FABRICATION OF DIE-SINKING ELECTRICAL DISCHARGE MACHINE FOR MACHINING OF HOLES ON COPPER PLATE

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Abstract: *Electrical Discharge Machining has been playing an important role in manufacturing sector especially industries like aerospace, ordinance, automobile, general engineering, etc. Electrical Discharge Machining (EDM) is one of the important non-traditional machining processes which is used for machining of conductive and semi conductive materials and also difficult to machine materials like super alloys and composites materials. However, selection of process parameters for obtaining higher cutting efficiency or accuracy in EDM is still not fully solved, even with the most updated EDM machine. An attempt is made in the present work to develop a prototype of EDM consisting of different units namely, dielectric filtering and recirculation unit, pulse generation and control unit and tool-feed control unit. They describe the utilization of various units and their components of proto-type EDM. Orthogonal Array, Taguchi Experimental design is developed for experimentation. The process parameters such as voltage, duty cycle and sensor value are by considered during machining. The experiments are carried-out to produce holes on copper plate using EDM Machine. The experimental results are analyzed and the optimal combinations of influential parameters are determined using Grey Taguchi Analysis. The optimum size of hole is obtained as 2.030 mm, at 40V and 0% Duty Cycle. The analysis is carried-out using Mini TAB and GRA.*

Keywords: *Die-Sinking EDM, Dielectric filtering, Voltage, Duty Cycle, Grey Taguchi Method*

1. INTRODUCTION

Electrical Discharge Machining (EDM) is also known as spark machining, spark eroding, burning, die-sinking, wire burning or wire erosion. It is a manufacturing process whereby a desired shape is obtained by using electrical discharges (sparks). Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the “tool” or “electrode,” while the other is called the workpiece-electrode, or “workpiece.” The process depends upon the tool and workpiece which is non-contact [5].

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 for machining insulating ceramics with EDM have also been proposed [4]. EDM can cut intricate contours or cavities in pre-hardened steel without the need for heat treatment to soften and re-harden them. This method can be used with any other metal or metal alloy such as Titanium, Hastelloy and Inconel [2].

The present work deals with following objectives

1. To fabricate Die-Sinking EDM for machining of holes.
2. To conduct experiments by considering parameters like Voltage, Duty cycle and Sensor value.
3. To analyze influence of process parameters on performance parameters like MRR and size of the hole by Grey Relation Analysis (GRA).

2. FABRICATION OF DIE SINKING EDM

Die-sinking EDM, also called cavity type EDM or volume EDM, consists of an electrode and workpiece submerged in an insulating liquid such as, more typically, de-ionized water and other dielectric fluids oil, kerosene etc. The electrode and workpiece are connected to a suitable power supply. The power supply generates an electrical potential between the two parts. As the electrode approaches the workpiece, dielectric breakdown occurs in the fluid, forming a plasma channel, and a small spark jumps.

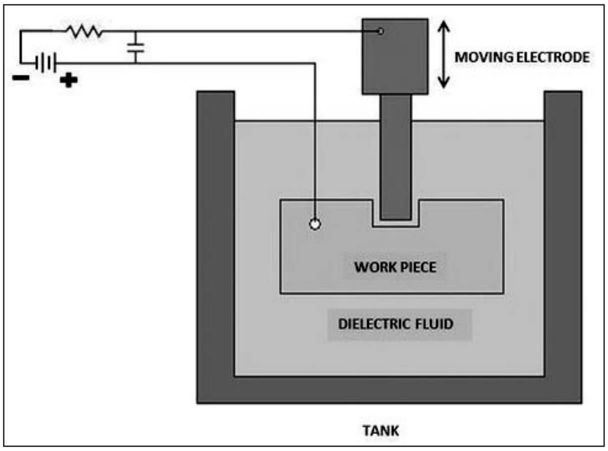


Fig 1. EDM Principle

These sparks usually strike one at a time because it is very unlikely that different locations in the inter-electrode space have the identical local electrical characteristics which would enable a spark to occur simultaneously in all such locations. These sparks happen in huge numbers at seemingly random locations between the electrode and the workpiece. As the base metal is eroded, and the spark gap subsequently increased, the electrode is lowered automatically by the machine so that the process can continue uninterrupted. Several hundred thousand sparks occur per second, with the actual duty cycle carefully controlled by the setup parameters. These controlling cycles are sometimes known as "on time" and "off time". The on time setting determines the length or duration of the spark. Hence, a longer on time produces a deeper cavity for that spark and all subsequent sparks for that cycle, creating a rougher finish on the workpiece. Based on the principle a prototype model of Die-Sinking EDM is fabricated and is shown in Fig.2.

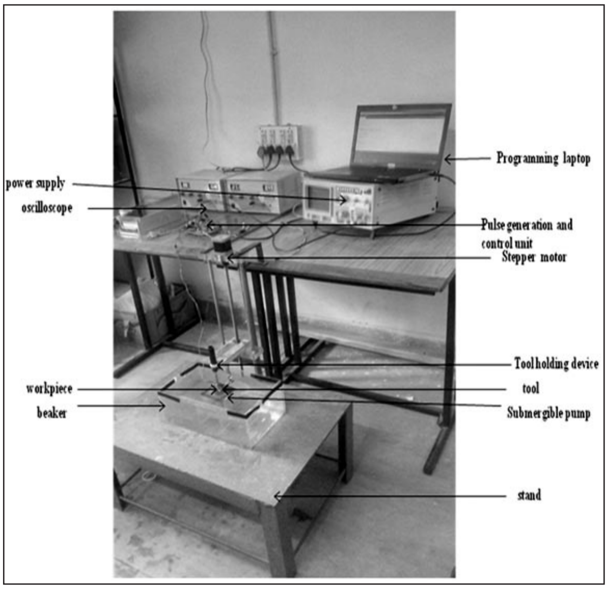


Fig 2. Experimental set-up of EDM

The Die-sinking EDM setup consists of following units:

2.1 Tool Feeding Unit: It is used to develop a feedback and to maintain the constant gap between the tool and the workpiece. The unit consists of the components like

- Tool holder
- Stepper motor

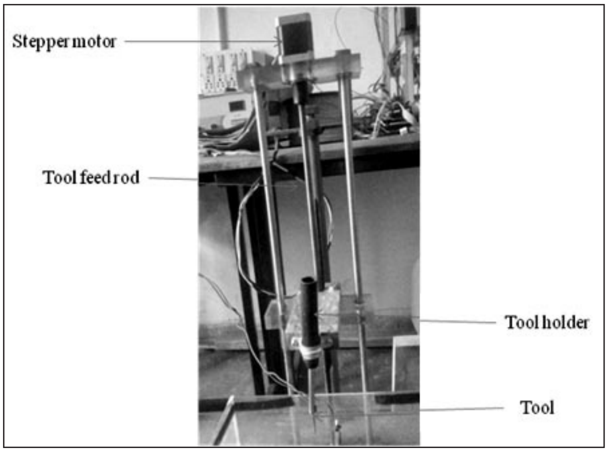


Fig 3. Tool Feed Control Unit

Tool feed during machining is equal to the sum of the axial tool wear and depth of machining on the workpiece. The tool feed controller should maintain a proper inter-electrode gap between the tool and the workpiece to sustain spark discharges. It consists of a tool holder setup and stepper motor which are controlled by pulse control unit. Tool feed control is achieved based on the average gap voltage as the feedback signal. In the setup, the tool is moved at a low feed rate till gap between the tool and workpiece

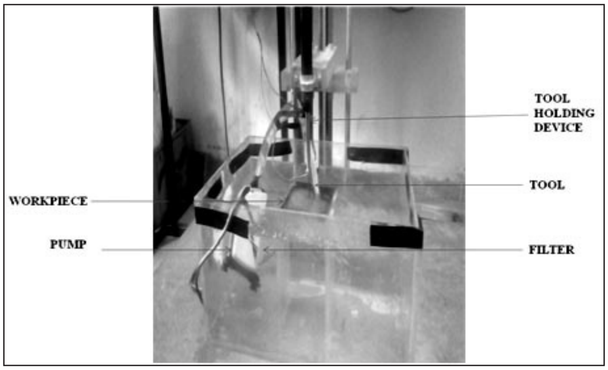


Fig 4. Filtering and Recirculation Unit

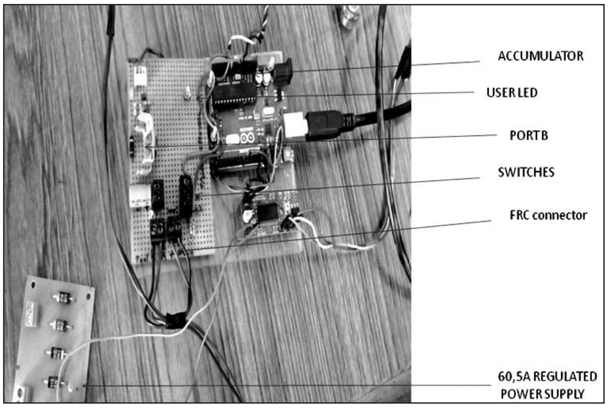


Fig 5. Pulse Generation and Control Unit

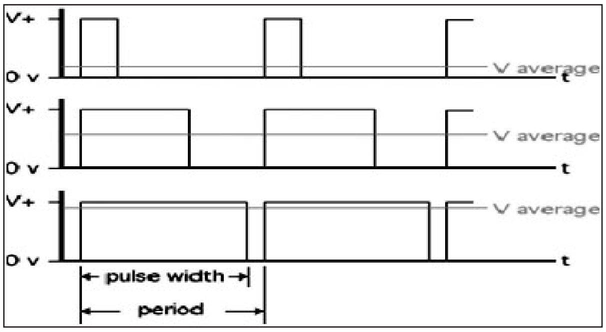


Fig 6. Pulse Width Modulation

reaches a gap equivalent to the desired spark gap. The Tool feed control unit used in the EDM setup is shown in the Fig. 3.

2.2 Dielectric Filtering and Recirculation unit: Filtering and recirculation unit is developed to flush the debris and to get good machining. The unit consists of the components like

- Dielectric Beaker with Workpiece holder
- Pump and Filter

Dielectric medium plays an important role affecting the material removal rate and properties of the machined surface. De-ionized water (DI-Water) and kerosene are the most widely used dielectric mediums used for EDM process. In the present work, DI Water is used as a di-electric medium for machining of holes. Submersible pumps are multistage centrifugal pumps operating in a vertical position. Liquids, accelerated by the impeller, lose their kinetic energy in the diffuser where a conversion of kinetic energy to pressure energy takes place. This is the main operational mechanism of radial and mixed flow pumps. The pump shaft is connected to the gas separator or the protector by a mechanical coupling at the bottom of the pump. Fluids enter the pump through an intake pipe and are lifted by the pump stages, filtered at the outlet pipe which is placed between workpiece and tool to flush out the debris and supplies the fresh filtered dielectric medium. The Dielectric Filtering and Recirculation Unit used in the setup is as shown in the Fig. 4.

2.3 Pulse Generation and Control Unit: It is designed to provide pulses of specified frequency and duty cycle to the tool and the workpiece. The unit consists of the components like

- Pulse Width Modulator
- DC Power Supply.
- Oscilloscope

For design of a pulse width modulation circuit, first it is necessary to understand the working of a microcontroller based board which follows the standard Arduino schematic and is flashed with the Arduino boot loader can be called an Arduino board. A specific circuit is designed to control the Pulse Width modulation for the present Experimental work [10]. The Pulse Generation and Control unit is shown in Fig. 5.

Pulse Width Modulation (PWM) is a way to provide a variable signal from a given set signal. PWM does this by changing the pulse width, which in turn, changes the duty cycle of a square wave to alter how much power is supplied to the attached component. The Pulse width modulation wave forms are shown in Fig. 6. It varies because the signal takes the duty cycle and averages the power signal that is output. So the larger the duty cycle percentage, the larger the output signal will be. The voltage that varies for the Arduino is shown in the figure 6.

DC power supply is used for entire circuit with a maximum voltage of 0 to 60 V and an oscilloscope is used to monitor the frequency of the sparks.

3. EXPERIMENTATION

Taguchi's method is a powerful technique for the design of a high quality system. It provides not only, an efficient but also a systematic approach to optimize designs for performance and quality. Furthermore, Taguchi parameter design can reduce the fluctuation of system performance.

This experiment is governed by the following steps are:

- Selection of process parameters to be evaluated.
- Selecting an appropriate orthogonal array and assign these parameters to the orthogonal array.
- Perform the experiments based on the arrangement of the orthogonal array.
- Analyze the experimental results using Grey Taguchi Technique (GRA).

3.1 Experimental Design

- **Step1 - Process parameters selection**: Process parameters and their ranges are determined based on the research papers. The parameters are identified as Voltage, Duty cycle and Sensor value. Table 1 show the machining conditions and control parameters.
- **Step 2 - selection of Orthogonal array:** To select an appropriate orthogonal array for the experiments, on the basis of parameter

Table 1: Machining Parameters

Machining Conditions			
Workpiece material	Copper (cu)		
Thickness of the workpiece	1 mm		
Electrode (Tool) material	Copper (cu)		
Size of the electrode	2 mm		
Control parameters	**Levels**		
	1	**2**	**3**
Voltage	30	40	50
Duty cycle	50%	60%	70%
Sensor value	390	470	560

Table 2: Experimental Layout Based on Orthogonal Array

Exp .No	Voltage	Duty cycle	Sensor value
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	1
5	2	2	2
6	2	3	3
7	3	1	1
8	3	2	2
9	3	3	3

Table 3: Experimental Data with Response Data

Exp. No.	Voltage (V)	Duty Cycle (%)	Sensor Value	Time (min)	Workpiece Initial Weight (gm)	Workpiece Final Weight (gm)	Hole Size (mm)	MRR (Mm^3/ min)
1	30	50	390	54	15.392	15.145	2.109	0.512
2	30	60	470	50	14.960	14.678	2.039	0.631
3	30	70	560	48	14.836	14.521	2.124	0.734
4	40	50	390	40	16.446	16.142	2.030	0.850
5	40	60	470	37	15.975	15.563	2.145	1.255
6	40	70	560	34	15.571	15.106	2.048	1.532
7	50	50	390	19	13.977	13.473	2.316	2.814
8	50	60	470	15	14.451	14.046	2.241	2.913
9	50	70	560	13	13.839	13.407	2.143	3.732

Table 4: Grey Relation Analyses

Expt. No	Grey relation Generation		Grey relation Coefficient		GRG
	Hole Size (mm)	MRR (mm^3/min)	Hole Size (mm)	MRR (mm^3/min)	
1	0.681	0.000	0.610	0.333	0.472
2	1.000	0.080	1.000	0.352	0.676
3	0.632	0.069	0.576	0.349	0.463
4	0.941	0.105	0.894	0.358	0.626
5	0.563	0.231	0.533	0.394	0.464
6	0.882	0.317	0.809	0.423	0.616
7	0.000	0.715	0.333	0.637	0.485
8	0.247	0.746	0.399	0.663	0.531
9	0.569	1.000	0.537	1.000	0.769

Fig 7. Vision Measuring System (VMS)

selection and its levels. Here three parameters and three levels are considered and the combination is shown in table 2.

- **Step 3 - Experimentation and its responses**: Nine experiments are conducted as per the Taguchi's L9 orthogonal array. The test runs are carried out at random to avoid a systematic error creeping into the experimental procedure. The experiments and its responses are shown in Table 3.
- **Step 4 - Analysis using Grey Taguchi Method for Multi Response Optimization**: The analysis of GRA is used to discuss the relative importance of all control factors on the machined material quality and also to determine which control factor has the most

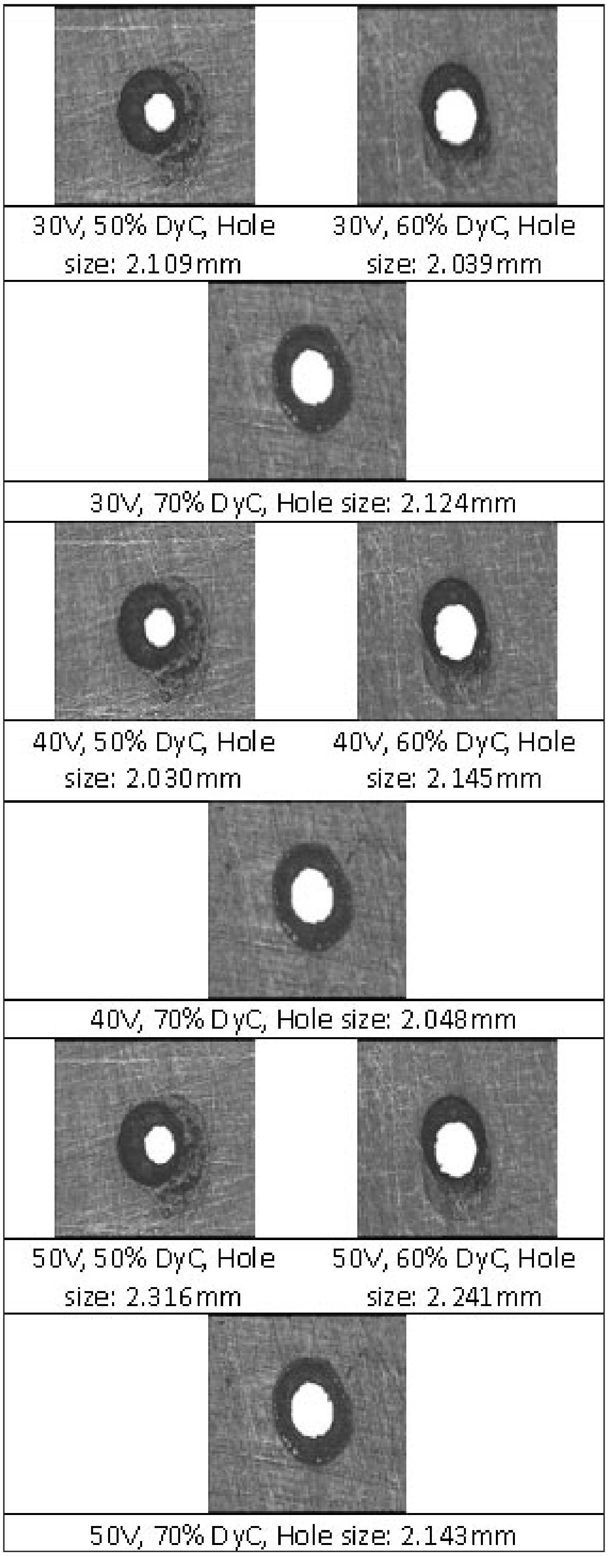


Fig 8. VMS Images of Holes for 30V, 40V & 50V and Duty Cycle (50%, 60% and 70%)

significant effect. Analysis of GRA is employed to find the optimal performance parameter levels and to analyze the effect of these parameters on Size of the hole and Metal Removal Rate values (MRR).

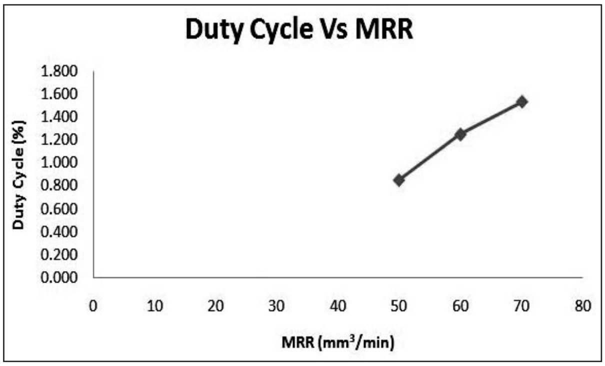


Fig 9. Duty Cycle Vs MRR

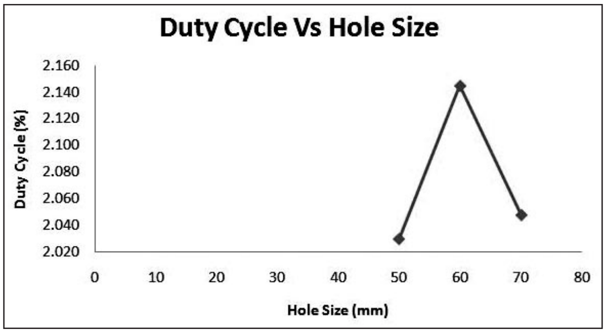


Fig 10. Duty Cycle Vs Hole Size

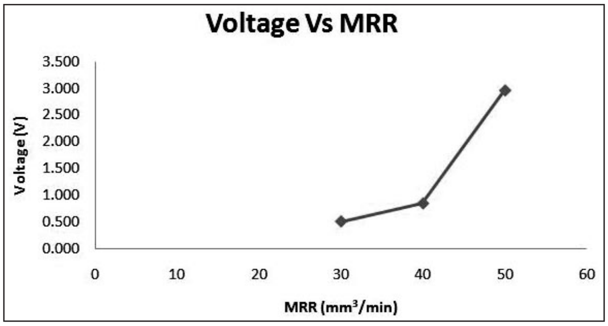


Fig 11. Voltage Vs MRR

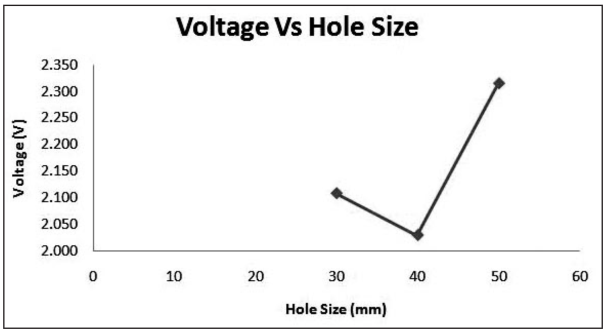


Fig 12. Voltage Vs Hole Size

Measurement of Hole Features

Measurement of diameter of holes is requiring high magnification and precise measuring equipment to get the accurate dimensions of the hole. Vision Measuring System (VMS) is used to Measure coordinate of point, distance between two points and center coordinate, diameter and area of circle by using Smooth tools and to make the measurement more accuracy. The Vision Measuring System used in the experimentation is shown in the Fig. 7.

Fig. 8 shows the Images of holes observed and measured by Vision Measuring System (VMS) with magnification (150X and 100X) for different input voltage of 30V, 40V & 50V and Duty cycle (50%, 60% & 70%).

4. RESULTS AND DISCUSSION

The holes are machined on copper workpiece with copper electrode using DI water. The effects of the process parameters on performance objectives like size and MRR are discussed below. Performance Characteristic Curves are drawn for MRR Vs Duty cycle, Duty cycle Vs Hole size, Voltage Vs MRR and Voltage Vs Hole size are shown in Fig. 9, 10, 11 & 12.

The graph for Duty cycle Vs MRR and it is observed that duty cycle is increased from 60% to 70% and MRR from 1.246 mm^3/min to 1.530 mm^3/min and it increased from 0.850 mm^3/min to 1.246 mm^3/min MRR from 50% to 60% Duty cycle. This is attributed due to increase in duty cycle the spark increases to a large extent therefore erosion of material with respect to time increases.

The graph for Duty cycle Vs Hole size and it is observed that Duty cycle is increased and Hole size is increased. The size of hole is increasing by 6% with increasing in Duty cycle, in which shows that smaller the Duty cycle gives the nearer the Hole size at 50% Duty cycle.

The graph for Voltage Vs MRR and it is observed that Voltage is increasing and MRR also increasing. The voltage is increased from 30 to 40V and MRR from 0.512 mm^3/min to 0.850 mm^3/min and it increased from 0.850 mm^3/min to 2.967 mm^3/min MRR from 40 to 50V voltage. This is attributed due to increase voltage the energy of the spark increase to a large extent and therefore erosion of material with respect to time increases.

The graph for Hole size Vs Voltage and it is observed that Voltage is decreased from 30V to 40V and Hole size increased and it increased hole size from 40V to 50V Voltage. The size of hole is increasing 5% with increasing in voltage.

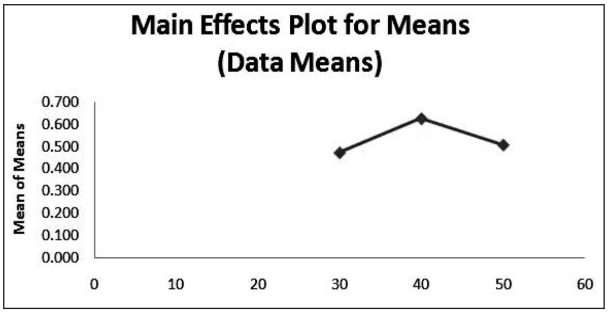


Fig 13 (a). Plot for GRG – Voltage

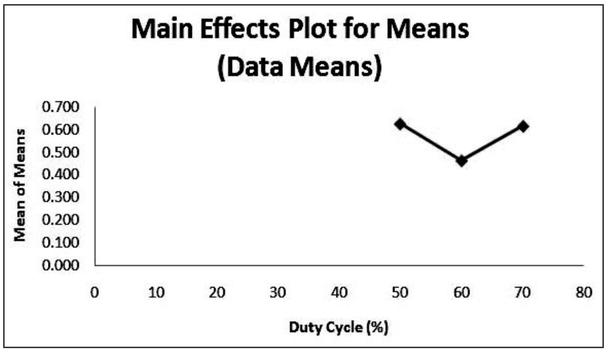


Fig 13 (b). Plot for GRG – Duty Cycle

In which shows that smaller the voltage gives the nearer the Hole size at 40 Voltage.

The main effect plot for GRG obtained in Table 4, gives optimal process parameters by using MINITAB R16 software and from the Fig. 13 (a) and 13 (b) it can be observed that the optimal input process parameters are 40V and 50% duty cycle.

4.1 Image of the Hole

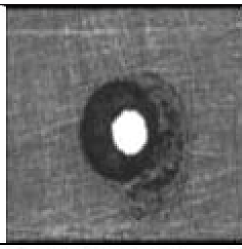
Size of the hole for the optimum parameters is 2.030 mm. From the results, it observed that with minimum Voltage of 40V and duty cycle of 50% the size of the hole obtained is 4% more the actual size of the hole is 2.030 mm.

5. CONCLUSIONS

Experiments are conducted on copper plate using Die-sinking EDM.

The following conclusions are drawn

- The Die-sinking EDM setup is developed for machining of holes.
- Through holes are produced on copper workpiece with copper electrode size 2 mm and de-ionized water as a dielectric medium by varying control parameters like Voltage, Duty cycle and Sensor value.
- Various combinations of input parameters are given as that through holes are machined by varying the Voltage (30V-50V, Duty cycle (50%-70%) and Sensor values (390-560).
- The effects of process parameters on performance parameters like MRR and size of the hole are discussed in detail and the constituent results are obtained.
- The optimum diameter of Hole size is obtained as 2.030 mm at 40V, 50% Duty Cycle.



40V, 50% DyC, Hole size: 2.030 mm

Fig 14. Image of Hole

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