method was used by many investigators for fabricating composites.

In this work Al6061 fly ash MMC was fabricated using a stir casting method. The base metal Al 6061 was melted at 7500C in an electric furnace and Fly ash was then added slowly to the molten metal added to the molten metal was pre-heated for 4000C to remove the moisture present (if any) in it. Then the mixer is used to stirrer the molten metal at 400 rpm for 10 minutes. During stirring, magnesium powder was added in small quantities to increase the wettability between metal matrix and reinforcement particles. After the stirring period, crucible was taken outside the furnace and the molten metal with the reinforced particulates was poured into a dried, coated and preheated permanent metallic mould to get the required specimens. The figure fabricated Al6061Fly ash composite given below.

Fig. 1 Fabricated Al6061fly ash composite

B. Machining of Composite by WEDM

Machining of fabricated composite is done by WEDM machine (ECOCUT CNC machine, CTTC BBSR, Odisha, India) which is Show in Fig 2. The specification of WEDM is given in Table. 3.

TABLE III-SPECIFICATION OF WEDM MACHINE

Machine Tool Parameter	Specification
Cutting tool	Diameter 250Microns
Work piece Size	100mmX100mmX10mm
Max work piece weight	200kg
Dielectric Fluid	Deionizer
Conductivity of dielectric	15-20mho
Number of axes and controller	5axis AC servo motor
Wire Feed	Servo Feed

Fig. 2 Wire cut EDM

Different ranges of machining control parameter are taken by conducting number of experiment. In this experiment the input parameter and the level selected which is given in the Table IV.

TABLE IV- INPUT PARAMETER AND LEVEL

Input parameters	Current (Amp)	Pulse on time (µs)	Pulse of time(µs)	Wire feed (mm/min)
Symbol	A	B	C	D
Level 1	4	6	4	1
Level 2	3	8	5	2
Level 3	2	10	6	3

C. Measurement of Surface Roughness

Surface Roughness is the measure of the texture of the surface. It is measured in µm. If the value is high then the surface is rough and if low then the surface is smooth. The Ra value, also known as centre line average (CLA) or arithmetic average (Ra) is obtained by averaging the height of the surface above and below the centre line. The values are measured using pocket surf gage (model: pocket surf gage III) shown in Figure. The arithmetic mean of two readings is taken as the final.

FIG. 3 SURFACE ROUGHNESS TESTER

TABLE V- SPECIFICATION OF SURFACE ROUGHNESS TESTER

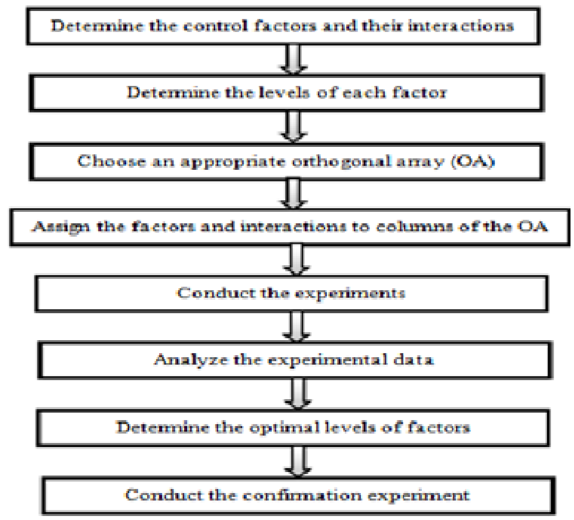
Specification of Surface Roughness Tester	
Measuring range	Ra - 0.025µm-16.00 µm Rmax /Ry - 0.02 µm to 160..0 µm Rz - 0.02 µm to 160.0 µm
Display Accuracy	+/-10%
Test Principle	Inductance type
Radius of probe pin	Diamond
Maximum driving stroke	17.5mm
Probe Angle	90 degree
Power	Li –ion battery (rechargeable)
Operating Temperature	0° to 50°C

The pocket surf gage is a rechargeable battery-powered instrument for checking surface roughness with the measured values displayed on a digital readout. The instrument can be used in the laboratory, an inspection area– horizontally. Pocket Surf is used to measure any one of four, switch-selectable, parameters.

- Ra — Average Roughness
- Rmax/ Ry — Maximum Roughness Depth
- Rz — Mean Roughness Depth also called Rt

D. Taguchi Analysis

The Taguchi method optimizes design parameters to minimize variation before optimizing design to hit mean target values for output parameters. Orthogonal arrays help to study all the design factors with minimum of experiments. The detail process of Taguchi analysis shown in figure-4.In this paper Taguchi L9 orthogonal was used.



III.RESULTS ANALYSIS

The effect of machining parameters on material removal rate and surface roughness in machining Al 6061 Fly ash MMC are investigated. The results from the experimental plan of MRR and SR are shown in table VI. In order to analyze the results of the experimental runs, analysis of variance (ANOVA) was utilized to examine the influence of cutting parameters of WEDM on the MRR and SR. The ANOVA was executed and the results are shown in tables VII to XI.

TABLE VI-EXPERIMENTAL RESULTS AND S/N RATIOS OF SR AND MRR

RUN	TON (µs)	TOFF (µs)	IP(A)	WF (mm/min)	SR (µm)	S/N Ratio	MRR (mm^3/min)	S/N Ratio
1	6	4	4	1	3.8	-11.59	8.82	18.90
2	6	5	3	2	3.6	-11.12	8.42	18.50
3	6	6	2	3	4.2	12.46	9.05	19.13
4	8	4	3	3	3.8	-11.59	9.15	19.22
5	8	5	2	1	4.2	-12.46	7.51	17.51
6	8	6	4	2	3.5	-10.88	6.83	16.68
7	10	4	2	2	3.09	-9.79	8.66	18.75
8	10	5	4	3	4.06	-12.17	8.28	18.36
9	10	6	1	1	3.56	-11.02	9.43	19.49

TABLE VII- ESTIMATED MODEL COEFFICIENTS FOR SN RATIOS (MRR)

Term	Coef
Constant	18.5088
A 1	0.3407
A 2	-0.6989
B 1	0.4539
B 2	-0.3823
C 1	-0.5227
C 2	0.5661
D 1	0.1286
D 2	-0.5272

TABLE VIII - ANALYSIS OF VARIANCE FOR SN RATIOS (MRR)

Source	DF	Seq SS	Adj SS	Adj MS	P
TON(µs)	2	2.19883	2.19883	1.09941	34
TOFF(µs)	2	1.07185	1.07185	0.53592	16
IP(A)	2	1.78684	1.78684	0.89342	27
WF	2	1.35975	1.35975	0.67987	21
TOTAL	8	6.41726			

TABLE IX- RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS (MRR)

LARGER IS BETTER

LEVEL	A	B	C	D
1	18.85	18.96	17.99	18.64
2	17.81	18.13	19.07	17.98
3	18.87	18.44	18.47	18.91
Delta	1.06	0.84	1.09	0.93
Rank	2	4	1	3

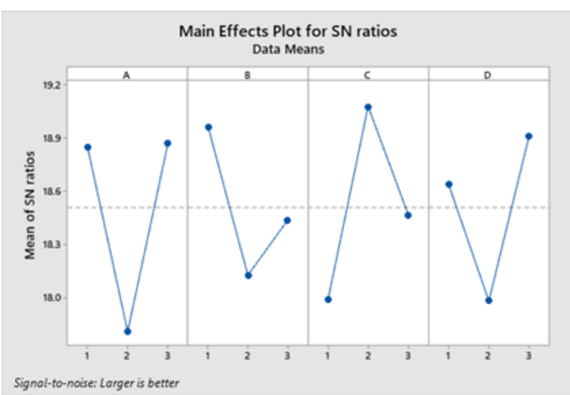


Fig. 5 Main effects Plot for SN Ratio(MRR)

TABLE X- ESTIMATED MODEL COEFFICIENTS FOR SN RATIOS (SR)

Term	Coef
Constant	-11.4586
A 1	-0.2703
A 2	-0.1887
B 1	0.4618
B 2	-0.4619
C 1	-0.0906
C 2	0.2084
D 1	-0.2380
D 2	0.8564

TABLE XI- ANALYSIS OF VARIANCE FOR SN RATIOS (SR)

Source	DF	Seq SS	Adj SS	Adj MS	P
TON(µs)	2	0.95820	0.95820	0.47910	16
TOFF(µs)	2	1.27978	1.27978	0.63989	21
IP(A)	2	0.19647	0.19647	0.09824	3
WF	2	3.51764	3.51764	1.75882	59
TOTAL	8	5.95209			

TABLE XII- RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS (SR)

SMALLER IS BETTER

LEVEL	A	B	C	D
1	-11.73	-11.00	-11.55	-11.70
2	-11.65	-11.92	-11.25	-10.60
3	-11.00	-11.46	-11.58	-12.08
Delta	0.73	0.92	0.33	1.47
Rank	3	2	4	1

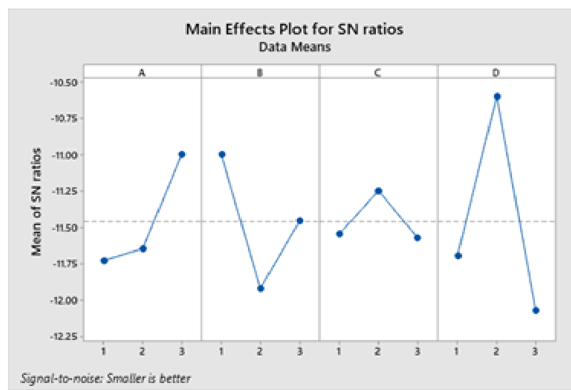


Fig.6 Main effects Plot for SN Ratio (SR)

From the table VIII it is found that the pulse- on time dominates the performance characteristics of material removal rate, contributing to almost 34% followed by the Peak current (27%).Wire feed contribution is also has some significant value of 21% on metal removal rate. From the table XI it is found that the wire feed plays a major contribution of 59% in Surface roughness followed by pulse off time, which has a contribution of 21%.From Figure 5 and 6 the effect of parameters and their levels on MRR and SR investigated in this work. From figure 5, when A is at level 3,B is at level 1,C is at level 2 and D is at level 3,the model achieved maximum metal removal rate. Similarly in the figure 6 when A is at level 1,B at 2,C at 1 and D is also at 1 level there is a less surface roughness. The Model summary for both metal removal rate and surface roughness was found to be 100%.From the response table it was found that wire feed was most significant factor for signal to noise ratio in surface roughness. Similarly current is the most significant factor for S/N ratio in metal removal rate.

IV.CONCLUSIONS

- It is found that the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for the optimization of the cutting parameters in EDM.
- The experimental results demonstrate that the pulse on time and peak current are the main influencing parameters for metal removal rate.
- Wire feed and pulse off time are major influencing parameters for Surface roughness.
- The confirmation experiments were conducted to verify the optimal cutting parameters. The percentage contributions of pulse on time, pulse off time, current and wire feed in MRR are 34%,16%,27% and 21% respectively. Whereas for surface roughness the same parameters contributed 16%,21%,3% and 9% .

REFERENCES

[1] S. M. Metev and V. P. Veiko, Laser Assisted Microtechnology, 2nd ed., R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.

[2] J. Breckling, Ed., The Analysis of Directional Time Series: Applications to Wind Speed and Direction, ser. Lecture Notes in Statistics. Berlin, Germany: Springer, 1989, vol. 61.

[3] S. Zhang, C. Zhu, J. K. O. Sin, and P. K. T. Mok, “A novel ultrathin elevated channel low-temperature poly-Si TFT,” IEEE Electron Device Lett., vol. 20, pp. 569–571, Nov. 1999.

[4] M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, “High resolution fiber distributed measurements with coherent OFDR,” in Proc. ECOC’00, 2000, paper 11.3.4, p. 109.

[5] R. E. Sorace, V. S. Reinhardt, and S. A. Vaughn, “High-speed digital-to-RF converter,” U.S. Patent 5 668 842, Sept. 16, 1997.

[6] (2002) The IEEE website. [Online]. Available: http://www.ieee.org/

[7] M. Shell. (2002) IEEEtran homepage on CTAN. [Online]. Available: http://www.ctan.org/tex-archive/macros/latex/contrib/supported/IEEEtran/

[8] FLEXChip Signal Processor (MC68175/D), Motorola, 1996.

[9] “PDCA12-70 data sheet,” Opto Speed SA, Mezzovico, Switzerland.

[10] A. Karnik, “Performance of TCP congestion control with rate feedback: TCP/ABR and rate adaptive TCP/IP,” M. Eng. thesis, Indian Institute of Science, Bangalore, India, Jan. 1999.

[11] J. Padhye, V. Firoiu, and D. Towsley, “A stochastic model of TCP Reno congestion avoidance and control,” Univ. of Massachusetts, Amherst, MA, CMPSCI Tech. Rep. 99-02, 1999.

[12] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification, IEEE Std. 802.11, 1997.

[13] Dhar S, Purohit R, Saini N, Sharma A and Kumar H G 2007 J. Mat. Pro.Tech194:24–29

[14] Liao Y S, Huang J T and Chen Y H 2004 J. Mat. Proc. Tech.149 165-171.

[15] RaoS P, Ramji K and Satyanarayana B 2014 Procedia Material Science 5 2197-2206

[16] Patil N G and Brahmankar P K 2010 Int. J. Adv. Manuf. Tech. 48 537-555

[17] Sujit K.Roy, Sukhomay pal, Samir k. Ghosh, PP dey . Transactions of the indian ceremic society, 2015,67:2, 75-80.