Experimental Study and Optimization of Process Parameters in Electric Discharge Machining for Material Removal Rate in Carbon Tool Steel (SK2MCr4) Using Copper Electrode

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Abstract

Tool steels are usually worked upon to give them desired shape and creating features for holding/fixing before final heat treatment and finishing. Adding new features/geometry elements after hardening and finishing is extremely difficult with conventional machines and the tools. Electric discharge machining is a technique which can be employed for machining of heat treated and finished tool materials without loss of their important properties. Alternative application of special cutting blades needs new geometric features likes holes to be created for holding and fittings. Being a new application study on machining parameters for optimization is needed for such work materials. The analysis and optimization of MRR became finished the usage of Taguchi approach to locate the contribution of various process parameters on MRR. The principle results from the present experimental work are summarized because the maximum prompted parameter with admire to MRR. The percentage contribution of the current, pulse on time and servo voltage are found to be 64.29%, 25.78% and 4.04% respectively on material removal rate in fractional DOE technique, whilst in full factorial DOE method, the share contributions are 62.05%, 26.39% and 1.09% respectively. The finest optimal value of current, pulse on time and servo voltage for maximizing MRR is found as 12 A, 60 **µ**s and 3 V respectively.

Keywords: MRR; Taguchi Method; ANOVA Analysis; SK2MCr4; Copper.

1. Introduction

Electric Discharge Machining (EDM) is an electrically thermal nonconventional machining process, wherein electrical energy is used to generate an electrical spark and elimination of material mainly because of the thermal energy of the spark. EDM is a modern machine, which can be used for drilling, milling, grinding and other conventional machining operations. The EDM is now one of the most considerable accepted technologies for metal machining and the complicated 3D shapes can be machined by way of simple size tool electrode. In the manufacturing enterprise, EDM is typically used for the production of mold and die components. The EDM is used because the ability of the machining manner is very accurate in creating complex or simple shapes within parts and assemblies. For the reason that inception of EDM, lots of theoretical and experimental works were executed to find the fundamental approaches involved. There is no direct physical contact between the electrodes; consequently, no mechanical stresses are developed on the work piece. The precise manufacturing parameters of the process are the material removal rate (MRR) and electrode wear rate [1, 2]. EDM techniques have developed in many areas. Trends on activities done by using researchers depend on the industry requirement, available material and contemporary manufacturing technologies.

2. Need of Optimization in EDM

Optimization is used for performing in order to obtain the best (optimum) desired result under the given specified experimental conditions. The most significant objective is either to minimize the effort/time required or maximize the desired results/benefits of the product or advantage in term of economics. In EDM, traditional method of choice of parameters combinations does not provide satisfactory or desired results. Optimization of process parameters of EDM has been handled as single objective optimization process and multi-objective optimization problem. Design of experiment (DOE) technique like Taguchi method is used to lessen the experimental runs in real way. According to this, it is best method for optimization of process parameters- pulse on time, pulse off time, current, servo voltage and many others of EDM [3].

Die-sink EDM is used to machine extremely hard materials, which are might be tough to system inclusive to machine such as tool steels, alloys, tungsten carbides and forth so. [4-6]. Proper choice of EDM parameters such as discharge current, pulse on time, pulse off time, discharge voltage, servo voltage, voltage gap, fluid pressure, dielectric fluid, duty cycle, etc. [7-11]. From the literature overview it can be visible that copper is the most broadly used as EDM electrode for its excellent electric and thermal resistance (ASM, 1990). A copper electrode has better EDM wear resistance than brass and graphite electrodes. It is the best material for the removal of material along with machining parameters such as the discharge current, pulse on time and servo voltage [12-16]. SK2MCr4, which is a widely used material within the manufacturing of tool steel blades, cutting tools and so on. From the numerous literature surveys, it is far understood that a whole lot work has not been executed for the machining of machining of SK2MCr4 carbon tool steel material [17, 18]. Design of experiment (DOE) technique like Taguchi method is used to lessen the experimental runs in actual manner. Analysis of variance (ANOVA), correlation and regression is employed to study the performance traits at different condition according to DOE. In step with these, it is best method for optimization of selected process [19-21].

In the present work experimental study is carried out for electric discharge machining of SK2MCr4 carbon tool steel material. The evaluation is completed with the aid of using design of experiment (DOE) and analysis of variance (ANOVA) strategies for most advantageous material removal rate.

3. Materials and Methods

The present work through the complete set of experimentation is carried out on an Electric Discharge Machine, ZNC-250 (die-sinking type) available in the workshop of the Mechanical Department, CTAE as shown in Fig. 1 is used. ZNC-250 has the provisions of programming in the Z-vertical axis-control and manually operating X and Y axes. Divyol spark errossion oil-25 (specific gravity= 0.750 @ 29.5°C, Min.) was used as dielectric fluid.

Fig.1. Experimental set-up for EDM.

3.1 Control parameters and their levels

First begin with five levels and three parameters: contemporary (i), pulse on time (T_{on}) and servo voltage (v) are varied as a substitute at the same time as pulse off time (T_{off}) as a steady. At some point of the experiments material removal rate has been referred to down. After dropping the redundant statistics L9 orthogonal array turned into fashioned with three parameters and three levels given in Table 1.

Table 1: Experimental levels of independent parameter

S. No.	Symbols	Independent parameters	No. of levels	Level 1	Level 2	Level 3
1.	Ton	Pulse on time	3	20	60	100
2.	V	Servo Voltage	3	3	4	6
3.	I	Current	3	4	8	12

4. Results and discussion

The fractional DOE approach is primarily based on the Taguchi DOE. Experimental run table generated the use of orthogonal array and now after performing the experimentation as proposed in the Fig. 2, the consequences of optimum material removal rate are collected as shown in Fig. 3 for current, pulse on time & servo voltage are 12 A, 60 **µ**s & 3 V. The Fig. 4 additionally indicates the value of S/N ratio obtained by Minitab-17 software using ‘The larger is the better’ technique [22, 23].

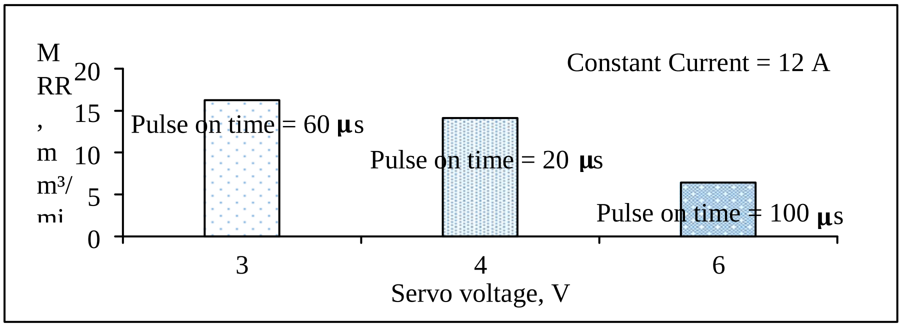

Fig. 2. Optimum value of I, T_{on} & V of MRR

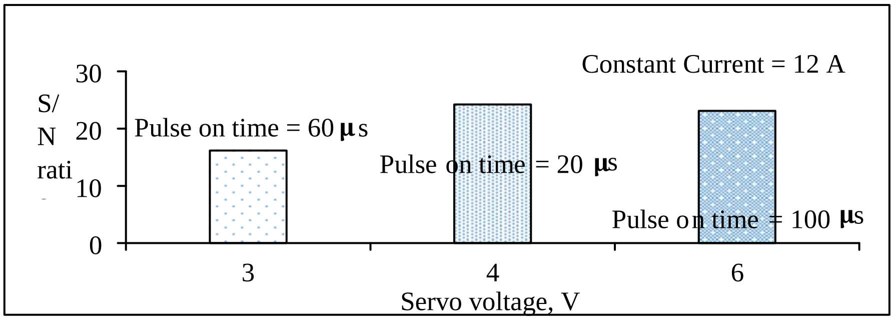

Fig. 3. Optimum value of I, T_{on}, & V of S/N ratio

4.1 Main effect plots for MRR

It can be evaluated from the main effect plots of means that to reap the optimized value of material removal rate, the current must be set to its maximum value (12A), pulse on time and servo voltage i.e. 60 **µ**s and 3 V respectively as because of optimization, largest MRR must be employed in Table 2 and Fig. 4.

Table 2: Rank Table for MRR with process parameters

Level	**I**	**Ton**	**V**
1	3.266	4.759	8.867
2	8.051	10.399	8.129
3	12.319	8.477	6.639
Delta	9.052	5.640	2.228
Rank	1	2	3

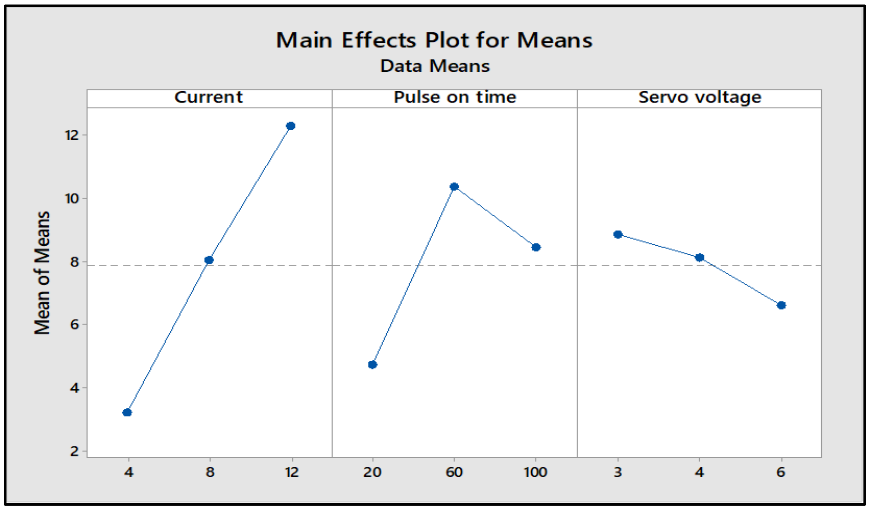

Fig. 4: Main effect plots of different parameters on MRR

4.2 Analysis of S/N Ratio for MRR

Fig. 5 suggests the primary effect plots of S/N ratio of different parameters terms such as current, pulse on time and servo voltage on MRR. Here we select the options for higher or 'larger is better (LB)'. It is observed from this Fig. 5 and Table 2 that MRR have highest S/N ratio for current at the level 3, but for the case of T_{on} (µs) it is having highest for the second level and for servo voltage at first level. Similarly MRR have optimal value for current (I) at 4 A, pulse on time (T_{on}) at 60 µs and servo voltage at 3 V while pulse off time as a constant at 6 µs.

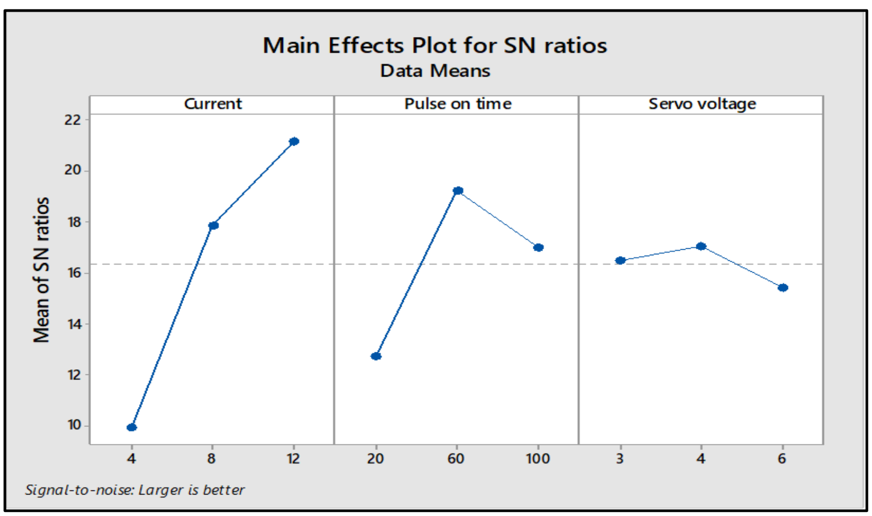

Fig. 5. S/N ratio plots of different parameters effects on MRR

4.3 Analysis of Variance (ANOVA) For MRR

According to the Analysis of variance, the percentage contribution of the current is 64.29%, pulse on time is 25.78% and servo voltage is 4.04% on the material removal rate, which is in a similar order as shown in the rank Table 2. The R-sq value represents the significance of the experimental work which is 94.11%. In ANOVA, “F” value also indicates more and less affecting parameter. The below Fig. 6 indicate that the current (I), have the highest affecting parameters on MRR which is 64.29% contribution among the all.

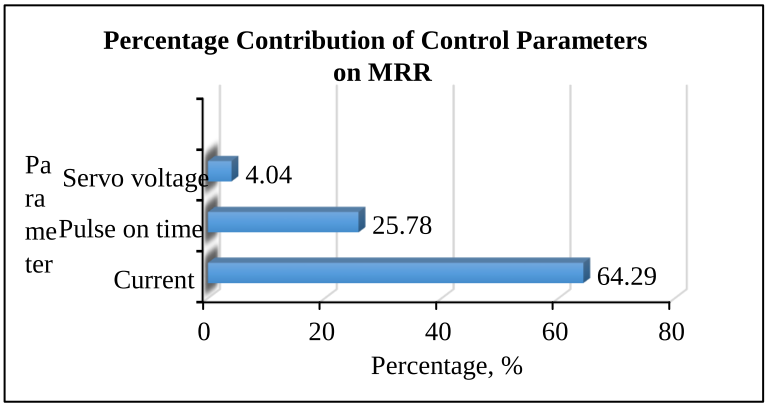

Fig. 6. Contribution ratio of each parameter to MRR

4.4 Full Factorial design of approach: After dropping the redundant data

In line with the approach of the present experimental work, this is a method after the dropping the redundant data with three one-of-a-kind parameters and three levels of the experimentation in which a full factorial experimental runs are created as in (Fig. 7, 8, 9 & 10).

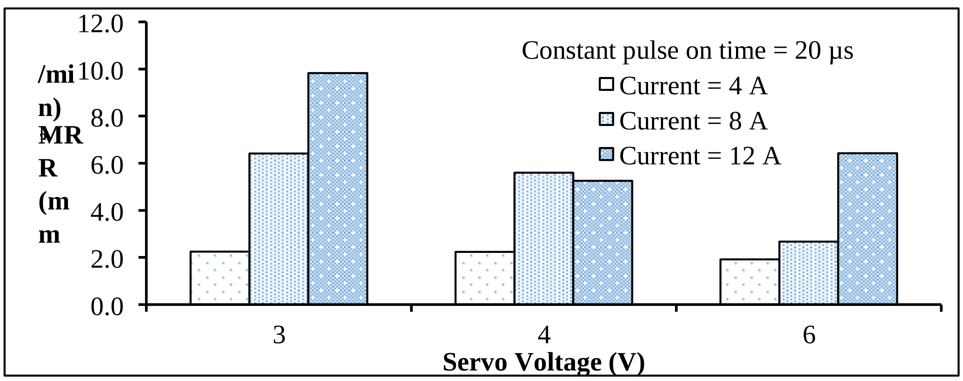

Fig. 7. Effect of V, & I on MRR at constant $T_{on\,=}$ 20 **μ**s

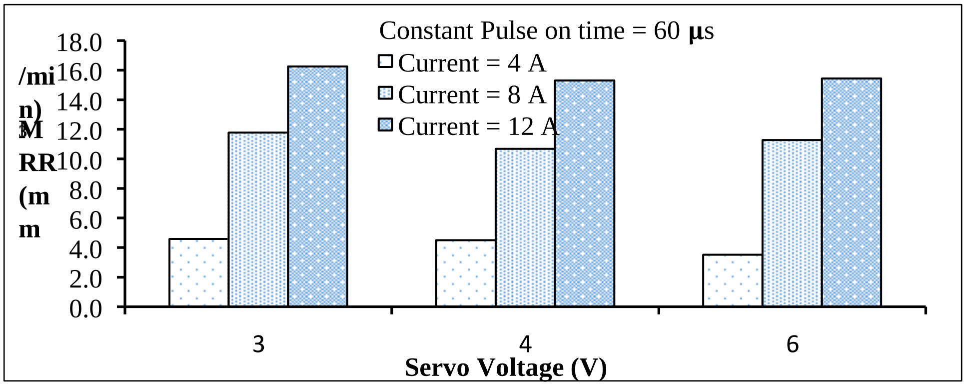

Fig. 8. Effect of V & I on MRR at constant T_{on}= 60 μs

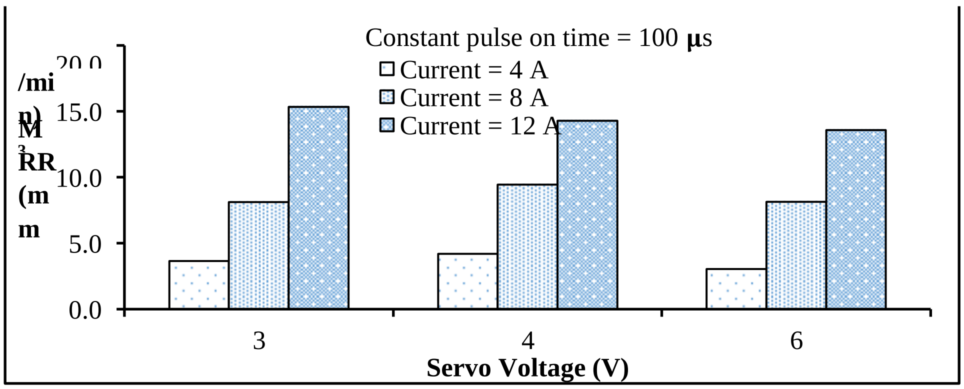

Fig. 9. Effect of V & I on MRR at constant T_{on}=100 μs

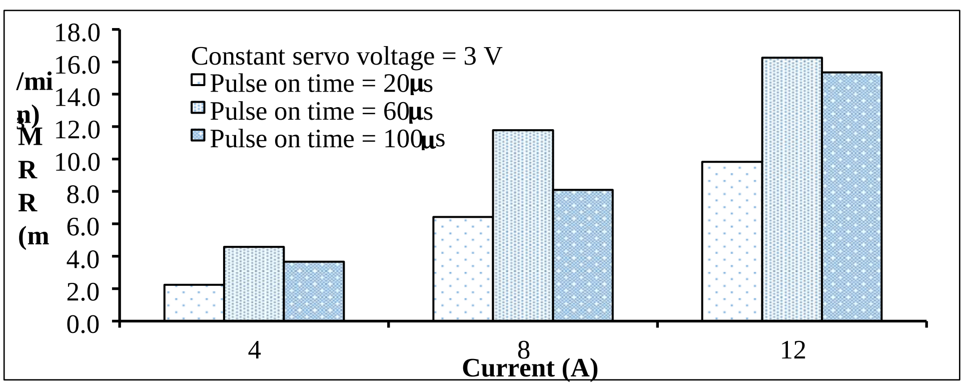

Fig. 10. Effect of I & T_{on} on MRR at constant V=3V

From the Analysis of variance, the contribution of the I is 62.05%, T_{on} is 26.39% and V is 1.09% on material removal rate. R-sq value represents the significance of the experimental work which is 89.51%.

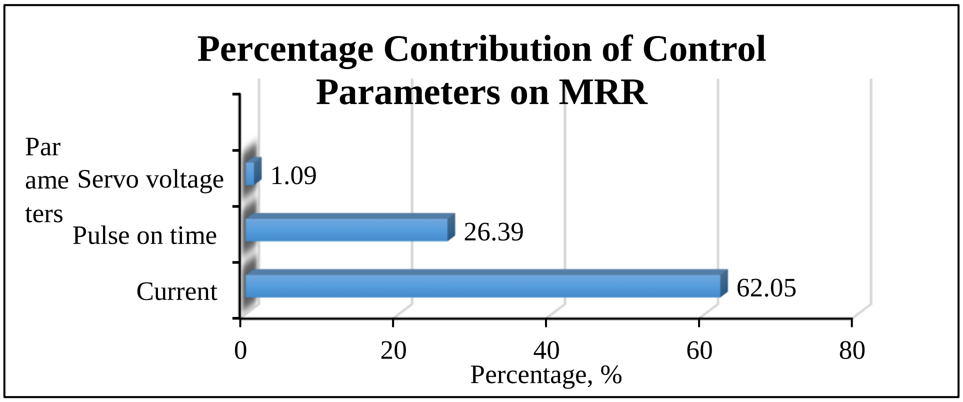

Fig. 11. Percentage Contribution of parameters on MRR

5. Conclusions

The present analytical study has been completed in order to acquisition, the optimal parameters to maximize the Material Removal Rate.

- Material removal rate (MRR) increases linearly with appreciate to increase in current from 4 A to 12 A. The current value is restricted to 12 A due to safety reasons and occurrence of firing in dielectric fluid.
- MRR increases initially with increase in pulse on time from 20 **µ**s to 60 **µ**s, however it decreases later on with further increase in pulse on time from 60 **µ**s to 100 **µ**s.
- The effects of servo voltage on MRR are having variable trend. The MRR to begin with increases and then decreases with increase in the servo voltage from 3 V to 7 V. In aggregate with current and pulse on time, the servo voltage of 3 V is preferable.
- Amongst the control parameters, the MRR is strongly affected by current, even as the pulse on time and servo voltage have lesser effect on MRR.
- L9 Orthogonal array was used.
- The value of max. MRR is 16.24 mm^3/min and the combination of parameter values as I, T_{on} & V are 12 A, 60 **µ**s and 3 V.
- The rate of error by way of Fractional DOE was found to be 5.89% that is lower in contrast to full factorial DOE which become observed to be 10.49%.

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