Effect of the parameters in electromagnetic field assisted electric discharge machining

S V Raut¹, a), Dr. A Bongale*², b) and Dr. S Kumar³, c)

¹Research Scholar, Symbiosis Institute of Technology, Symbiosis International University(S.I.U.), Lavale,Pune-412115, Maharashtra, India
² Associate Professor, Symbiosis Institute of Technology, Symbiosis International University(S.I.U.), Lavale,Pune-412115, Maharashtra, India
³ Assistant Professor, Symbiosis Institute of Technology, Symbiosis International University(S.I.U.), Lavale,Pune-412115, Maharashtra, India
a) sandeep.raut.phd2018@sitpune.edu.in, b) arun.bongale@sitpune.edu.in
b) satish.kumar@sitpune.edu.in

Corresponding Author. arun.bongale@sitpune.edu.in, arunbongale1980@gmail.com

Abstract. The electric discharge machining is a non-conventional machining process, in which the spark is electric spark is generate in gap between the work piece and electrode. Due to heat generated by spark in between the workpiece and electrode, the material get vaporized from small area form workpiece and get cool down with the help of dielectric fluid. In present study low carbon mold steel use as a work piece and copper electrode is used. The electromagnetic field included in the process to analyze the effect of the input parameters on the machine response parameters like MRR and the surface roughness value (Ra). The study is done on EDM process with and without EMF by varying the input parameters Ton (μs) and keeping the other parameters constant (T_off (μs), Current (A) & Voltage (V)). The set of the neodymium magnets are used in the set up having 4500 gauss units. The circular plate is designed to hold the neodymium magnets nearer to the work piece using CATIA V5 version. 3D printer is used to fabricate the circular plate that holds the electromagnets precisely near to the area under spark to have a maximum effect of EMF in the EDM process. The experimentations shows that response parameter shows good output at pulse on time of 200 ms and 300 ms with and without EMF respectively.

Keywords: Electrical discharge machining, electromagnetic field, pulse on time, material removal rate and surface roughness.

1. Introduction

In EDM the work piece and electrode are meant to be electrically conductive and no direct contact is observed in between work piece and electrode. In process the electrode does not have tool force. EDM is a thermal process as the material is removed by heat. The dielectric fluid is used in EDM process around the tool and the workpiece as the EDM used is die sinking type for the experimentation. The dielectric fluid that used in EDM process act as conductor only for the closet area between electrode and workpiece except the remaining part from the dielectric fluid tank where fluid act as insulator. Figure 1 a) and Fig 1 b) shows the die sinking type EDM machine. The different input machining parameters of the EDM may have different output with respect to the output response.
The EDM is one of the most generally applied non-customary machining measures for assembling of passes on in forging/extrusion businesses. EDM can be used to machine the materials with extraordinary properties. Materials like advanced ceramic and super alloys. In EDM surface finishing could achieve with high degree of precision where it could not be achieved by other traditional processes (Khanra et al 2006)[1]. The Material which used in EDM are graphite and the copper. The main drawback of the tool in the EDM is poor wear resistance of the tool (Khanra et. al 2009) [2]. The characteristics as well as hardness of the surface of workpiece can improved through the tool electrodes in EDM process. Measures of the EDM could be done over the effect on melting point and electrical conductivity i.e properties of the electrode (Muthuramalingam and Mohan, 2014)[3]. Even surface treatment (acid pickling and oxidation treatment) before the MEDM process increase the MRR and enhanced the surface quality of the steel alloy [4]. The need of some elective components emerges to break down the impact of attractive field on the plasma shaped between the workpiece-terminal hole while EDM of material which is free of workpiece attraction, along these lines building up a framework that could be generally applied in EDM [5]. The study is done that EDM process has more benefits as it is operated under magnetic field as it enhanced MRR, dimensional accuracy and surface quality of the workpiece with the same high degree of the effect is observed on the surface integrity as compared to other parameters due to magnetic flux [6]. Improved MRR and electrode (tool) wear rate could be achieved by the interference of the magnetic field. [7]. The studies shows that the inclusion of the magnetic field improve the quality of the surface quality of the workpiece and the enhance the process by improving material removal rate of workpiece. Hardik B. and Pulak P. studied the difference in Magnetic field assisted EDM process occurs with insertion of air and argon gas which increase the MRR and reduce the wear of electrode and shows that result could be improved by the insertion of ferromagnetic material [8]. Fused Deposition Modeling is an additive manufacturing process use for the layer by layer manufacturing for the complex shaped design using 3D printer. Computer Aided Design software is used to design file which later converted into .stl file for 3D printing of the design. The improvement in mechanical properties of the product made through the FDM is one can achieved by optimizations well as directional stability in X, Y and Z axis and setting up the different reliable levels of the parameters [9]. The use of different grade material likes PCABS, ABS-M30, ABS-plus, ABSi, ABS-M30i in FDM process could enhance the stability of the specimen in different aspects as compare to traditional material ABS [10]. The process optimization techniques like Taguchi methods could be used with multi-response performance index which could result in optimal parameters setting for multiple responses in input parameters [11].

2. Material and Methods

Electrical discharge machining process are used for machine the material having very high hardness as the material removal rate is very low. In present study the die-sinking type of the EDM C 400x 250 (EDM Pulse Generator V-20Z) made by Electronica Machine Tool Ltd. use as shown in figure 1 b) and diagrammatic presentation in figure 1b). The die-electric fluid used in the experimentation is EDM oil which not only provide the connectivity in between tool and the workpiece but also act as a coolant and remove the debris as well as deposited carbon from the area under spark. The workpiece use in the experimentation low-carbon mold steels and the tool (electrode) use is made up of copper with 99% purity as shown in figure 2 and fig 3. The (workpiece) specimen having the dimensions like 30 mm (dia) x 20 mm (thickness) and the diameter for the copper electrode is 35 mm. Hence the complete area of the specimen (workpiece) come under the spark generated in EDM.
In experimentation, material removal rate is taken one of the output response parameters by giving the set of control parameters. To calculate the MRR the precise weight of the specimen is measured using Sartarius Electronic weighing balance (BSA 224SCW) includes the least count of 0.0001 gram (Figure 4). The formula for the MRR is given below,

\[
\text{Material Removal Rate} = \frac{(\text{Initial Weight of Workpiece} - \text{Final Weight of the Workpiece})}{\text{Machining Time}}
\]

The another factor to compute the precise condition for EDM is surface roughness value and for the same surface roughness tester is used (Mitutoyo 178-561-01A Surftest SJ-210) as shown in figure 5.

The circular plate to hold the neodymium magnets is made up of ABS material and developed using on Flashforge Dreamer 3D printer (Figure 6). The circulate plate was design in CATIA V5 CAD software with consideration of the dimensions of the electrode, specimen and the neodymium magnets.
as shown in figure 7 a) and figure 7 b) shows the actual 3D printed circular plate developed using white ABS material.

![Figure 6. 3D printer (Flashforge Dreamer).](image)

![Figure 7 a) Circular plate design CAD model.](image) ![Figure 7 b) 3D printed circular plate.](image)

The neodymium magnets used in the setup is of the 3 different type and the details are given in the table below.

| Sr. no. | Structure of the neodymium magnet | Quantity | Holding in total (Gauss) |
|---------|----------------------------------|----------|--------------------------|
| 1       | Small cylindrical                | 2        | 500                      |
| 2       | Long cylinder                    | 2        | 1500                     |
| 3       | Block                            | 2        | 3000                     |

3. Result and discussion

The neodymium magnets are placed in circular plate structure in such a way that electromagnetic force could be observed all around the specimen (workpiece) in the experimental machining setup. Figure 8 shows the position of the pair of block type and two pair of cylindrical magnets in the circular plate structure. The specimen is get aligned at the center of the circular plate near to magnets so that the effect of the electromagnetic force efficiently observed. Figure9 shows the EDM setup with specimen in circular plate structure. Fig 10 shows the electrical discharge machining on the specimen in the
The table 2 shows the EDM machining parameters and its levels used to for the positive machining output response, where the effect of the pulse on time (Ton) is observe by varying its level and keep the other parameters at constant level like pulse off time (T_{off} μs), Current (A) & Voltage (V). These parameters remains constant for both setup with neodymium magnets and without neodymium magnets.
Table 2. Details of the EDM parameters.

| Sr.No. | T_on (μs) | T_off (μs) | Current (A) | Voltage (V) |
|--------|-----------|------------|-------------|-------------|
| 1      | 50        | 12         | 6           | 50          |
| 2      | 100       | 12         | 6           | 50          |
| 3      | 150       | 12         | 6           | 50          |
| 4      | 200       | 12         | 6           | 50          |
| 5      | 300       | 12         | 6           | 50          |
| 6      | 400       | 12         | 6           | 50          |

In the experimentation the continuous flow of the EDM oil is maintained in EDM tank for removal of the debris as well as to deposited carbon from the area under spark. Machining time also closely monitor during the each cycle of to void excessive machining over the specimen. Table 3 and table 4 shows the output response that are MRR and surface rough (Ra) in the experimentation with and without neodymium magnets setup within structure respectively.

Table 3. Output response with neodymium magnets.

| Sr.No. | T_on (μs) | T_off (μs) | Current (A) | Voltage | MRR (g/min) | Surface Roughness (Ra) µm |
|--------|-----------|------------|-------------|---------|-------------|---------------------------|
| 1      | 50        | 12         | 6           | 50      | 0.1084      | 10.963                    |
| 2      | 100       | 12         | 6           | 50      | 0.1587      | 10.624                    |
| 3      | 150       | 12         | 6           | 50      | 0.2324      | 10.264                    |
| 4      | 200       | 12         | 6           | 50      | **0.2442**  | **9.366**                 |
| 5      | 300       | 12         | 6           | 50      | 0.1618      | 9.719                     |
| 6      | 400       | 12         | 6           | 50      | 0.1294      | 10.772                    |

Table 4. Output response without neodymium magnets.

| Sr.No. | T_on (μs) | T_off (μs) | Current (A) | Voltage | MRR (g/min) | Surface Roughness |
|--------|-----------|------------|-------------|---------|-------------|-------------------|
| 1      | 50        | 12         | 6           | 50      | 0.0911      | 10.882            |
| 2      | 100       | 12         | 6           | 50      | 0.0897      | 10.969            |
| 3      | 150       | 12         | 6           | 50      | 0.1121      | 11.124            |
| 4      | 200       | 12         | 6           | 50      | 0.1741      | 11.254            |
| 5      | 300       | 12         | 6           | 50      | 0.1971      | 11.412            |
| 6      | 400       | 12         | 6           | 50      | 0.2174      | 11.494            |
Figure 11 shows that material removal rate in the EDM is improved with implication of electromagnetic field within the setup. It specifically shows high MRR response when Ton set at 200 µs with EMF that is 0.2442 g/min and in the EDM setup without EMF it is observed that Ton directly proportional to the MRR. It states that inclusion of the EFM will induced the positive results in output response.

Similarly figure 12 shows that the surface roughness value of the specimen with the inclusion of EMF in EDM setup is get improved up to 50 to 200 µs and further it shows reverse functionality till 400 µs (Ton). It also shows that the Ton (µs) is directly proportional to the surface roughness (output response) when the EMF is not included in the EDM setup.

4. Conclusion

In this study it is observed that electromagnetic field is having the significant impact on the machining output response like material removal rate (MRR) and the surface roughness (Ra) on the specimen in electrical discharge machining (EDM) process. In the result it is observed that in EDM parameters like pulse on time (Ton at 200 µs) shows significantly positive result in output response like MRR and Ra when inclusion of the electromagnetic field in setup is observed. Whether EDM setup without EMF shows direct proportionality with machining parameter like pulse on time with the output responses i.e. MRR and surface roughness value (Ra). From the result it is conclude that electromagnetic field helps to improve the surface quality of the specimen under EDM process and efficiency of the process is also increase with respect to the material removal rate. This experimental deal in the research leads the further hypothesis which could be consider with the other parameters of the EDM process in near future as a necessity in optimization in process parameters with inclusion of EMF in EDM process.
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