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Optimization of parameters during EDM with copper electrode

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Abstract

EDM is one of the important non traditional machining processes to machine hard metals, alloys and ceramics material that is not easily possible to cut or machine with conventional process. The main advantage of this process it is non contact type machining in which fear of stress after machining is negligible. The current research work shows the effect of copper electrode on HSLA steel workpiece using Die sink EDM machine. The process parameter is selected pulse on time, duty factor and current to evaluate the machining performances like material removal rate, tool wear rate. The other electrical and non electrical parameters were constant. It is concluded that high peak current value directly affects the material removal rate as well as tool wear.

Keywords: EDM, copper electrode, MRR, TWR

Introduction

EDM or spark erosion machining is a type of non-conventional machining Processes, in which electrical spark is generated by electric energy and thermal energy helps to remove the excessive material from workpiece. The word non-traditional is used in sense that the metals like hardened stainless steel, tungsten, tantalum, some high strength steel alloys etc. they required some special technique to machine. Electrical conductivity of material is must to machine the workpiece. EDM can be used to machine difficult geometries, intricate shapes in small batches or highly delicate sections.

Types of EDM

Basically, there are two types of EDM machines used.

A. DIE SINK EDM

Die sinking, is also known as cavity EDM. In which there is no physical contact of the workpiece and the electrode. Workpiece and electrode is connected with electric supply of DC voltage source. Power supply generates electrical potential difference between two polarities of electrode and the workpiece, it may be tool as negative and workpiece is positive or vice-versa. As tool approaches the workpiece in linear direction the gap between them is very small and the flow takes place through a dielectric medium that creates the plasma channel. After this repeated spark occurs between the tool and workpiece and the removal of stock from workpiece is high in rate as compared to the tool. Several thousand sparks occur between tool and workpiece and servo controlled mechanism continuously feed the tool in linear downward direction to maintain the spark gap. [1]

B. WIRE EDM

Modified EDM used for machining component of different profile and intricate shapes is known as wire EDM. It is also called spark EDM. The movement of the wire is numerically precision controlled. It is an electro thermal process in which thin wire (usually brass) is used to cut the metals. Machining of the workpiece is made with metal wire by applying series of discrete spark between wire and work metal and separated by the dielectric fluid typically used deionised water. Wire cut EDM is used for machining of thick plates upto 300mm.[1]

EDM PROCESS PARAMETERS

Input Parameters

Peak Current, Discharge Current, Pulse on time, Pulse off time, Dielectric flushing pressure, Duty Cycle, Taper Angle, Voltage.

Process performances

Material Removal Rate (MRR), Tool Wear Rate (TWR), Relative Wear Ratio (RWR), and Surface Roughness (SR), Micro Hardness, Overcut & taper cut.

Tool or Electrode material

The material used for electrode can be copper, brass, bronze, tungsten, graphite, Copper–tungsten, copper-chromium alloy, chromium coated copper alloy, Cu Tac etc.

Work-piece Material

The materials investigated on EDM generally of HSS and other Tool materials are Hot Die material, Cold Die material, Nickel alloys and Titanium alloys which are hard to compare to other material. These materials are AISI D2, AISI D3, AISI D5, AISI H11, AISI 4140, Mold Steel 8407, HSLA steel, WC/Co ceramic composite, Titanium (grade-5) alloy, Ti-6Al-4V and Ti-5Al-2.5Sn alloy, Hardened Cold Work Steel 210CR12, High Purity ZrC_2 etc.

Literature survey

Neeraj Sharma and Kamal Jangra evaluated the Surface Roughness of HSLA using Response Surface Methodology in WEDM. The input parameters were selected as pulse on time, pulse off time, gap voltage and peak current. It was seen that the surface roughness increases with increase in pulse on time the reason was may be that increase in pulse on time, discharge energy increases causing a stronger spark which increases surface roughness. Higher the pulse off time, surface roughness decreases. It was observed from that the surface roughness slightly increases with increase in the peak current. The result has been attributed to the increase in peak current which leads to the increase in the rate of the heat energy and hence in the rate of melting and evaporation.[2]

Kuo-Ming Tsai and Pei-Jen Wang evaluate the effect of three different electrode material viz. graphite, silver tungsten and copper using semi-empirical model on three different grades of steel. Peak current, polarity, properties of workpiece and pulse duration were parameters considered. It was concluded that the model is dependent on workpiece and tool material. Constant parameters cannot use for various tool workpiece combination.[3]

M. M. Rahman et. al discuss the evolution of machining parameters (SR, MRR and TWR) in EDM on the machining of austenitic stainless steel. The experimental work was done on EDM machine model AQ55L using copper as electrode material having size of Ø19X37 mm. From result it was concluded that TWR does mot effect by long pulse on time with reverse polarity. On the other side MRR and SR increases with peak current.[4]

V. D. Patel et. al. analyse the effect of tool materials on mild steel workpiece with considering machining parameters MRR and SR. Three different tool material copper, aluminum and brass with diameter Ø20mm were used for machining on 20mm X 20mm

X10mm workpiece in the presence of kerosene dielectric fluid. Structural analysis was done by scanning electron microscope (SEM). Following conclusions were made by authors[5]

(i) Copper and aluminum electrode gives high MRR at high discharge current. Whereas good surface finish was achieved with brass.

(ii) Aluminum electrode produces deeper HAZ compared to copper and brass.

Dilshad Ahmad Khan investigated the influence of tool polarity on silver steel grade 28 with statistical modeling. Copper was used as tool material for experimental work to evaluate the machining parameters surface roughness (SR), material removal rate (MRR) and percentage relative electrode wear (%REW). The experiment was done on tool craft EDM model G-45 at three levels of pulse duration (20µs, 100µs, 500µs) and current (6.25A, 14.06A, 21.875A) taking 50% duty factor. The conclusion drawn by author that the reverse polarity was better for SR because it gives 1.3-2.7 times better surface finish as compared to direct polarity.[6]

Dhanajay Pradhan showed the behavior of aluminum and copper electrode on EN-8 alloy steel. Peak current, duty factor and pulse on time were considered main parameters by taking remaining parameters as constant. The following conclusions were made:[7]

(i) In all cases on current and pulse on time combination copper gives better machined surface as compared to aluminum.

(ii) It was observed that black layer was formed on the tool surface that was due to decomposition of dielectric.

N. Annamalai et. al investigated the machining process parameter on AISI 4340 steel using electrolytic copper electrode. The input parameters were considered pulse on time, pulse off time and peak current to investigate the effect on machining parameters surface roughness and material removal rate. SR was increase with peak current, so the value of peak current should be optimum as possible. Surface roughness does not affected by pulse on time in this experiment work.[8]

Sonu Mathew et. Al studied process parameters and evaluated the effect on MRR and SR during EDMing of AISI 420 stainless steel. Taguchi L9 orthogonal array method was used by author's later S/N ration and ANOVA techniques used to evaluate the effect of different selected parameters on surface roughness and material removal rate. Copper electrode having size Ø40mm X 350mm with square profile at bottom 10mm X 10mm used for machining. Average surface roughness (R_a) was measured in this experiment with TALYSURF CLI 2000 roughness tester. From the result it was found that pulse on time and current significantly affect the SR, pulse off time does not shows any effect.[9]

EDM Principle

In this process the repeated spark applied between electrode and workpiece to erode the material from parent metal. The servo system maintain gap about 5µm [8]. This is basically thermal erosion process, in which supplied electrical energy is converted into thermal energy, which significantly helps in erosion. Generally kerosene or water is chosen as dielectric fluid for EDM, in certain cases gas medium can be use. Both tool and work piece are submerged in a dielectric fluid.

Fig. 1: EDM machine.

This figure 1 is shown the setup of the EDM machine. The tool is made cathode and work piece is anode. When the voltage is applied, it breakdowns the strength of dielectric initiated with tool movement. This increases the electric field in gap until it reaches the value of breakdown. As the breakdown occurs voltage starts fall and current rises. Due to presence of current plasma channel created at this stage. Discharge current continuously strikes the ions and electron on workpiece. This cause heating of workpiece and creates molten metal on surface. Small quantity of metal vaporized. Removal of material occurs due to instant vaporization and melting of material. At this stage gap between tool and electrode is important parameter. At the end of discharge current and voltage shut down and dielectric helps to impose the plasma under pressure. When the plasma collapses, it solidifies the molten metal into small particles. Availability of metal particle in gap increases the conductivity that behaves badly for stability of machining.

Material properties

A. Workpiece Material

HSLA steel is selected for experimental work.

B. Electrode Material

Copper electrode Ø16mmX100mm electrode selected and properties of copper material given in table

Table 1: Properties of Copper Electrode.

Density	8.9g/cm^3
Melting Point	1083 °C
Electrical Resistivity	1.96μΩ/cm
Electrical Conductivity compared with silver	92%
Specific Heat	0.092cal/g°C
Coefficient of thermal expansion	6.6
Thermal conductivity	160W/mK

Experimental data

The parameters selection for the present work is pulse on time, duty factor and current.

A. Experimental procedure

The 24 numbers of experiments on ELEKTRA EDM machine carried out using kerosene as dielectric fluid. The time duration for the experiment was taken 25 minute.

Duty cycle = $(T_{on} \text{ x } 1000)/(T_{on}+T_{off})$

MRR= Difference in weight of workpiece before and after machining/ Machining time

TWR= difference in weight of tool before and after machining/ Machining time

The machining parameters and levels are given in table.

Table 2: Machining Parameters and Levels.

Current	4	10
Pulse on time	100	200
Duty Factor	50%	80%

Conclusion

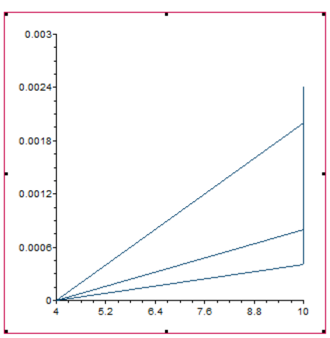
The performance of copper tool examined on HSLA workpiece surface. The attempt is made to determine the effect of different parameters like pulse on time and current during machining. The following conclusion are made

- The material removal rate (MRR) directly affected by current. It increases with current value.
- Tool wear rate was negligible at lower peak current. High current values affect the TWR.
- Pulse on time helps to gain material removal rate.

Table 3: Observations.

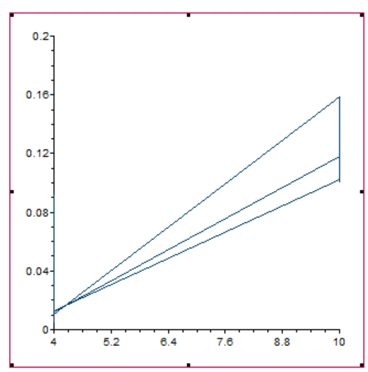
I_p	T_{on}	DF(%)	Initial Weight(W)	Final Weight(W)	Initial Weight(T)	Final Weight (T)	MRR (gm/min)	TWR (gm/min)
4	100	50	251.00	250.77	166.89	166.89	0.092	0.0000
4	100	50	247.81	247.50	166.89	166.89	0.0124	0.0000
4	100	50	247.50	247.17	186.62	186.62	0.0132	0.0000
4	100	80	247.17	246.88	186.62	186.62	0.0116	0.0000
4	100	80	246.88	246.58	179.10	179.10	0.012	0.0000
4	100	80	246.58	246.27	179.10	179.10	0.0124	0.0000
10	100	50	250.77	247.81	189.52	189.50	0.1184	0.0008
10	100	50	246.27	243.27	189.50	189.47	0.12	0.0012
10	100	50	243.27	240.40	175.21	175.16	0.1148	0.002
10	100	80	240.40	236.44	175.16	175.12	0.1584	0.0016
10	100	80	236.44	232.69	173.95	173.89	0.15	0.0024
10	100	80	232.69	228.72	173.89	173.84	0.1588	0.002
4	100	50	228.72	228.46	172.80	172.80	0.0104	0.0000
4	200	50	228.46	228.18	172.80	172.80	0.0112	0.0000
4	200	50	228.18	227.88	174.50	174.50	0.012	0.0000
4	200	80	227.88	227.72	174.50	174.50	0.0064	0.0000
4	200	80	255.46	255.32	164.78	164.78	0.0056	0.0000
4	200	80	255.32	255.00	164.78	164.78	0.0128	0.0000
10	200	50	255.00	252.45	165.61	165.60	0.102	0.0004
10	200	50	252.45	249.94	165.60	165.59	0.1004	0.0004
10	200	50	249.94	247.24	171.66	171.65	0.108	0.0004
10	200	80	247.24	243.71	171.65	171.63	0.1412	0.0008
10	200	80	243.71	240.05	162.84	162.80	0.1464	0.0016
10	200	80	240.05	236.52	162.80	162.77	0.1412	0.0012

TWR



Current

MRR



Current

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