

# Analysis & Optimization of Parameters during EDM of Aluminium Metal Matrix Composite

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**Abstract:** In now days Aluminium Metal Matrix Composite (AMMC) has become one of the most favorite material for automotive, aerospace, shipyard etc. industry because of their outstanding properties such as high wear and corrosive resistance, remarkable hardness and toughness, low density, light weight etc. But because of the complexity of the cutting geometry and mechanical properties of work materials the use of convectional machining process becomes limited. Such difficulties are easily sort-out by using electric discharge non convectional machining process (EDM) because in this case material removal takes place by thermal erosion process. The present research work highlight the effect of process parameter on output response during the EDM of Aluminium7075- Boron carbide-Graphite (Al/B<sub>4</sub>C/Gr) metal matrix composite (MMC). Taguchi technique is used for design of experiments. Fitness and adequacy of the experimentation has tested through the analysis of variance (ANOVA).

**Keywords:** EDM, AMMC, Taguchi, Process Parameter, ANOVA, Process Responses.

## 1. INTRODUCTION

Metal matrix composite materials are one of the newly developed materials and in now days it has becomes the interest of the industries because of their superior mechanical properties. But it is very difficult to machine such materials through convectional machine tool because of high tool erosion. Such a problem can be short out through the non convectional machining process. Hence non convectional machining process is most suitable to machine said materials. Among all non convectional machining process Spark erosion machining (EDM) process is mostly used to machine such materials [1, 2]. George et al. [3] evaluated the optimal setting of input parameter through Taguchi technique in term of pulse current (I), gap voltage (V<sub>g</sub>), spark on time (T<sub>ON</sub>) for getting better responses in term of electrode wear rate (EWR) and material removal rate (MRR) during EDM of carbon-carbon composite material. Pandey and Shrivastava [4] compared the conventional EDM and vibration assisted electric arc machining (VEAM) during the machining of Al/B<sub>4</sub>C MMC. Result implied that VEAM enhanced the MRR 300 % more as compare to conventional EDM. Khan et al. [5-7] was found out the effect of biodiesel and powder mixed di electric fluid on the machining performance of EDM.

## 2. EXPERIMENTAL DETAILS

OCARMAX EDM machine was chosen to conduct the experiment which was manufactured by OSCAR E.D.M. Company Ltd. Taichung, Taiwan (shown in Fig. 1) in Indo Danish Tool Room (IDTR), Jamshedpur, Jharkhand. AMMC metal matrix was selected as work piece materials. Three different percentage of weight fraction of boron carbide (B<sub>4</sub>C) and graphite (Gr) were reinforced with Al-7075 such as 3% wt. B<sub>4</sub>C & 7 % wt. Gr, 5 % wt. B<sub>4</sub>C & 5 % wt. Gr, 7 % wt. B<sub>4</sub>C & 3 % wt. Gr respectively. The MMC was developed through the stir casting process. Experiments was performed by using copper electrode having diameter 18 mm with negative polarity and fluid SE 180 as a di-electric fluid during the EDM of Al/B<sub>4</sub>C/Gr metal matrix composite materials. Chemical composition of Al-7075 is tabulated in table 1. In this research h work four input parameter with their three levels was selected to perform the experiments (shown in table 2) and kept spark off time 150 µsec and tool workpiece gap 10 mm constant. Operational setup is shown in Fig. 2.



Fig. 1 Spark Erosion Machine



Fig. 2 Operational setup of EDM machine

Table 1. Chemical composition of Al-7075 alloy

| Composition    | Percentage (%) |
|----------------|----------------|
| Aluminium (Al) | 89.60          |
| Zinc (Zn)      | 5.70           |
| Magnesium (Mg) | 2.30           |
| Copper (Cu)    | 1.50           |
| Ferrous (Fe)   | 0.41           |
| Chromium (Cr)  | 0.18           |
| Silicon (Si)   | 0.13           |
| Manganese (Mn) | 0.13           |
| Titanium (Ti)  | 0.05           |

Selection of level of input variable was done through the study of literature survey [8-12]. By using Taguchi Technology total 09 experiments were designed as shown in table 3. Wear Ratio (WR) was considering as a machining responses during the research work.

Table 2. Independent variable and their levels

| Process parameter                 | Low level | Medium level | High level |
|-----------------------------------|-----------|--------------|------------|
| Survo voltage (V)                 | 3         | 6            | 9          |
| Spark on time ( $\mu\text{sec}$ ) | 300       | 400          | 500        |
| Pulse current (A)                 | 2         | 4            | 6          |
| Sample                            | 1         | 2            | 3          |

### 3. MEASUREMENT OF RESPONSE VARIABLES

Tool Wear Rate (TWR) and Material removal rate (MRR) had been founded through the weight method [13, 14]. Wear Ratio (WR) is defined as the ratio of MRR to TWR and mathematically it can be expressed as

$$WR = \frac{MRR}{TWR}$$

The experimental finding of machining responses such as MRR, TWR and WR has been shown in table 4.

**Table 3. L9 Orthogonal Matrix**

| Experiment no. | Survo voltage (V) | Spark on time (μsec) | Pulse current (A) | Sample |
|----------------|-------------------|----------------------|-------------------|--------|
| 01             | 3                 | 300                  | 2                 | 1      |
| 02             | 3                 | 400                  | 4                 | 2      |
| 03             | 3                 | 500                  | 6                 | 3      |
| 04             | 6                 | 300                  | 4                 | 3      |
| 05             | 6                 | 400                  | 6                 | 1      |
| 06             | 6                 | 500                  | 2                 | 2      |
| 07             | 9                 | 300                  | 6                 | 2      |
| 08             | 9                 | 400                  | 2                 | 3      |
| 09             | 9                 | 500                  | 4                 | 1      |

**Table 4. Experimental determination for output responses**

| Serial no. | Survo voltage (V) | Spark on time | Pulse current (A) | Sample | WR     |
|------------|-------------------|---------------|-------------------|--------|--------|
| 01         | 3                 | 300           | 2                 | 1      | 55.988 |
| 02         | 3                 | 400           | 4                 | 2      | 30.510 |
| 03         | 3                 | 500           | 6                 | 3      | 24.007 |
| 04         | 6                 | 300           | 4                 | 3      | 41.417 |
| 05         | 6                 | 400           | 6                 | 1      | 27.653 |
| 06         | 6                 | 500           | 2                 | 2      | 31.042 |
| 07         | 9                 | 300           | 6                 | 2      | 30.160 |
| 08         | 9                 | 400           | 2                 | 3      | 10.004 |
| 09         | 9                 | 500           | 4                 | 1      | 51.207 |

### 4. RESULTS & DISCUSSION

#### 4.1 EDM PARAMETR EFFECT ON WR

WR is one of the important factors of machining which helps to enhance the productivity, reduce the production time and make the product more economical. Signal to Noise ratio was determined by using the technique larger is better shown in table 5[15].

ANOVA table 6 implies that pulse current and percentage of reinforcement having the significant effect on WR. It is found that on increasing the T<sub>ON</sub> time WR initially decreases upto 400 μsec and after that start to increase.

On increasing the pulse on time pressure inside the plasma channel starts to decrease which decrease the MRR as a result of which WR decreases. But beyond 400  $\mu\text{sec}$  because of longer effect of high thermal energy TWR becomes low as a result of which WR again starts to increase.

**Table 5. Signal to Noise ratio for WR**

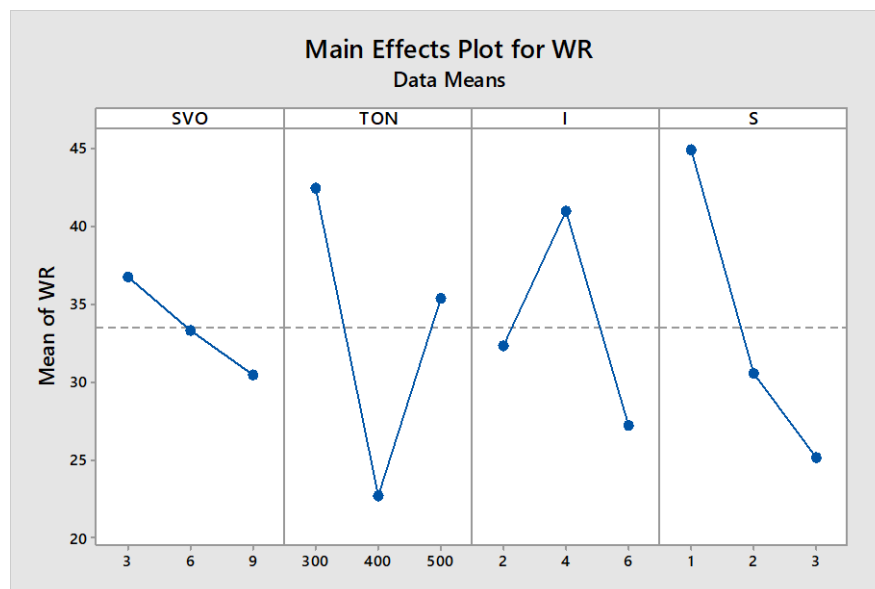
| Level | SVO   | T <sub>ON</sub> | I     | S     |
|-------|-------|-----------------|-------|-------|
| 1     | 30.75 | 32.30           | 28.27 | 32.66 |
| 2     | 30.34 | 26.18           | 32.07 | 29.71 |
| 3     | 27.93 | 30.54           | 28.68 | 26.65 |

Pulse current also affects the WR as shown in table 6. It is shown in Fig. 3 that WR is first increases on increasing pulse current upto 4 ampere after that start to decrease. On increasing pulse current both electrodes subjected to high thermal energy which enhance the WR. After 4 ampere pulse current WR start to decrease because high thermal energy enhance the crater size which produces resistance in the conductive path after the removal of ceramic particles. Hence WR decreases beyond 4 ampere pulse current.

**Table 6. Analysis of variance for WR**

| Source          | df | Seq.SS  | Adj.SS  | Adj.MS  | % Contribution |
|-----------------|----|---------|---------|---------|----------------|
| SVO             | 2  | 61.17   | 61.170  | 30.585  | 3.86           |
| T <sub>ON</sub> | 2  | 603.66  | 603.663 | 301.832 | 38.10          |
| I               | 2  | 291.06  | 291.058 | 145.529 | 18.37          |
| S               | 2  | 628.51  | 628.513 | 314.257 | 39.67          |
| Total           | 8  | 1584.40 |         |         | 100            |

It is found that on increasing the percentage of reinforcement WR decreases as shown in fig. 3. On decreasing the percentage of graphite MRR decreases because graphite having good thermal conductivity as a result of which WR also decreases. But on increasing the percentage of boron carbide MRR decreases and TWR increases as a result of which WR decreases. Fig. 3 shows that WR is decreases non-linearly with increase in servo voltage.



**Fig. 3 Parametric Effect on WR during EDM**

## 5. PREDICTION OF RESULTS

Table 7. Comparison between predicted and finding results

| Optimum machining parameter |                  |                  |                     |
|-----------------------------|------------------|------------------|---------------------|
|                             |                  | Predicted result | Investigated result |
| WR                          | Level            | A1B1C2D1         | A1B1C2D1            |
|                             | WR               | 64.688           | 924.227             |
|                             | S/N ratio for WR | 38.7668          | 59.3156             |

Table 7 implies that for WR, there is acceptable variation between predicted and experimental result.

## 6. CONCLUSIONS

This experimentation highlights the effect of process parameter on the machining responses in term of WR during the EDM of Al/B<sub>4</sub>C/Gr metal matrix composite [16].

On increasing the T<sub>ON</sub> time WR initially decreases upto 400 µsec and after that start to increase. WR is first increases on increasing pulse current upto 4 ampere after that start to decrease. On increasing the percentage of reinforcement WR decreases. WR is decreases in non-linearly fashion with increase in servo voltage. Taguchi Analysis has been used to design the experimental work and their fitness and adequacy has been tested through the analysis of variance (ANOVA).

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