Parametric Optimization of Electro Discharge Machining of Al/Al_2O_3 MMC

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Abstract: Al/AL_2O_3 metal matrix composite has been fabricated by using stir casting technique. The properties of Al/AL_2O_3-MMC is superior, it's have high strength, high hardness and high wear resistance. In this experimentation Electric discharge machining (EDM) is selected for machining of Al/AL_2O_3-MMC. The effect of different input parameters (Peak Current, Pulse ON Time, Duty Cycle and Gap Voltage) of EDM on Electrode Wear Rate (EWR) and Metal Removal Rate (MRR) is analyzed. Main effect plot and S/N ratio graphs have been used to optimize the machining parameters of EDM on Al/AL2 O3-MMC. Results showed that the peak current is most dominating parameters which effects EWR and MRR.

Keywords: Al/AL_2O_3-MMC, Stir Casting, EDM, EWR, MRR

I. INTRODUCTION

Composite materials are multi phase materials obtained through the artificial combination of different materials in order to attain properties that the individual component by itself cannot attain. Metals and ceramics can well be embedded with particles or fibers, to improve their properties; these combinations are called Metal Matrix Composite (MMC) and Ceramic Matrix Composite (CMC) respectively. Advance composite materials Al/AL_2O_3 metal matrix composite are gradually becoming very important materials for their scope of uses in manufacturing industries e.g. aerospace, nuclear, automotive, defense, and automobile industries due to their superior properties such as high strength, high hardness, high temperature resistance, high thermal shock resistance, superior wear resistance, high corrosive resistance, high specific modulus, high fatigue strength, vibration damping capabilities, energy absorption under earthquake loading, electromagnetic transparency, low value of co-efficient of thermal expansion, pigment-ability and decorative characteristics and high strength-to-weight ratio. Advance composite materials like Al/AL_2O_3 metal matrix composite is gradually becoming very important materials for their scope of uses in modern industries e.g. aerospace, automotive and automobile industries due to their superior properties. However, the improved properties of the Al/AL_2O_3-MMC pose new challenges to the present manufacturing and process engineers, as often haunted by the needs of machining those materials economically and efficiently. At the same time design, manufacturing and quality engineers are also attempting to specify the precision and accuracy of product, component or parts as implied by high tolerance, high surface finish and other related product quality features. Hence, tremendous needs have been arisen for developing efficient, accurate as well as cost effective machining techniques for processing the Al/AL_2O_3-MMC.

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis.

Oguzhan Yilmaz and M. Ali Okka (2010) presented a comparative experimental investigation of electrical discharge machining fast hole drilling of aerospace alloys, namely Inconel 718 and Ti–6Al–4V. The comparisons were made from the results of material removal rate, electrode wear, micro hardness, and scanning electron microscope images taken from the machined/drilled hole surfaces. J.A. Sanchez et al. (2008) presented an original method for form truing of metal bonded cubic boron nitride (CBN) form wheels. The method uses a single-point metallic electrode, thus eliminating the need for expensive form electrodes. Katsushi Furutani et al. (2009) described the influence of the discharge current and the pulse duration on the titanium carbide (TiC) deposition process by electrical discharge machining (EDM) with titanium (Ti) powder suspended in working oil. M. S. Sohani et al. (2009) presented the application of response surface methodology (RSM) for investigating the effect on EDM process of tool shapes such as triangular, square, rectangular, and circular with size factor consideration along with other process parameters like discharge current, pulse on-time, pulse off-time, and tool area. They concluded that the interaction effect of discharge current and pulse on-time is highly significant on MRR and TWR, whereas the main factors such as pulse off-time and tool area are statistically significant on MRR and TWR. Ko-Ta Chiang (2008) proposed Mathematical models for the modeling and analysis of the effects of machining parameters on the performance characteristics in the EDM process of Al_2O_3+TiC mixed ceramic which were developed using the response surface methodology (RSM) to explain the influences of four machining parameters (the discharge current, pulse on time, duty factor and open discharge voltage) on the performance characteristics of the material removal rate (MRR), electrode wear ratio (EWR), and surface roughness (SR).

P. Narender Singh et al. (2004) optimized the process parameters of EDM by the Taguchi methods to achieve high quality without cost inflation. Optimization of multiple response characteristics was more complex compared to optimization of single performance characteristics. P. Koshy, and J. Tovey (2011) demonstrated electrical discharge texturing of cutting tools to bring about a significant reduction in machining force through enhanced lubrication of the tool-chip interface. They showed that the texture need be situated away from the cutting edge at a distance that depends on the feed. Can Ogun and S. Akaslan (2002) investigated the variation of tool electrode edge wear and machining performance outputs, namely, the machining rate (workpiece removal rate), tool wear rate and the relative wear, with the varying machining parameters (pulse time, discharge current and dielectric flushing pressure) in EDM die sinking. They observed that the exponential function models the edge wear profiles of the electrodes very accurately. Manna A and Bhattacharya B (2006) experimentally investigated machining of Al/AL_2O_3-MMC by utilizing CNC-Wire cut EDM. They concluded that low input pressure of dielectric is not sufficient to remove the reinforcement particles during machining. Mustafa Ilhan Gokler, and Alp Mithat Ozanozgu (2000) performed a series of experiments on 1040 steel material of thicknesses 30, 60 and 80 mm, and on 2379 and 2738 steel materials of thicknesses 30 and 60 mm. The test specimens have been cut by using different cutting and offset parameter combinations of the “Sodick Mark XI A500 EDW” wire electrical discharge machine in the Middle East Technical University CAD/CAM/Robotics Center.

II. EXPERIMENTAL PROCEDURE

Al/AL_2O_3 Metal Matrix Composite materials are to be used as work-piece materials. It is essential to select proper machining parameters for effective machining of Al/AL_2O_3-MMC’s. Stir casting technique will be used to prepare the work-piece samples.

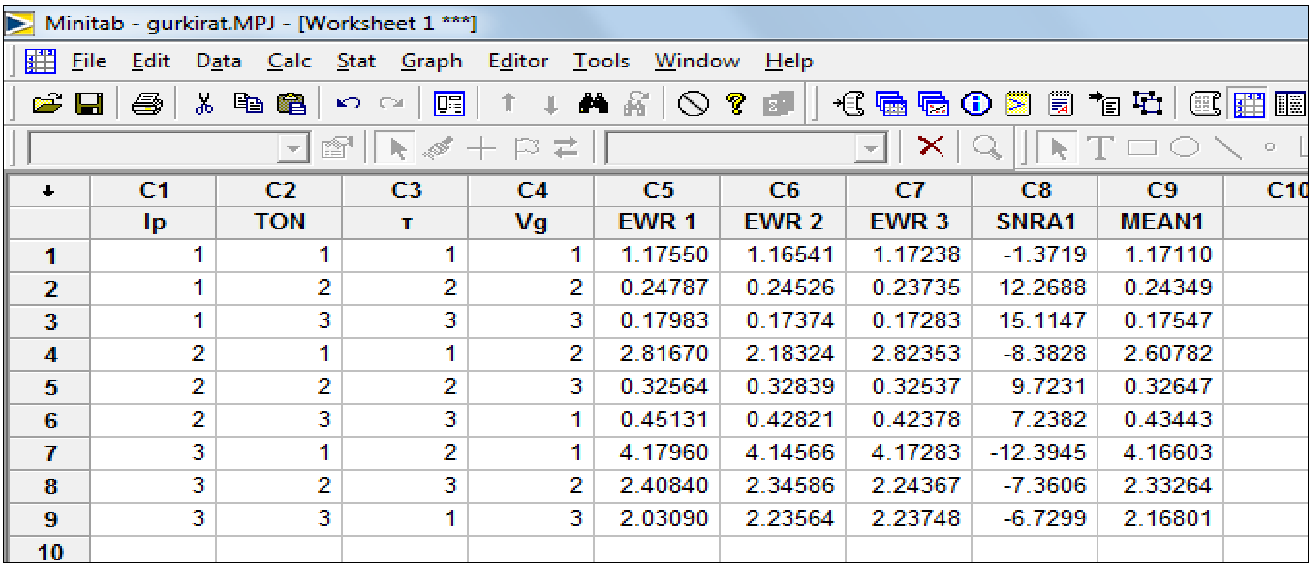
Experiments will be conduct based on Taguchi's method and as per $L_9(3^4)$ orthogonal array with considering three controllable factors (i.e. parameters). Each factor has three levels. The levels of parameters will be deciding through detailed study of literature and based on the preliminary experimentation. The values take by factor are termed to be levels. The factors will be study and their levels chosen are detailed in the Table1. Table 2 format for $L_9(3^4)$ orthogonal array i.e. matrix which will be used for conducting experiment.

TABLE 1: CUTTING PARAMETERS AND THEIR LEVELS TO BE USED IN EDM

S. No.	Input parameters	Level		
		1	2	3
1.	Peak Current (I_P)	5	10	15
2.	Pulse On-Time(T_{ON})	45	80	120
3.	Duty Cycle(τ)	6	10	15
4.	Gap Voltage (V_g)	20	30	40

III. RESULTS AND DISCUSSION

After all the experimentations and measurements, it is required to study the effect of different machining parameters of EDM for machining of Al/AL_2O_3 MMC. The electrode wear rate and metal removal rate has been measured for each experiment to study the effects of the peak current, pulse on time, duty cycle, and gap voltage performance during machining. The brief experimental results obtained during machining of Al/AL_2O_3 MMC by EDM have been explained through various graphs are shown below.



↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
	Ip	TON	τ	Vg	EWR 1	EWR 2	EWR 3	SNRA1	MEAN1	
1	1	1	1	1	1.17550	1.16541	1.17238	-1.3719	1.17110	
2	1	2	2	2	0.24787	0.24526	0.23735	12.2688	0.24349	
3	1	3	3	3	0.17983	0.17374	0.17283	15.1147	0.17547	
4	2	1	1	2	2.81670	2.18324	2.82353	-8.3828	2.60782	
5	2	2	2	3	0.32564	0.32839	0.32537	9.7231	0.32647	
6	2	3	3	1	0.45131	0.42821	0.42378	7.2382	0.43443	
7	3	1	2	1	4.17960	4.14566	4.17283	-12.3945	4.16603	
8	3	2	3	2	2.40840	2.34586	2.24367	-7.3606	2.33264	
9	3	3	1	3	2.03090	2.23564	2.23748	-6.7299	2.16801	
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Figure 1: Results of EWR

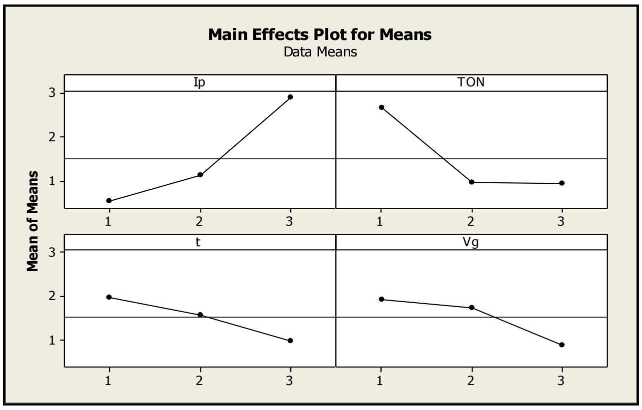

Fig 2: Graph of mean for EWR

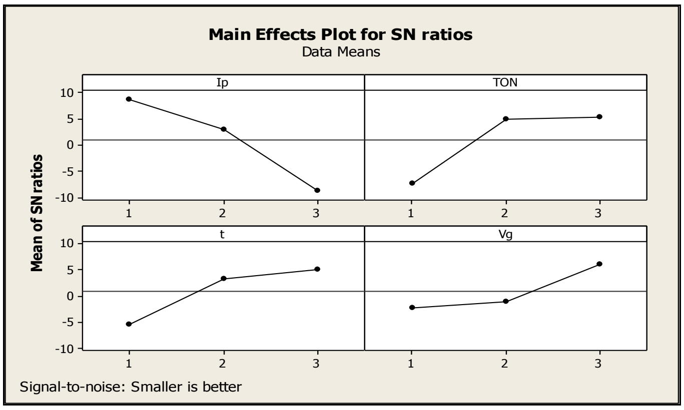

Fig 3: Graph of S/N ratio for EWR

Response Table for Signal to Noise Ratios
Smaller is better

Level	Ip	TON	τ	Vg
1	8.671	-7.383	-5.495	-2.176
2	2.860	4.877	3.199	-1.158
3	-8.828	5.208	4.997	6.036
Delta	17.499	12.591	10.492	8.212
Rank	1	2	3	4

Fig 4: Ranking of parameters for EWR

	C1	C2	C3	C4	C5	C6	C7	C8	C9
	Ip	TON	τ	Vg	MMR 1	MRR 2	MRR 3	SNRA2	MEAN2
1	1	1	1	1	7.5442	7.5425	7.2637	17.4391	7.4501
2	1	2	2	2	6.5440	6.2632	6.3743	16.1110	6.3938
3	1	3	3	3	6.5253	6.2368	6.2362	16.0260	6.3328
4	2	1	1	2	9.6235	9.7652	9.5363	19.6818	9.6417
5	2	2	2	3	13.7390	13.6383	13.3573	22.6550	13.5782
6	2	3	3	1	9.4933	9.3557	9.4572	19.4947	9.4354
7	3	1	2	1	13.0510	13.1723	13.2831	22.3902	13.1688
8	3	2	3	2	11.7240	11.7293	11.8363	21.4103	11.7632
9	3	3	1	3	14.7330	14.6382	14.7393	23.3483	14.7035
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Fig 5: Results of MRR

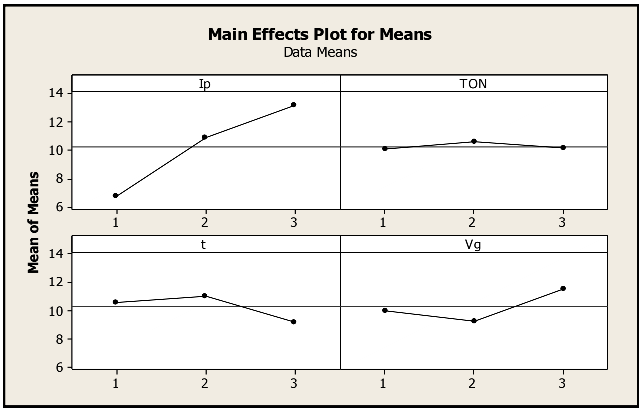


Fig 6: Graph of mean for MRR

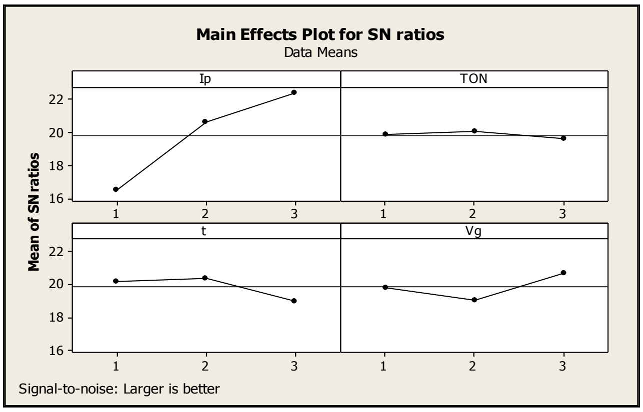
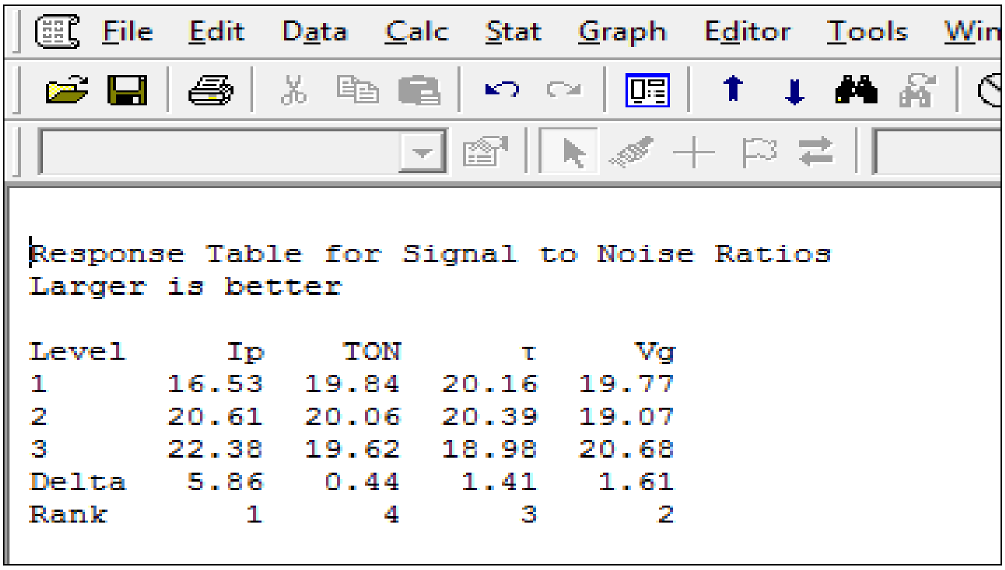


Fig 7: Graph of S/N ratio for MRR



Response Table for Signal to Noise Ratios
Larger is better

Level	Ip	TON	τ	Vg
1	16.53	19.84	20.16	19.77
2	20.61	20.06	20.39	19.07
3	22.38	19.62	18.98	20.68
Delta	5.86	0.44	1.41	1.61
Rank	1	4	3	2

Fig 8: Ranking of parameters for MRR

IV. CONCLUSIONS

Based on the experimental results and analysis the following conclusions are drawn for machining of Al/AL_2O_3 MMC by EDM as listed below:

1. The lowest Electrode Wear Rate is 0.17 mm^3/min is noted at peak current 5 A, pulse ON 120µs, duty cycle 15, and gap voltage 40V.
2. The highest metal removal rate is 14.73mm^3/min is noted at peak current 15 A, pulse ON 120µs, duty cycle 6, and gap voltage 40V.
3. The S/N ratio smaller is better for EWR. S/N ratio is smaller for lowest current value i.e. 5 A, highest pulse ON 120 µs, highest duty cycle 15, and highest gap voltage 40V. It is concluded that the Electrode Wear Rate is lower at low current value, higher pulse on time, highest duty cycle, and highest supply gap voltage.
4. The S/N ratio is larger is better for MRR. S/N ratio is higher for 15 A peak current, 120 µs of pulse ON, 10 of duty cycle, and 40V supply gap voltage. It is concluded that the metal removal rate is increases by increasing the current, and supply gap voltage.
5. The peak current has rank 1 for EWR as well as MRR, so that it is most dominating parameters which affect the EWR and MRR. Gap supply voltage has rank 4 in EWR graph, which means it

is least dominating parameters. The Pulse ON has 4 in MRR graph, which means it is least dominating parameters for affects of MRR.

V. REFERENCES

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