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Electro-discharge machining of die tool steel for the recommendation of the suitable electrode by response surface methodology

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ABSTRACT

Electrical discharge machining (EDM) is one of the important non-traditional machining processes and it is widely accepted as a standard machining process in the manufacture of forming tools to produce moulds and dies. Since its introduction to manufacturing industry in the late 1940s, EDM became a well-known machining method. The method is based on removing material from a work piece by means of a series of repeated electrical discharges, produced by electric pulse generators at short intervals, between an electrode (tool) and a part being machined in the dielectric fluid medium. in the present study, the performance parameters of EDM process are to be evaluated to achieve the feasibility in machining of H13 tool steel it has wide application in the Hot punches and dies for blanking, forging, swaging and bending, Nozzles for aluminium, tin, and lead die casting, Hot extrusion dies for aluminium, cores ejector pins, inserts, Hot shear blades. here the machining is done by EDM using three different electrodes like copper, brass, and bronze and investigates which type of electrode give a better result for increasing MRR, and decrease SR.

The experiments planned, conducted and analyzed using Response surface methodology and it is found that the MRR and SR are mainly influenced by which EDM machining parameter.

Keyword: *MRR, SR, EDM, RSM etc.*

1. INTRODUCTION

Electrical Discharge Machining, commonly known as EDM is a non-conventional machining method used to remove material from a number of repetitive electrical discharges of small duration and high current density between the work piece and the tool. EDM is an important and cost-effective method of machining extremely tough and brittle electrically conductive materials. In EDM, since there is no direct contact between the work piece and the electrode, hence there are no mechanical forces existing between them. Any type of conductive material can be machined using EDM irrespective of the hardness or toughness of the material. EDM has been substituting traditional machining operations.

Now today EDM is a popular machining operation in several manufacturing productions all over the world's countries. Most of the traditional machining process such as drilling, grinding, and milling, etc. are failed to machine geometrically complex or difficult shape and size. Those materials are easily machined by EDM non-traditional machining process which leads to broadly utilized as die in addition to mould assembly industries, making aeronautical parts and nuclear instruments at the minimum cost. Electric Discharge Machining has also established its presence touched on the different subject areas such as make use of sporting things, medicinal and clinical instruments as well as motorized research and development regions.

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2. PRINCIPLE OF EDM

In this process, the material is removed from the work piece due to erosion caused by rapidly recurring electrical spark discharge between the work piece and the tool electrode. There is a small gap between the tool and the work piece. The work piece and tool both are submerged in dielectric fluid, commonly used are EDM oil deionized water, and kerosene.

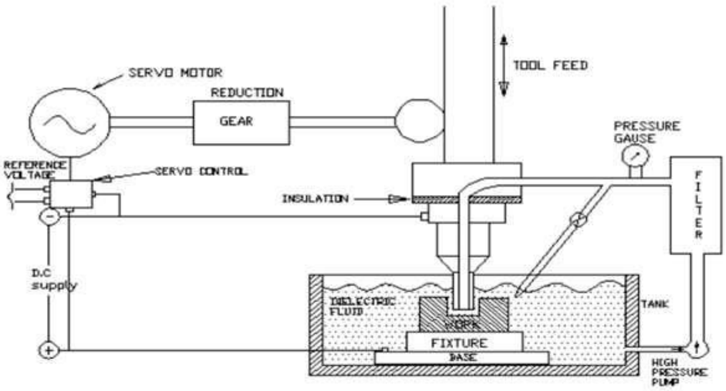

Fig.1.1 Principle of EDM

3. CLASSIFICATION OF EDM

Basically, there are two types of EDM: Die-sinking EDM and Wire-cut EDM

Die-Sinking EDM: Die-sinking EDM, also known as Volume EDM or cavity type EDM consists of an electrode and a work piece which is submerged in an insulating fluid such as oil or other dielectric fluids.

Wire-cut EDM: Wire-cut EDM, also known as Spark EDM is mostly used when low residual stresses are required, as it does not needs high cutting forces for removal of material.

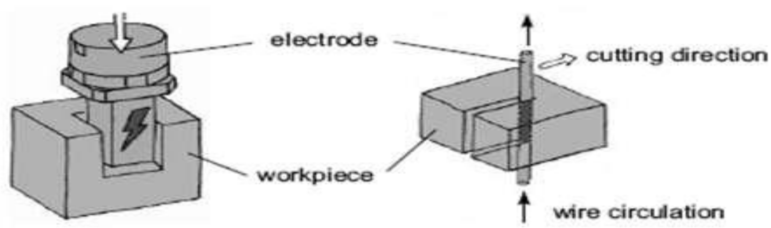

Fig.1.2.die sinking EDM & wire cut EDM

4. IMPORTANT PARAMETER OF EDM

- **Spark time or (pulse on time T_{on}):** It is the duration of time expressed in micro seconds in which the peak current is ready to flow in every cycle. This is the time in which energy removes the metallic particles from the work piece.
- **-time (pause time or T_{OFF}):** It is the duration of time (µs) between the sparks (that is to say, on-time). This time allows the molten material to solidify and to be washed out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable.
- **Arc gap (or gap):** It is the distance between the electrode and the part during the process of EDM. It may be called as a spark gap.
- **Duty cycle:** It is a percentage of the on-time relative to the total cycle time. This parameter is calculated by dividing the on-time by the total cycle time (on-time plus off-time). The result is multiplied by 100 for the percentage of efficiency or the so-called duty cycle.
- **Intensity (I):** It points out the different levels of power that can be Supplied by the generator of the EDM machine.(I) represents The mean value of the discharge current intensity.
- **Discharge current (Ip):** Current is measured in ampere (A) allow to per cycle. The discharge current is responsible directly for material removal. It contains energy for melting and evaporation.
- **Voltage (v):** It is a potential that can be measured by volt it is also affected the material removal rate and allowed to per cycle.

5. CHARACTERISTIC OF EDM

Mechanism of process	Controlled erosion (melting and evaporation) through a series of electric spark
Spark gap	0.010- 0.500 mm
Spark frequency	200 – 500 kHz
Peak voltage across the gap	30- 250 V
Metal removal rate (max.)	5000 mm3/min
Specific power consumption	2-10 W/mm3/min
Dielectric fluid	EDM oil, Kerosene liquid paraffin, silicon oil, de-ionized water etc.
Tool material	Copper, Brass, graphite, Ag-W alloys, Cu-W alloys.
MRR/TWR	0.1-10
Materials that can be machined	All conducting metals and alloys.
Shapes	Micro-holes, narrow slots, blind cavities
Limitations	High specific energy consumption, non-conducting materials can't be machined.

6. LITERATURE REVIEW

In this chapter, some selected research papers have been discussed related to Electrical Discharge Machining. The studies carried out in these papers are mainly concerned with the EDM parameters such as current, voltage, pulse on time, duty cycle, etc. and selected specific electrode for machining specific material and also shows that how these affect the machining characteristics like MRR, SR, TWR etc.

Sr no	TITLE	AUTHOR	YEAR OF PUB & JOURNAL NAME	WORK PIECE & ELECTRODE	OBJECTIVE	CONCLUSION
1	Experimental Studies for Material Removal Rate on AISI D2 Steel using Electrical Discharge Machining	Praveen Kumar Singh, Dinesh Kumar Rao	2017 (International Journal of Emerging Technologies (IJET)	AISI d2 steel. with copper and brass electrode	The objective of the author is to find the effect of copper and brass electrode on MRR for AISI D2 tool steel by using die-sinker EDM	It was found that the MRR was maximum for the copper electrode. In case of increasing the value of current Copper gives better MRR than Brass. In case of increasing the value of gap voltage for both Brass and Copper, MRR will decrease
2	effect of tool material on surface roughness in electrical discharge machining.	Himanshu Payal, Sachin Mahesh-wari	2016 (Journal of production engineering) (JPE)	H11 tool steel with cylindrical shaped copper, graphite and copper tungsten electrode.	to find the effect of pulse-on-time (Ton) on surface roughness during EDM of H11 tool steel by taking three different tool electrode materials.	On the basis of experimental results, it is concluded that.The results demonstrate that Copper-tungsten electrode offers the best surface finish followed by graphite and copper electrode in EDM of H11 Tool steel.

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3	Experimental Investigation to Optimize Process Parameters Using Copper Electrodes in Die Sinking EDM Process Machining P20 Steel	Seepala Siva Kiran	2016 (international Journal & magazine of engineering, Technology, management, and research) (IJMETMR)	P 20 steel with round shaped copper and the hexagonally shaped copper electrode.	The objective of the author is that by using round and hexagonal copper electrode with sinker EDM to investigate the effect of various process parameter on MRR, SR, TWR, and P20 steel is work piece material.	The following conclusions can be made the hexagonal electrode give better MRR with increase pulse on off time and current. Round electrode gives less TWR and SR .its increase with increase pulse on pulse off time and current as a process parameter.
4	Experimental investigations into EDM behaviors of EN41b using copper and brass rotary tubular electrode	Nivin Vincent Arun. B. Kumar	2016 (Procediya technology)	EN41b nitride steel With rotary tubular shaped copper and brass electrode	Taguchi's signal-to-noise ratio and grey relational analysis were applied in this work to improve the multi-response characteristics such as MRR and EWR on En41b steel and the optimum combination of control parameters such as current, gap voltage, pulse ON time and pulse OFF time were obtained.	He concluded that if we use copper electrode and gray relational analysis use to determine the optimum combination of the control parameter. copper electrode gives best MRR and lows EWR. also brass give high MRR and low EWR but it requires high gap voltage, pulse on time, off time and current remain same in both the case.
5	Analysis of EDM parameters influencing on material removal rate and surface roughness of high-speed steel.	Pradeep Kumar	2016 (International Journal of scientific and research publication) (IJSRP)	HIGH-SPEED STEEL with the cylindrically shaped copper electrode.	The objective of the author analyzes the behavior of high-speed steel by using EDM with various parameters. Apply design of experiment (DOE) techniques have been used in order to obtain mathematical models to predict the most influential factors by using a small number of experiments.	The following conclusions have been made from this experiment: Silicon powder mixed EDM oil as a dielectric medium gives more MRR and better surface finish as compared to EDM oil without silicon powder.The high value of current and pulse on time is most affected surface roughness.MRR also affected if increase value of current and pulse on time.

6	An Experimental Study of Material Removal Rate and Electrode Wear Rate of High Carbon-High Chromium Steel(AISI D3) In EDM Process Using Copper Tool Electrode.	Avdesh Chandra Dixit, amit kumar.	2015 (an international journal of innovative research in advanced engineering) (IJIRAE)	AISID3(High carbon high chromium steel with copper electrode	By using taguchi method to find out the influence of EDM parameter on MRR, EWR while machining of AISI D3 Material.	It is found that the MRR is mainly influenced by (Ip); where as other factors have very less effect on material removal rate. Electrode wear rate is mainly influenced by peak current (Ip) and pulse on time (Ton), fluid pressure has no effect on electrode wear rate.
7	Modeling and analysis of process parameter of die sinking EDM on EN31 tool steel.	A.jyoti swarup, raj ballav	2014 (an international journal of mechanical and production engineering) (IJMPE)	EN 31 steel with copper electrode	By proper controlling on the process parameters, we can reach a point at which material removal rate(MRR) can be maximum and electrode wear rate(EWR) can be minimum.	By selecting various process parameter discharge current, voltage and pulse on time at three different levels are taken. A regression model is developed for each output response viz. MRR and EWR. The ANOVA table depicts that most influence of input parameter.
8	Parametric Analysis of Material removal rate and surface roughness of Electro Discharge Machining on EN 9	Hitesh b. Prajapati, hiren r. Prajapati	2013 (an international journal of research in modern engineering and emerging technology) (IJRMEET).	EN 9 steel with three diff. electrode like copper, graphite, and brass.	by using three important process parameter like a pulse on time pulse off time and current and analysis its effect on MRR SR of electro discharge machining on EN9.by using three different electrodes like copper, graphite, and brass.	He concluded that the ANOVA shows that the peak current and pulse on time are more influence to MRR and SR also effected by current and pulse on time. brass electrode gives poor MRR but the better surface finish. Graphite electrode gives highest MRR among three electrodes but it gives higher electrode wear ratio. copper electrode gives poor surface finishing among three electrodes.
9	Investigation on the Effect Of Process Parameters For Machining Of EN31 (Air Hardened Steel) By EDM.	N. Arun Kumar. H. Shareef Abdur Rawoof.	2012 (an international journal of engineering research and applications) (IJERA)	EN 31 Air hardened steel with three diff. Electrode like Copper, aluminum and EN-24.	The objective of author is to investigate influence of various process parameter on machining EN31 is carry out at different process parameter level and there affect on MRR, TWR, SR taper.	he concluded that if Machining is done with copper electrode it gives less tool wear and also give high material removal rate, EN24electrode give very less SR. Taper value is less when copper is used as tool electrode.

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10	Examination of machining parameters on surface roughness in EDM of tool steel.	M. Kiyak , O. Cakır	2007 (Journal of materials processing technology) (JMPT).	40CrMnNiMo8 64 tool steel with the cylindrically shaped copper electrode.	to study of the influences of EDM parameters on surface roughness for machining of40CrMnNiMo864 tool steel (AISI P20) which is widely used in the production of plastic mould and die.	The selected EDM parameters were pulsed current, pulse time and pulse pause time. It was observed that surface roughness of work piece and electrode were influenced by pulse current and pulse on time, higher values of these parameters increased surface roughness. Lower current, lower pulse time and relatively higher pulse pause time produced a better surface finish
11	Parametric Optimization for MRR on H-13 Die Tool Steel on EDM using Taguchi Techniques.	Pardeep Narwal, Jai Singh	2017 International Journal of Engineering and Management Research (IJEMR).	H 13 tool steel with copper electrode	purpose of this paper to The works on h13 tool steel shows the effect of various process parameters like peak current, Pulse on Time, and Feed rate on Material Removal Rate using EDM Drilling. For the response variables, Taguchi technique is used.	According to this research paper, we give the results that following parameters such as current [55.78%], Pulse on time[26.40%] and feed rate [7.75%] which are influencing metal removing rate(MRR). MRR is influenced by current, Pulse on time and feed rate respectively. We know that MRR which is a volumetric loss of H-13 die tool steel is highly influenced by the current.
12	Analysis of EDM Process Parameters Using Response Surface Methodology And Grey Relational Analysis.	Vishwajeet Kumar, Prof. Rakesh.	2016 International journal of scientific research and education (IJSRE)	EN-31 tool steel with copper electrode	In this study, pulse on time, duty cycle, discharge current and gap voltage are chosen as machining parameters for performance characteristics material removal rate (MRR) and surface roughness (SR). The experiments were designed and performed on the basis of response surface methodology (RSM).	The experiments have been performed by using RSM. The discharge current is the most significant factor for material removal rate as well as surface roughness. The increase in discharge current produces a stronger spark. It generates higher temperature, which causes more material to melt and erode from the work piece. Therefore, MRR and SR increase with an increase in discharge current. The material removal rate decreases with rising in gap voltage. It has also a significant effect on of gap voltage is lesser than discharge current.

7. RESEARCH GAP

- According to the specific application of H13 tool steel such as ejector pin, inserts, cores, forging die extrusion die and hot shear blade manufacture so we have to select H13 tool steel as work piece material.
- H13 is hardening tool steel which has excellent high tensile properties, high wear resistance, and adequate toughness and resists tempering at high operating temperature.
- From the above research paper, it is observed that work has been done on H13 tool steel with only copper and graphite electrode
- So the objective of the present work is to investigate the effect of three different electrode like copper, brass, and bronze on H13 tool steel while machining will do by EDM and also show the influence of different electrode on process parameter and find which response parameter is most affected by in out of this three input parameter.
- The input parameter has been selected pulse on time, pulse off time and discharge current.

8. METHODOLOGY

The response surface method is the best method to optimizing output variable. A central composite design is the most commonly used response surface designed experiment. Central composite designs are a factorial or fractional factorial design with center points, augmented with a group of axial points (also called star points) that let you estimate curvature. You can use a central composite design to:

- Efficiently estimate first- and second-order terms.
- Model a response variable with curvature by adding a centre and axial points to a previously-done factorial design.
- Central composite designs are especially useful in sequential experiments because you can often build on previous factorial experiments by adding axial and center points.
- The **central composite design** and three-level full factorial **design** created significantly better models comparing to the other methods.

By using CCD design we have to generate a graphical analysis of output parameter slike MRR, SR, and EWR according to their level, by using MINITAB software. The response regression analysis will be done by central composite design.

9. EXPERIMENTAL SETUP

- In this research study, EDM characteristic such as MRR, EWR, and SR is considered as the output responses for EDM Machining. Experimental set up is as under

Fig 1.3 experimental setup

- During the EDM process, both the work piece and tool electrode is eroded. MRR is calculated as the work piece weight loss over the machining time. Simultaneously EWR is expressed as the ratio of tool weight loss to the machining time and wear ratio is expressed as the ratio of decrease in length of the electrode to the length of work piece machined.

Table no 1.1 machining parameter and their levels

Sr.No	PARAMETER	LEVEL 1	LEVEL 2	LEVEL 3
1	CURRENT(amp)	12	18	24
2	PULSE ON TIME(µs)	6	7	8
3	PULSE OFF IME(µs)	5	6	7

- **GRAPHICAL ANALYSIS FOR COPPER ELECTRODE: MRR VERSUS CURRENT, PULSE ON TIME, PULSE OFF TIME**

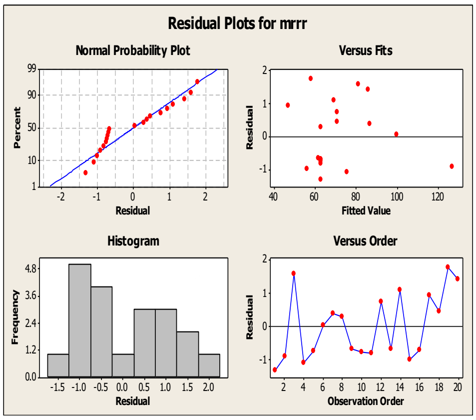

Table no 1.2 Analysis of variance

Source	DF	AdjSS	AdjMS	F-value	p-value
Regression	3	6377.89	708.654	942.66	0.000
Current	1	50.87	50.866	67.66	0.000
Pulse on time	1	910.77	910.773	1211.51	0.000
Pulse off time	1	84.21	84.213	112.02	0.001
Error	5	0.30	0.061		
Total	8				

Model summary			
S	**R-sq**	**R-sq(adj)**	**R-sq(Pred)**
0.867043	99.88%	98.91%	99.78%

From the analysis of variance table 5.2.2, it is seen that current, pulse on time and pulse off time having value is less than α-level 0.05 which is shows that current, pulse on time and pulse off time is a most significant factor for material removal rate.

10. CONCLUSION

By analyzing the results of the experiment on H13 die tool steel with copper, brass and bronze electrode materials, the following conclusions are arrival at.

- Higher material removal rate obtained using copper electrode as compared to brass and bronze electrode.
- Copper electrode offers lower electrode wear rate compared to brass and bronze electrode.
- Surface roughness is better for the brass electrode as compared to copper and bronze electrode.
- Current is most significant process parameter for material removal rate and electrode wear rate for copper electrode drawn by Response surface analysis.
- Current and pulse on time are most significant process parameter for electrode wear rate and Surface Roughness for brass drawn by Response surface analysis.

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