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Review Article

DIE SINKING EDM PROCESS PARAMETERS: A REVIEW

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Electrical Discharge Machining is a one of the electrical energy based Unconventional Machining Technique. The electrical energy is directly used to remove or cut the metals. It's also called as Spark Erosion Machining or Electro Erosion Machining. The metal is removed by electrical spark discharge between tool (Cathode) and workpiece (Anode). Electrical Discharge Machining is used in mould and die making industries, Automobile industries and making of Aerospace components.

Keywords: Die sinker EDM, MRR, TWR, SR, Taguchi

INTRODUCTION

Newer materials such as Tungsten, Molybdenum, Columbium, Alloys and Super Alloys which have high strength, heat resistance and hardness are very difficult to machine by conventional or traditional methods. And also obtaining complex shapes of the products are time consuming processes. These problems are overcome by nontraditional machining processes. Many Unconventional machining processes are as follows:

1. Electrical Discharge Machining (EDM)
2. Electrical Chemical Machining (ECM)
3. Electro Chemical Grinding (ECG)
4. Ultrasonic Machining (USM)
5. Laser Beam Machining (LBM)
6. Chemical Machining (CHM)
7. Abrasive Jet Machining (AJM)
8. Water Jet Machining (WJM)
9. Plasma Arc Machining (PAM)

Unconventional machining processes are mainly used for machining high strength alloys, higher accuracies, complex geometries and higher surface finish.

WORKING PRINCIPLE OF EDM

EDM consists of the following components,

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1. Power supply Unit – Used to provide the Direct Current to produce spark between the tool and workpiece.
2. Dielectric fluid reservoir, pumps, filters and control valve – Used to supply dielectric to the tool and workpiece. The tool and workpiece are immersed in dielectric fluid.
3. Workpiece holder, Tool holder and table – Used to hold tool and workpiece firmly so that the vibrations are reduced.
4. Servo control Mechanism – Used to provide a constant gap between tool and workpiece.

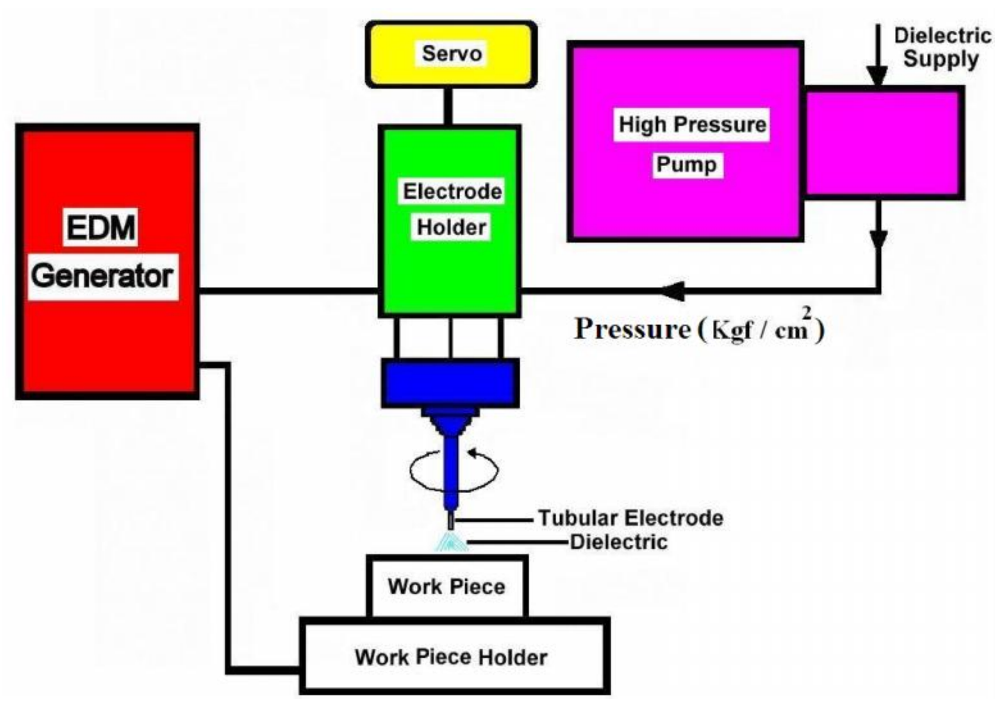
The tool and workpiece are directly connected with DC power supply. The workpiece is connected into positive terminal and tool is connected into negative terminal of DC supply. The tool and workpiece are submerged in the dielectric medium. The servo feed mechanism is used to give a constant gap (spark gap) between the tool and workpiece. Figure 1 shows the schematic diagram of EDM.

When the DC supply is given to the circuit, the voltage reaches at 250 V. And high spark is produced at the spark gap. So that the dielectric breaks down and electrons are emitted from cathode, the gap is ionized and thousands of sparks/sec occurred at the gap. This high spark produces high temperature. Due to that high temperature and high pressure the metal is removed and flushed away by the dielectric fluid. When the voltage drops, the dielectric fluid gets deionised (Panday, 1980).

PROCESS PARAMETERS OF EDM

Unconventional Machining Process depends upon the number of process parameters.

Figure 1: Diagram of EDM



These parameters will affect the output performance of EDM processes by varying the input characteristics. These controlling parameters are mainly divided into Electrical and Non-electrical parameters.

Electrical Parameters

Electrical parameters such as the Ton, Toff, Voltage and Peak Current are playing an important role in output performance measures. Here we discuss about the effects of electrical parameters on the various performance measures.

Discharge Voltage

It is a voltage which is produced in between the Workpiece and Tool when DC power supply is given to the circuit.

Peak Current

Peak Current is the most influencing factor in EDM. It is nothing but the amount of power used in EDM.

Average Current

It is a maximum current available for each pulse from the power supply.

Average current (A) = Duty Factor (%) x Peak Current

Pulse On

It is the duration of time for which current is allowed to flow per cycle.

Pulse Off

It is the duration of time between each spark.

Polarity

Polarity may be positive or negative. MRR is higher when tool is connected to positive polarity.

Pulse Frequency

Pulse Frequency is defined as number of cycles produced at the gap in one second.

Pulse Frequency (KHz) = 1000/Total Cycle Time (μs)

= 1000/Pulse on + Pulse off (μs)

Duty Factor

Duty Factor is the percentage of ratio between pulse duration and total cycle time.

Duty Factor (%) = [Ton (μs)/Total Cycle Time (μs)] x 100

Electrode Gap (Spark Gap)

It is the distance between the Tool and Workpiece during the process of EDM. Servo Mechanism is used to provide a constant gap between the gaps.

Gap Voltage

Gap voltage is classified into open gap and working gap voltage. Open gap voltage can be measured at the gap before the spark current discharge begins to flow and working gap voltage can also be measured at the gap during spark current discharge.

Intensity

It is the different levels of power generated by the generator.

Non Electrical Parameters

Non-electrical parameters such as the Rotations of electrode, flushing of dielectric fluid and tool shape are also influencing the output performance measures. Here we discuss about the effects of non-electrical parameters on the various performance measures.

Workpiece Material

Workpiece material is one of the non-electrical parameters which influence the performance characteristics of EDM. There are many materials such as die materials, alloys, super alloys and titanium alloys which are very hard to cut.

Electrode Material

Generally tool materials are classified into metallic, non-metallic and combination of metallic and non-metallic materials. Usually Copper, Brass, graphite, Copper-Tungsten, Silver Tungsten, Copper Graphite and Tungsten Carbide are used as a tool material in EDM which have better conductivity, good resistance and wearing capacity.

Electrode Shape

The performance characteristics mainly depend upon the tool shape. Many shapes in electrode such as Rectangular, Square, Cylindrical, Hexagonal and Circular are used.

Rotation of Tool Electrode

The rotational movement of electrode is used to increase the Metal Removal Rate in EDM due to the centrifugal force on workpiece.

Type of Dielectric

Dielectric medium acts as an insulator medium which doesn’t conduct electricity and used to flush the eroded particles. And it cools region, tool and work material. Paraffin, White Spirit, Kerosene, deionised water, hydrocarbon Fluids and transformer oil are the different EDM dielectric fluids.

Flushing System and Pressure

The dielectric fluid must be circulated freely between Tool and Work Material. Eroded particles should be flushed out at the earliest. There are many methods of flushing. They are, Pressure Flushing, Suction Flushing and Side Flushing.

EDM PERFORMANCE MEASURES

A significant number of papers have been focused on ways of yielding optimal EDM performance measures of high Material Removal Rate, low Tool Wear Rate (TWR) and satisfactory SQ. This section provides a study into each of the performance measures and the methods for their improvement.

Material Removal Rate (MRR)

MRR is the ratio of the difference of weight of the workpiece material before and after machining to the machining time. The MRR is calculated by,

$$MRR\ (g/\min) = \frac{Initial\ weight\ of\ w/p - Final\ weight\ of\ w/p}{Time\ of\ machining}$$

Tool Wear Rate (TWR)

TWR is the ratio of the difference of weight of the tool before and after machining to the machining time. TWR is calculated using the formula given as,

$$TWR\ (g/\min) = \frac{Initial - Final\ weight\ of\ tool}{Time\ of\ machining}$$

Wear Ratio (WR)

WR is the ratio of Tool Wear Rate and Material Removal Rate. Choosing same material of tool and workpiece improve the Material Removal Rate.

$$WR = \frac{Tool\ Wear\ Rate\ (TWR)}{Material\ Removal\ Rate\ (MRR)}$$

Average Surface Roughness (Ra)

Surface roughness is an important output performance in EDM which is influences the product quality and cost. Surface roughness is measured by surface roughness tester.

Over Cut (OC)

An EDM cavity is always larger than the electrode used to machine it. The difference between the size of the electrode and the size of the cavity (or hole) is called as the overcut.

Surface Quality (SQ)

Surface Quality is determined by two thermally affected layers. The White Layer or Recast Layer (WL/RCL) is the layer which is formed by the unexpelled molten metal being rapidly cooled by the dielectric fluid during the flushing process. The Heat-Affected Zone (HAZ) is the layer which lies below the recast layer. This is formed due to altering the metallurgical properties of the metal. Below the heat affected zone is the parent material and this area is unaffected by the EDM process.

Table 1: Review of Literature

Name of Researchers	Contribution	Workpiece Material	Electrode Material	Input Parameters Taken Into Account		Output Parameters Taken Into Account	Technique
				Electrical	Non-Electrical		
Guu (2005)	AFM surface imaging of AISI D2 Tool steel machined by the EDM process	AISI D2 Tool steel	Copper	Pulse Current, Pulse on Duration	Non	SR, Micro Crack	Atomic Force Microscopy
Yusuf Keskin *et al.* (2006)	An experimental study for determination of the effects of machining parameters on surface roughness in electrical discharge machining (EDM)	Steel	Copper	Power, Pulse Time, Spark Time	Non	SR	Multiple Regression
Ali Ozgedik and Can Cogun (2006)	An experimental investigation of tool wear in electric discharge machining	1040 Steel	Copper	Discharge Current, Pulse Durations	Injection Suction Flushing Pressures	MRR, TWR, RWR, SR	Non
Ting-Cheng Chang *et al.* (2006)	Data mining and Taguchi method combination applied to the selection of discharge factors and the best interactive factor combination under multiple quality properties	SKD-61 Hot-Working Mold Steel	Red Copper	Pulse on Time, Pulse off Time, Open Discharge Voltage, Interval Voltage	Non	Machining and Reaming Amount, MRR, SR, Electrode Corner Loss	Taguchi
Ko-Ta Chiang and Fu-Ping Chang (2007)	Applying grey forecasting method for fitting and predicting the performance characteristics of an electro-conductive ceramic (Al_2O_3 + 30% TiC) during electrical discharge machining	Al_2O_3 + 30% TiC	Copper	Voltage, Current, Pulse Duration	Non	MRR, Rmax, EWR	RGM

Table 1 (Cont.)

Name of Researchers	Contribution	Workpiece Material	Electrode Material	Input Parameters Taken Into Account		Output Parameters Taken Into Account	Technique
				Electrical	Non-Electrical		
José Carvalho Ferreira (2007)	A study of die helical thread cavity surface finish made by Cu-W electrodes with planetary EDM	AISI H13 tool steel	Copper-Tungsten (Cu-W)	Open-Circuit Voltage, Discharge Voltage, Peak Discharge Current, Pulse on Time, Duty Factor	Flushing Pressure	MRR, TWR, SR, WLT, HAZ	Non
Fred Amorim and Walter Weingaertner (2007)	The Behavior of Graphite and Copper Electrodes on the Finish Die-Sinking Electrical Discharge Machining (EDM) of AISI P20 Tool Steel	AISI P20 Tool Steel	Graphite, Copper	Discharge Current, Discharge Duration, Tool Polarity	Non	MRR, VRW Ra	Non
Kanagarajan *et al.* (2008)	Optimization of electrical discharge machining characteristics of WC/Co composites using non-dominated sorting genetic algorithm (NSGA-II)	Tungsten Carbide Cobalt Composites (WC/Co)	Copper (Cylindrical Shape)	Pulse Current, Pulse on Time	Electrode Rotation, Flushing Pressure	MRR, SR	NSGA II
Ko-Ta Chiang (2008)	Modeling and analysis of the effects of machining parameters on the performance characteristics in the EDM process of Al_2O_3 + TiC mixed ceramic	Al_2O_3 + Tic Mixed Ceramic	Copper	Discharge Current, Pulse on Time, Duty Factor, Open Discharge Voltage	Non	MRR, EWR, SR	RSM, CCD, ANOVA.
Kuppan *et al.* (2008)	Influence of EDM process parameters in deep hole drilling of Inconel 718	Inconel 718	Copper Tube	Peak Current, Pulse on Time, Duty Factor	Electrode Speed	MRR, DASR	CCD, RSM
Salonitis *et al.* (2009)	Thermal modeling of the material removal rate and surface roughness for die-sinking EDM	Steel (St-37)	Copper (Rect-angular Shape)	Arc Voltage, Current, Spark Duration	The Idling Time	MRR, SR	Theoretical Model
Amir Abdullah *et al.* (2009)	Effect of ultrasonic-assisted EDM on the surface integrity of cemented tungsten carbide (WC-Co)	Cemented Tungsten Carbide (WC-Co)	Copper	Open-Circuit Voltage	Non	SR	SEM, MH

Table 1 (Cont.)

Name of Researchers	Contribution	Workpiece Material	Electrode Material	Input Parameters Taken Into Account		Output Parameters Taken Into Account	Techni-que
				Electrical	Non-Electrical		
Yan-Cherng Lin and Ho-Shiun Lee (2009)	Optimization of machining parameters using magnetic-force-assisted EDM based on gray relational analysis	SKD 61 Steel	Copper	Polarity, Peak Current, Pulse Duration, High-Voltage Auxiliary Current, No-Load Voltage, Servo Reference Voltage	Non	MRR, EWR, SR	GRA, ANOVA
Ponappa *et al.* (2010)	The effect of process parameters on machining of magnesium nano alumina composites through EDM	Microwave Sintered Magnesium Nano Alumina Composites	Brass (Hollow Tubular)	Pulse on Time, Pulse off Time, Voltage Gap, Servo Speed	Non	SR	Taguchi, ANOVA
Kao *et al.* (2010)	Optimization of the EDM parameters on machining Ti-6Al-4V with multiple quality characteristics	Ti-6Al-4V Alloy	Cylindrical Copper Rod	Discharge Current, Open Voltage, Pulse Duration, Duty Factor	Non	MRR, EWR, SR	Taguchi, GRA
Yonghong Liu *et al.* (2010)	Investigation of emulsion for die sinking EDM	AISI 1045 Steel	Copper	Pulse on Time, Pulse off Time, Peak Voltage, Peak Current	Non	MRR, EWR, SQ	SEM
Promod *et al.* (2011)	Taguchi analysis of surface modification technique using W-Cu powder metallurgy sintered tools in EDM and characterization of the deposited layer	C-40 Steel	W-Cu Powder Metallurgy Sintered Tools	Pulse on Time, Peak Current, Duty Factor	Composition, Compaction Pressure, Sintering Temperature	LT, MTR, TWR, SR, MH	Taguchi Method
Hao Ning Chiang and Junz Wang (2011)	An analysis of overcut variation and coupling effects of dimensional variable in EDM process	AISI D2AISI S2Tool Steel	Copper (Square Shape)	Current, Voltage, Pulse on Time, Pulse off Time	Non	OC, Electrode Dimensions, Spark Hole Dimensions, Machine Positioning, Accuracy	Variance Analysis

Table 1 (Cont.)

Name of Researchers	Contribution	Workpiece Material	Electrode Material	Input Parameters Taken Into Account		Output Parameters Taken Into Account	Technique
				Electrical	Non-Electrical		
Horacio Sánchez *et al.* (2011)	Development of an inversion model for establishing EDM input parameters to satisfy material removal rate, electrode wear ratio and surface roughness	Carbon Steel AISI 1045	Prismatic Copper	Peak Current, Pulse on Time, Pulse off Time,	Non	MRR, EWR, SR	ANOVA and Regression Models
Lei Li *et al.* (2012)	Influence of flushing on performance of EDM with bunched electrode	Carbon Steel (S45C)	Copper (Hexagonal shape)	Non	Flushing Modes, Flushing Parameters	MRR, TWR	Non
Renjie Ji *et al.* (2012)	Influence of dielectric and machining parameters on the process performance for electric discharge milling of SiC ceramic	Silicon Carbide (SiC)	Steel-Toothed Wheel	Tool Polarity, Pulse Duration, Pulse Interval, Peak Voltage, Peak Current	Dielectric type	MRR, SR	SEM, EDS, XRD.
Ignacio Puertas and Carmelo Luis (2012)	Optimization of EDM conditions in the manufacturing process of B4C and WC-Co conductive ceramics	Boron Carbide (B4C), Cobalt-Bonded Tungsten Carbide (WC-Co)	Copper	Intensity, Pulse Duration, Duty Cycle, Open-Circuit Voltage	Dielectric Flushing Pressure	MRR, SR, EWR	Fractional Factorial Design with CCD
Shailendra Kumar Singh and Narinder Kumar (2013)	Optimizing the EDM Parameters to Improve the Surface Roughness of Titanium Alloy (Ti-6AL-4V)	Ti- 6AL- 4V	Copper	Pulse on Time, Pulse off Time, Current	Non	SR	Taguchi, ANOVA
Shivendra Tiwari (2013)	Optimization of Electrical Discharge Machining (EDM) with Respect to Tool Wear Rate	Mild Steel	Copper	Peak Current, Pulse on Time, Pulse off Time	Non	MRR, TWR	Non
Singaram Lakshmanan and Mahesh Kumar (2013)	Optimization of EDM parameters using Response Surface Methodology for EN31 Tool Steel Machining	EN31 Tool Steel	Copper	Pulse on Time, Pulse off Time, Pulse Current, Voltage	Non	MRR, SR	RSM, ANOVA

Table 1 (Cont.)

Name of Researchers	Contribution	Workpiece Material	Electrode Material	Input Parameters Taken Into Account		Output Parameters Taken Into Account	Technique
				Electrical	Non-Electrical		
Annamalai *et al.* (2014)	Investigation and Modeling of Electrical Discharge Machining Process Parameters for AISI 4340 steel	AISI 4340 steel	Copper	Pulse on Time, Peak Current, Pulse off Time	Non 2	MRR, SR	RSM, ANOVA
Viral Prajapati and Rajput (2014)	A Review on Optimization of Process Parameters for Improving Performance in Electrical Discharge Machining	SS 410	Copper	Discharge Current, Pulse on Time, Pulse off Time	Non	MRR, SR	Non
Shashikant *et al.* (2014)	Optimization of machine process parameters on material removal rate in EDM for EN19 material using RSM	EN19	Copper	Pulse on Time, Pulse off Time, Discharge Current, Gap Voltage	Non	MRR, SR	RSM, ANOVA

SUMMARY

The review of research trends in Sinker EDM has been taken for recent 10 years. From the above reviews we conclude that,

- Most of the EDM work that has been carried on Steel materials, EN series, Ti-6AL-4V, S45C, SiC, B4C, WC-Co, Al2O3+Ti and Inconel 718.
- Copper is often used as a tool material in Rectangular, Square, Cylindrical, Hollow Tubular and Hexagonal shapes.
- Pulse on, Pulse off, Peak Current, Voltage are the primary electrical parameters and Dielectric fluid, Flushing Pressure, Electrode Rotation are the non electrical parameters which are considered in EDM.
- Most of the research work that has been carried out for improving the performances on EDM are measured in terms of Material Removal Rate, Tool Wear Rate, Wear Ratio and Surface Finish.
- Many research works have been taken by the optimization techniques like, Response Surface Methodology, ANNOVA, Taguchi, Scanning Electron Microscope, Central Composite Design, Grey Relational analysis, and Multiple Regression analysis.

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