DOE based investigation to study the effect of various parameters, including electrical conductivity and thermal conductivity of electrodes, on MRR & Surface finish in EDM process

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Abstract

This paper is the outcome of research work conducted on EN-8 material by Electric Discharge Machine through Response-Surface Methodology approach by selecting 3-parameters discharge current(I), pulse-on time (T_{on}) and pulse-off time (T_{off}) along with effect of electrical-conductivity of 3-tools copper, aluminium and brass. Material Removal Rate (MRR), and spacing roughness parameter (R_a) Responses.

Keywords— Electric Discharge Machine, Response Surface Methodology, electrical conductivity, material removal rate, surface roughness etc)

1. Introduction

Today's manufacturing industry is facing challenges from advanced difficult-to-machine materials (super alloys, ceramics and composites), stringent design requirements (high precision, complex shapes and high surface quality) and machining costs. Advanced materials play an increasingly important role in modern manufacturing industries, especially in aircraft, automobile, tool, die and mould making industries. The use of Electrical Discharge Machining (EDM) in the production of forming tools to produce plastics mouldings, die castings, forging dies etc., has been firmly established in recent years. Development of the process has produced significant refinements in operating technique, productivity and accuracy, while widening the versatility of the process. Advanced materials play an increasingly important role in modern manufacturing industries, especially in aircraft, automobile, tool, die and mould making industries. In conventional machining process it involves the concept of removal of material by an edged tool that involves plastic deformation process and leads to formation of chips. This is a known concept to man from much number of years. EDM continues to grow, therefore, as a major production tool in most tools making companies, machining with equal ease hardened or annealed steel. The greatly-improved thermal, chemical and mechanical properties of material (such as improved strength, heat resistance, wear resistance and corrosion resistance), while having yielded enormous economic benefits to manufacturing industries through improved product performance and product design, are making traditional machining processes unable to machine them or unable to machine them economically.[1] Electrical discharge machining is a non-traditional manufacturing process. EDM is the method used for the machining of harder materials which have complicated profiles. They provide good precision. In present days the research work which is conducted in Electric discharge machining is aimed at machining at a faster rate and also it must lead to good surface characteristics. The present work has been carried out by identifying the influence of three parameters discharge current (I), pulse-on time (T_{on}) and pulse-off time (T_{off}),along with the effect of electrical conductivity of three tools viz. copper, aluminium and brass, that are considered pertinent parameters in Electrical Discharge Machining of this material. The responses obtained are Material Removal Rate (MRR), and one spacing roughness parameter such as R_a. Study is carried out using design of experiments (DOE). Central-Composite experimental design (CCD) is used to generate the design matrix with the three parameters. On analysis it is concluded that the MRR and Surface roughness both are affected by the three parameters chosen in combination with the electrical conductivities of the tools.

2. Material and Methodology

In this work EDM process is used as machining process and type of machines used are Electric discharge machine (EDM) and Taylor Hobson SurtronicS-100 series surface roughness measuring instruments. The material for work is selected as EN-8 steel and 3 different tools are used for the machining. These are Aluminium, Copper and Brass. Methodology generally gives a foundation to analyses of the work done. It's a kind of a scientific process using theoretical concepts and has particular set of methods that are used always by the leading researchers. The methodology which is used in this project work is this. In this outcome-responses are influenced by different variable. Main aim of Response-Surface is to find the correlation between the responses obtained and the variables like current, pulse on and off. By using RSM the response obtained can also be modified and optimized. CCD is one of the experimental design methods which is basically used to fit the second-order model and is most popular effective class which fits the 2^{nd}order model. This design basically consists of 2^k factorial with n_F runs, 2^k star runs, centre points n_C. In CCD 2^k has been used.

3. Tabulations and Result

3.a. Machining parameters, their levels and ranges available on machine.

	Machining Parameters	Uncoded Values	Coded Values	Levels			Ranges
				Low (-1)	Mid (0)	High (+1)	
1	Current	C	M_1	8	12	16	1 to 20A
2	Pulse on time	T_{on}	M_2	30	40	50	0 to 99µs
3	Pulse off time	T_{off}	M_3	3	5	7	0 to 9µs
4	Electrical Conductivity						

3.b. Tabulation of Material Removal Rate

CURRENT (A)	Pulse on (μs)	Pulse of ((μs))	MRR(Al) (gm/min)	MRR (Cu) (gm/min)	MRR (Br) (gm/min)	S R of CU (μm)	S R of BR (μm)	S R of Al (μm)
8	50	5	0.07	0.17	0.13	10.2	9.3	8.2
8	50	7	0.32	0.28	0.2	8.7	6.5	8.1
8	30	7	0.28	0.25	0.24	11.9	8.7	12.6
8	30	3	0.18	0.17	0.16	9.9	5.6	8.6
8	40	5	0.22	0.17	0.14	11.9	6.5	8.3
12	50	3	0.27	0.21	0.19	12.4	10.6	10.3
12	40	5	0.16	0.24	0.16	9.3	9	8.4
12	40	5	0.34	0.26	0.2	12.5	9.7	11.6
12	40	7	0.24	0.22	0.15	11.2	7.8	10.9
12	40	5	0.19	0.23	0.13	10.2	9.5	12
12	50	7	0.1	0.15	0.07	13.6	10.4	10.3
12	40	5	0.24	0.2	0.14	11.9	9.5	14.3
12	30	3	0.11	0.12	0.05	9.2	6.6	9.1
12	50	3	0.18	0.11	0.08	13.1	9.3	7.5
12	40	3	0.18	0.24	0.11	11.7	7.7	13.3
16	30	7	0.12	0.1	0.07	13.2	10	11.5
16	30	5	0.17	0.16	0.13	9.9	4.3	12.7
16	40	5	0.23	0.19	0.15	9.4	8.6	8.5
16	40	5	0.17	0.13	0.07	15.5	10.7	12.4
16	40	5	0.25	0.2	0.15	12.2	11.1	11.3

3.c. Graph of Current Vs MRR by using all three tools.

1

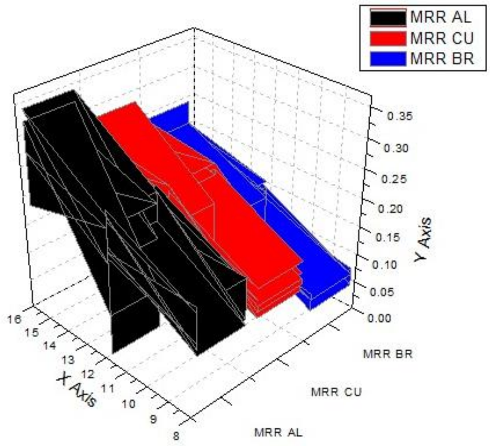

Fig: 3.1: Graph of Current Vs MRR by using all three tools.

The figure explains increase in removal of material is influenced by discharge current. This trend is observed because as the current increases the intensity of spark generation rises and more ionization leads to faster removal of material. Also the increase in the value of material removal rate is influenced by their thermal and electrical conductivities of the tool. Hence for Brass the material removal is the least as the thermal conductivity value is 115 W/m-K, and then in the order is Aluminum and the Material removal rate is highest in Copper having the higher thermal conductivity value of 401 W/ m-K.

3.d. Graph of Pulse on Vs MRR by using all three tools.

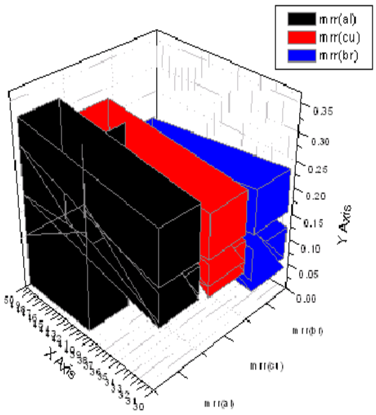

Fig: 3.2: Graph of Pulse on Vs MRR by using all three tools.

The figure shows that, the value of MRR increases as the pulse on value increases. This trend is observed because as the pulse on increases from 30 μs to 50 μs the continuous sparks generated produces faster ionization which leads to faster removal of material. Also the increase in the value of material removal rate is influenced by their thermal and electrical conductivities of the tool. Hence for Brass the material removal is the least as the thermal conductivity value is 115 W/ m-K, and then in the order is Aluminum and the Material removal rate is highest in Copper having the higher thermal conductivity value of 401 W/ m-K

3.e. Graph of Current Vs Surface Roughness of EN-8 by using all three tools.

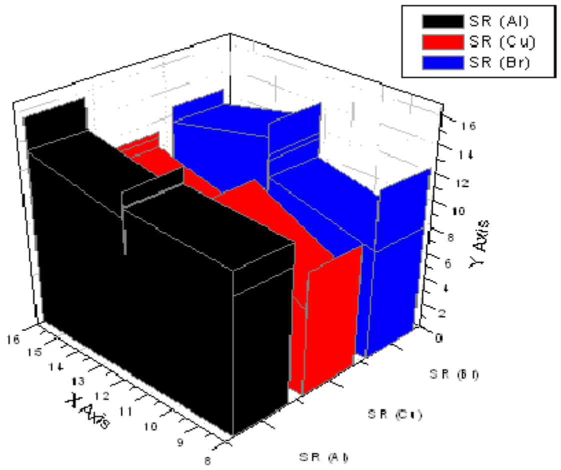

Fig: 3.3: Graph of Current Vs Surface Roughness of EN-8 by using all three tools.

The figure above shows that the effect of current on Ra. This graphical result shows that, Ra value increases with increasing current at a faster rate for Aluminum. For aluminum the current has maximum response on the roughness of surface. The surface finish obtained depends on the tool electrode which has particular electrical conductivity value. The effect of current on the surface finish of brass is the medium having a value of electrical conductivity as $16.9*10^7$ S/m. The least affected surface finish is for the copper having the electrical conductivity value of $5.95 *10^7$ S/m.

3.f. Graph of Pulse on Vs Surface Roughness of EN-8 by using all three tools.

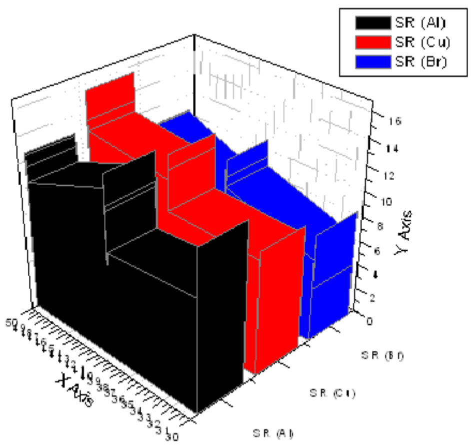

Fig: 3.4: Graph of Pulse on Vs Surface Roughness of EN-8 by using all three tools.

The figure above shows the effect of pulse on time on Ra. The graph shows a linear relationship from value of 30 to 40 µs but for the further values it shows a constant trend. However the roughness is also affected by the values of pulse on time as well as the electrical and thermal conductivities of the different tools used for machining EN-8. As per the analysis the roughness of the surface of EN-8 is most affected by Brass tool, and then it's affected medially by Copper tool and the least affected by Aluminium tool.

3.g. Graph of Pulse off Vs Surface Roughness of EN-8 by using all three tools.

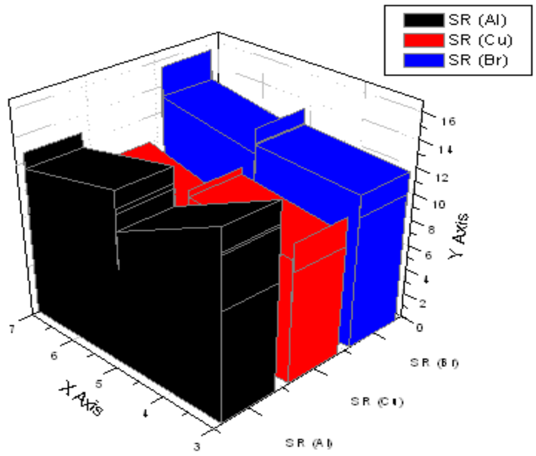

Fig: 3.5. Graph of Pulse off Vs Surface Roughness of EN-8 by using all three tools.

The figure above shows the effect of pulse off time on Ra. The graph shows almost a constant relationship for the entire range of pulse off.. However the roughness is also affected by the Ra values by pulse off time as well as the electrical and thermal conductivities of the different tools used for machining EN-8. As per the analysis the roughness of the surface of EN-8 is most affected by the pulse off time of Copper tool, and then it's affected medially by Brass tool and the least affected by Aluminium tool.

Conclusion

Conclusion is to efficiently machine EN-8 Steel and increase the productivity we should use Aluminium as the tool to obtain maximum MRR having lowest electrical conductivity value $3.54*10^{-2}$ S/m. To reduce surface roughness we should use brass as the electrode material having highest electrical conductivity value of 16.9 $*10^{7}$ S/m.

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