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Preparation, Evaluation and Optimization of Electric Discharge Machining Parameters on Machining of Al6063 Reinforced with Sic and Graphene Particles

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ABSTRACT:

In today's world, aluminum plays a very important role in the various manufacturing industries due to its significant properties like high strength to low weight ratio, high resistance to corrosion, manufacturing flexibility etc. The present work includes the preparation of AMMC along with reinforcement by stir casting process. The matrix material used in the preparation of casting is Al6063 composite and 0.5 wt% SiC,0.5 wt% graphene nano particles are used as reinforcement materials. SiC and graphene are selected because they have high strength, high hardness, high thermal conductivity, high electrical conductivity, light weight than paper etc. The prepared Al6063-T6 reinforced with SiC and graphene is used for machining on edm machine.

Electrical discharge machining is prominent non-traditional machining approach that is capable of machining of geometrically convoluted and very hard composites. The main objective of the current work is to optimize the edm process parameters such as peak current, pulse-on-time, voltage and flushing pressure on machining of Al6063 reinforced with SiC and graphene. Experiments are carried out on edm machine to evaluate the MRR and TWR with different values of process parameters.

In this current work, Taguchi based mathematical model with 27 experiments was developed to optimize the edm process parameters. From the experimental results, it was noticed that peak current is more impacting on MRR and TWR followed by other parameters.

1. INTRODUCTION:

Wide range of composites have been developed in the present modern world. Even though there are many composites developed, aluminum composites play a prominent role due to their significant properties. The significant properties of aluminum composite are they are very rigid, durable and strong but possess light weight.

Nowadays, Industries like military, automobile, athletics, electrical components, space technology etc, are looking for light weight material with improved properties. For enhanced physical and mechanical properties, aluminum metal matrix composite plays a major role.

For any metal matrix composite, addition of reinforcement material significantly improves the properties of initial material. This improvement in properties can be done to enhance the hardness, toughness, wear resistance, corrosion resistance, strength, fatigue, creep, malleability, ductility etc according to industrial need. SiC, Al_2O_3, TiC, MoS_2, B_4C, TiB_2, ZrO_2, Graphite, Graphene, carbon nano tubes etc are the various types of reinforcements. The composite materials are very hard and difficult to machining by using conventional machining processes.

For machining of composites which are difficult to machine by conventional machining methods, Nontraditional machining methods like electical discharge machine (EDM), Electro chemical machining (ECM), Laser beam machining (LBM), EBM can be employed.

Among the various nontraditional machining methods, electrical discharge machine has established itself to be the most important method in shaping difficult-to-machine materials. EDM has been effectively used in large number of industrial areas such as automobile industries, aeronautical industries, surgical instruments manufacturing, toys manufacturing etc. In EDM, tool and work piece are of non-contact type in which a thin gap of about 0.025mm is maintained by a servo system.

From the literature survey, it can be observed that a lot of research has been done on EDM machining and on fabrication of aluminum metal. In this work, optimization of Edm process parameters is been done on machining of Al6063-T6 reinforced with SiC and graphene nano particles.

1.2 WORKING PRINCIPLE OF EDM:

Electrical Discharge Machining (EDM) is a thermal erosion process used to remove material by a number of repetitive electrical discharges of small duration and high current density between the work piece and the tool as shown in Figure 3.

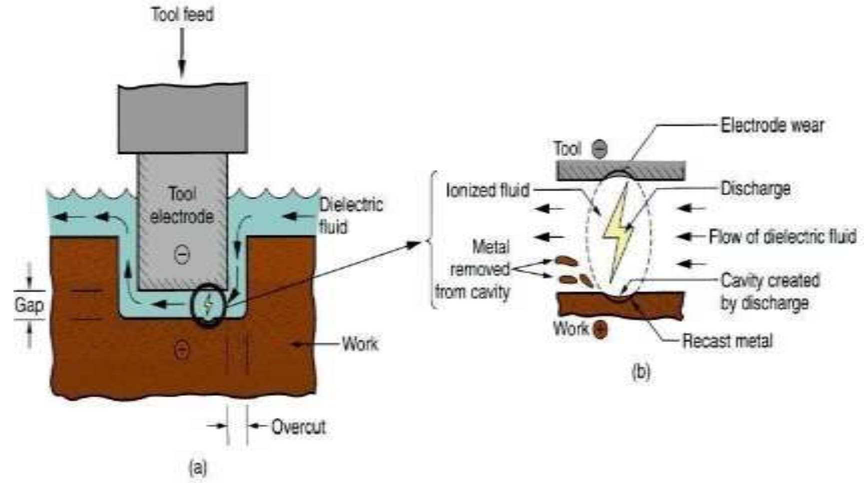


Figure 1.5(a) EDM process showing discharge and metal removal

EDM is mainly used to machine high strength temperature resistant alloys and materials which are difficult-to-machine. EDM can be used to machine irregular geometries in small batches or even on job-shop basis. In EDM, as there is no direct contact between the workpiece and the electrode, hence there are no mechanical forces existing between workpiece and electrode but work material must be electrically conductive to be machined by EDM.

2. MATERIALS:

2.1 composition of Al6063:

ELEMENTS	COMPOSITION (wt%)
Si	0.40
Fe	0.20
Cu	0.06
Mn	0.05
Mg	0.60
Zn	0.01
Ti	0.01
Cr	0.02
Al	Balance

Fig-1: Al 6063-T6 composite

2.2 SiC:

Silicon carbide, also known as carborundum, is a compound of silicon and carbon. Silicon carbide is a semiconductor material as an emerging material for applications in semiconductor devices.

It is one of the most important industrial ceramic materials. It plays a key role in the industrial revolution and is still widely used as an abrasive and steel additive and structural ceramic.

Properties of sic:

- Molecular weight - 40.11g/mol
- Melting point - 2730℃
- Compound formula – SiC

2.3 PROPERTIES OF GRAPHENE:

Graphene is a material that has superior mechanical, electrical and thermal properties. Graphene stands out for being tough, flexible, light, and with a high resistance. It is five times lighter than aluminium material. With these properties, graphene has applications in the energy, construction, health, and electronics sectors.

3. PREPARATION OF CASTING:

Initially, a measured chemical composition of Al6063 was melted in the electrical furnace assisted graphite crucible at 800^{0}C. The melt is super-heated until it gets the required fluidity. A mild steel impeller at the speed of 600 rpm is used to stir the molten metal to create the vortex. Two grams of Tetrachloroethane is added to the melt to remove the trapped gases from the melt. Silicon carbide and graphene nano particles each of 0.5 wt% are preheated in the preheater along with two grams of potassium hexa fluoro titanate for 3hours. To reduce moisture content, to avoid reactions from foreign particles and to increase the wettability between matrix and reinforcement materials, potassium hexa fluoro titanate is added. The molten Al6063 which is present in the furnace is stirred continuously and in 5 steps the preheated reinforcements are added to improve the distribution in the matrix and obtain better properties. The automatic mechanical stirring is carried out for 15 minutes at 800 rpm to turn the liquid into homogenous mixture. After perfect mixing of matrix and reinforcement, it is poured into the preheated mold with the help of gravity.

Fig-4: STIR CASTING COMPUTER SET UP

FIG-5: MOLTEN AL6063

4. EXPERIMENTAL SET-UP:

4.1 ELECTRIC DISCHARGE MACHINING:

Electrical discharge machining (**EDM**), also known as **spark machining**, **spark eroding**, **die sinking**, **wire burning** or **wire erosion**, is a manufacturing process whereby a desired shape is obtained by using electrical discharges (sparks).

Electrical discharge machining is a machining method primarily used for hard metals or those that would be very difficult to machine with traditional techniques. EDM typically works with materials that are electrically conductive, although methods have also been proposed for using EDM to machine insulating ceramics. EDM can cut intricate contours or cavities in pre-hardened steel without the need for heat treatment to soften and re-harden them.

Fig-6: EDM MACHINE

Fig-7: TOOL HOLDER IN EDM

Selection of work piece

In this experiment we use aluminium metal matrix composite as work material, and copper as tool material since we can machine high hard materials using

EDM.

4.2 DESIGN OF EXPERIMENTS:

To generate effective combination of process parameters by reducing number of experiments, Design of experiments is mainly used. More number of experiments should be done to get the better results in the optimization process. Therefore, in this work, Taguchi based mathematical model with 27 experiments is developed. From the literature survey, there are various parameters that affect the machining characteristics of EDM machine. They are pulse-on-time (T_{on}), Flushing pressure (P), pulse-off-time (T_{off}), Duty factor (T_D), peak current (I_p), voltage(v), Spark gap. In this study, $T_{on,}$ p, I_p and v are taken as input variables. MRR and TWR are taken as output variables.

TABLE-1: CONSIDERED PROCESS PARAMETERS AND DIFFERENT LEVELS.

S.NO	Parameter	symbol	units	Level 1	Level 2	Level 3
1.	Pulse-on-time	T_{on}	µs	100	200	300
2.	Peak current	I_p	A	20	30	40
3.	voltage	v	v	40	50	60
4.	Flushing pressure	P	Kg/cm^2	0.3	0.4	0.5

The above parameters are converted into 3 levels with each level having different parameter values. Using the above parameters 27 experiments have been conducted. MRR and TWR value is calculated for each experiment using the given below formula.

MRR = workpiece weight loss (grams) * 60 *60 (gm/hr)

Machining time (sec)

TWR = Tool weight loss (grams) *60 * 60 (gm/hr)

Machining time (sec)

Workpiece weight loss = (initial weight of workpiece)- (final weight of workpiece)

Tool weight loss = (initial weight of workpiece)-(final weight of workpiece)

Fig-9: workpiece after EDM

5. RESULTS AND DISCUSSIONS:

To generate the relationship between parameters MINITAB 21 has been used. To find the relative effect of one parameter on the other, analysis of variance (ANOVA) tool is used.

The responses for calculated MRR and TWR is shown in the below table.

Table-2:

S. No	I	T_{on}	V	P	MRR	SNR for MRR	TWR	SNR for TWR
1	100	20	40	0.3	21.6	26.68	1.028	0.59
2	100	20	50	0.4	22.9	27.21	1.350	3.00
3	100	20	60	0.5	19.5	25.80	0.216	0.63
4	100	30	40	0.3	27.1	28.67	0.295	2.07
5	100	30	50	0.4	27.1	28.67	1.180	1.86
6	100	30	50	0.5	26.8	28.58	0.571	1.95
7	100	40	40	0.3	35.3	30.96	0.666	2.10
8	100	40	50	0.4	38.5	31.71	0.837	0.42
9	100	40	60	0.5	35.3	30.96	0.679	3.41
10	200	20	40	0.4	18.3	25.25	0.642	0.06
11	200	20	50	0.5	17.8	25.01	0.378	0.49
12	200	20	60	0.3	10.3	20.33	0.371	4.41
13	200	30	40	0.4	33.2	30.42	0.400	4.11
14	200	30	50	0.5	27.6	28.82	0.493	1.26
15	200	30	60	0.3	26.2	28.37	0.888	-0.01
16	200	40	40	0.4	45.3	33.13	2.347	5.60
17	200	40	50	0.5	43.2	32.70	0.800	2.76
18	200	40	60	0.3	44.0	32.86	0.800	6.32
19	300	20	40	0.5	14.6	23.31	0.610	1.11
20	300	20	50	0.3	16.3	24.26	0.302	3.09
21	300	20	60	0.4	15.5	23.81	0.878	3.33
22	300	30	40	0.5	24.8	27.92	0.222	4.05
23	300	30	50	0.3	22.6	27.09	0.257	3.67
24	300	30	60	0.4	25.7	28.22	0.486	-0.31
25	300	40	40	0.5	42.4	32.55	0.642	0.29
26	300	40	50	0.3	34.0	30.63	1.309	5.33
27	300	40	60	0.4	41.0	32.26	0.720	1.01

5.1 Effect of process parameters on Material removal rate:

Table-3: response table for SN ratio – MRR (Larger is better)

LEVEL	$\mathbf{T_{on}}$	$\mathbf{I_p}$	**V**	**P**
1	28.83	24.63	28.84	27.77
2	28.55	28.53	28.46	29.97
3	27.80	32.98	27.93	28.41
DELTA	1.03	8.34	0.91	2.20
RANK	**3**	**1**	**4**	**2**

From the above table, it is observed that peak current is the first important factor that is influencing on MRR. The next parameter is flushing pressure (P) and T_{on}, V are ranked at the third and fourth position.

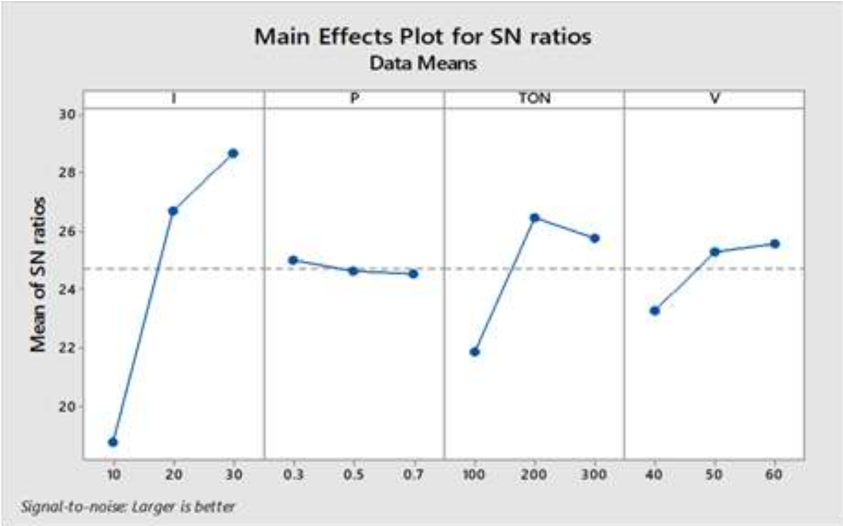


Fig-10: Main effects plot for MRR

5.2 Effect of process parameters on Tool wear rate (TWR)

Table-4: Response table for SN ratio for TWR. (Smaller is better)

LEVEL	T_{on}	I_p	V	P
1	3.1	5.234	4.3	5.0
2	3.2	6.7	3.5	2.0
3	5.8	1.0	5.0	7.0
Delta	**2.7**	**5.7**	**1.5**	**5.0**
Rank	**3**	**1**	**4**	2

From the above table, it is observed that peak current is the most influencing factor on reducing the tool wear. The next parameter that influences the TWR is flushing pressure (P) and T_{on}, V are ranked at the third and fourth position.

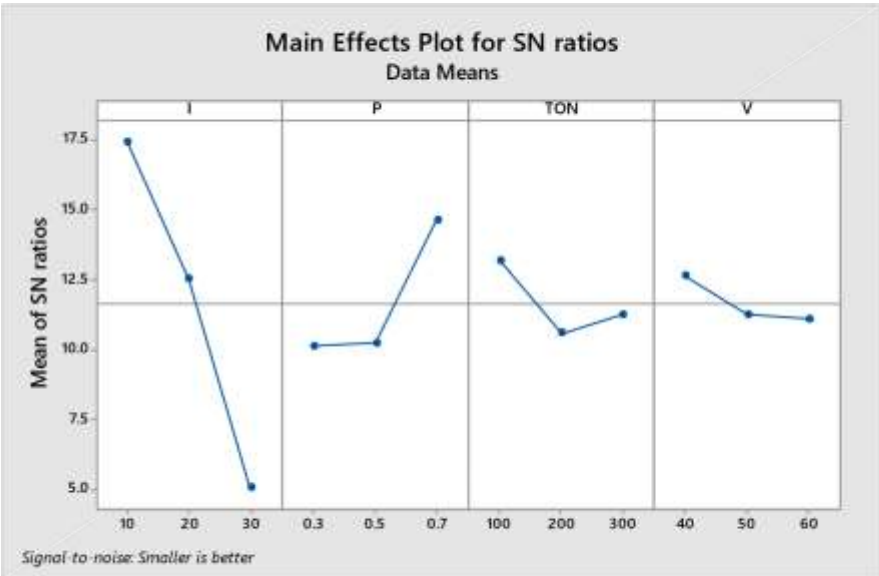
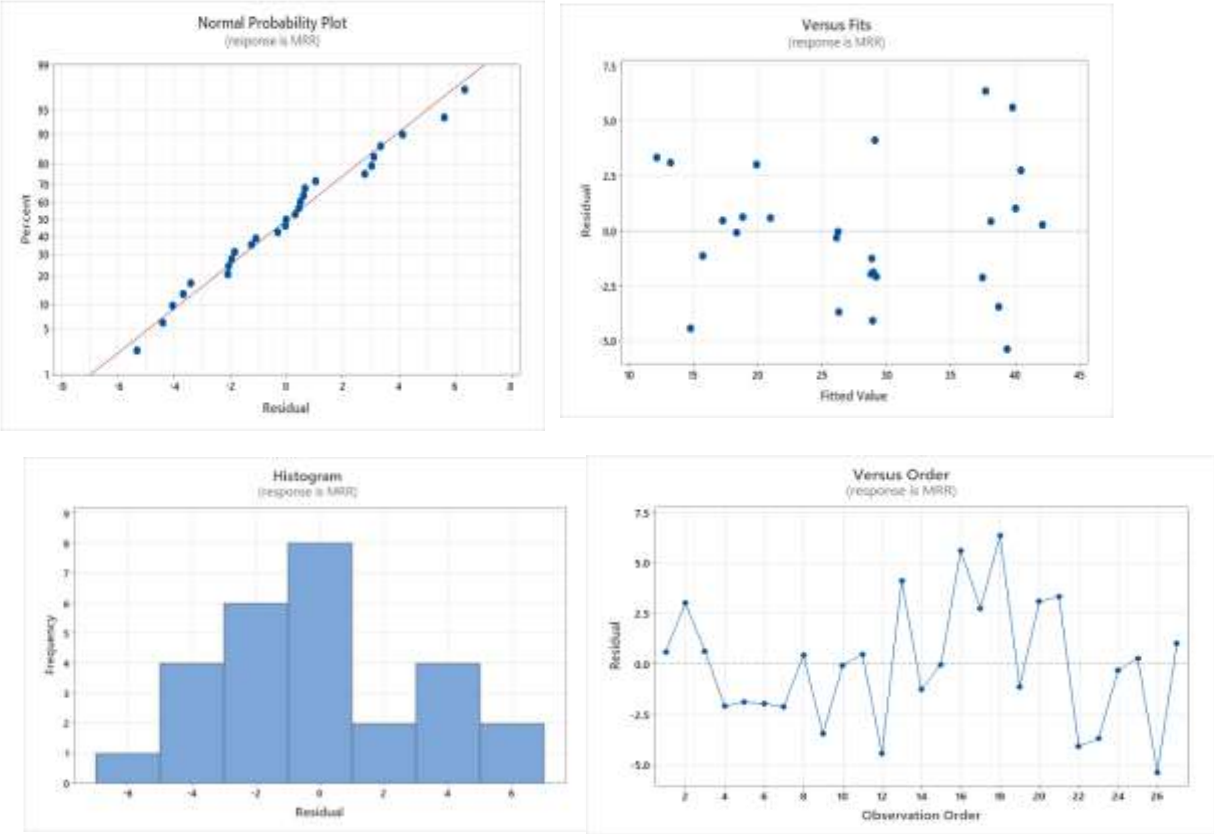


Fig-10: Main effect plot for TWR

5.3 Regression equation for MRR

$$MRR = 22.9-0.0743T_{on}+0.296I_p-0.260V-1.7P+0.00216T_{on}*I_p+0.0053I_p*V$$



Conclusion:

Al6063 along with the reinforcements SiC and graphene are prepared by stir casting process and then considering the process parameters,the prepared casting is machined on electrical discharge machining. The primary objective of this project is to optimize the most influencing process parameters that affect MRR and TWR on EDM. From the experiments conducted in this study, peak current and flushing pressure are the most influencing factors that affect MRR and TWR. In this experimental study, the optimal process parameters that maximizes the MRR and minimizes the TWR are also found.

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