Investigation of EDM Process Parameters and Their Optimization: A Review-Based Study

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ABSTRACT

Among the thermal mode of machining, electrical discharge machining (spark erosion machining) is mainly a method for the manufacturing of a multitude[1] of ever changing geometries very often produced as unit job or in small batches.The basic concept of Electrcal Discharge Machining (EDM) process is creating out of metals affected by the sudden stoppage of the electron beam[3] by the solid metal surfaces of the anode.The portion of the anode facing the direct electrical pulse reaches the boiling point.Even in case of medium long pulse the rate of temperature increases in tens of millions of degree per second which means dealing with an explosion process.In the present work, a combined optimization approach is used for the estimation of maximum metal removal rate(MRR) [5]and minimum tool wear rate(TWR), surface roughness(SR) and overcut(OC) of produced in electrical discharge machining. The important input parameters current (I), pulse on time (Ton), pulse off time (Toff) and voltage (V) are considered.

KEYWORDS: Electro discharge machining (EDM), Process parametes, Performance parameters, Optimization, wire cut EDM.

INTRODUCTION

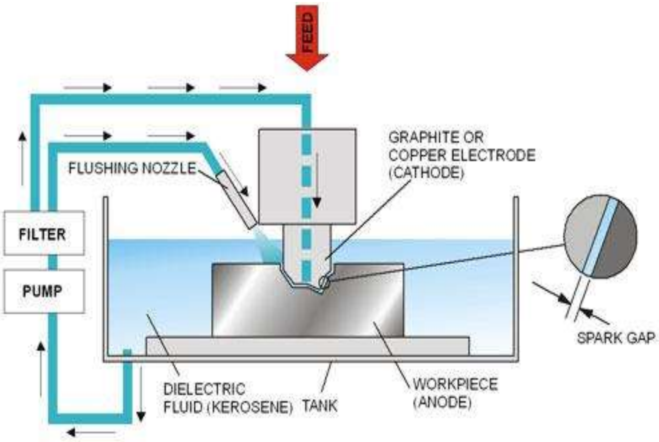
BACKGROUND OF EDM

Removal of metals by spark was first introduced by Joseph Priestily in 1878 and electric-sparking has been utilized since long for its by-products,collidal metal powders,but sparks are not used for machining as much until the late thirties .However, controlled machining by electrical sparks was initially introduced by Lazarenko.The first patent was granted to Rudoff in 1950.USA, Japan and Switzerland developed their machines around 1950.Amachine for spark machining by method X' was patented in USA in 1952.After the pioneering investigations of Lazarenko, the EDM process has attracted worldwide attention as a technique for metal machining and since then considerable research and development have been carried out.

EDM has been replacing the almost all conventional and traditional machining operations and is now a well-established machining option in many production industries throughout the universe. And is capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries. Electric Discharge Machining has also made its presence felt in the new fields such as sports, medical and surgical, instruments, optical, including automotive R&D areas.

PRINCIPLE OF EDM

The workpiece and electrode are separated by a gap, called spark gap(0.005 to 0.05mm) and a suitable dielectric slury,which is non-conductor of electricity, is forced through this gap at a pressure of about 2kgf/cm^2.When a proper voltage is applied the dielectric breaks down and electrons are emitted from cathode and the gap is ionized.Avalanche of electrons takes place with collection of more electrons in the gap,consequently the resistance drops causing electric spark to jump between the workpiece and the tool.Each electric discharge causes a focused stream of electrons to move with a very high velocity from the cathode towards anode and their collision with the work results in the generation of compression shock waves on high spots of workpiece closest to the tool which consequently developes local rise in temperature the tune of 10000^{0}C sufficient enough to melt a part of the workpiece metal.



TYPES OF EDM

Basically, there are two different types of EDM:

1) Die-sinking
2) wire-cut.

DIE-SINKING EDM

In the Die sink EDM, two metal parts submerged in an insulating liquid are connected to a source of current which is switched on and off automatically depending on the parameters set on the controller. When the current is switched on, an electric tension is created between the two metal parts. If the two parts are brought together to within a fraction of an inch, the electrical tension is discharged and a spark jumps across. Where it strikes, the metal is heated up so much that it melts. Sinker EDM, also called cavity type EDM or volume EDM consists of an electrode and work piece submerged in an insulating liquid such as, more typically, oil or, less frequently, other dielectric fluids. The electrode and work piece are connected to a suitable power supply. The power supply generates an electrical potential between the two parts. As the electrode approaches the work piece, dielectric breakdown occurs in the fluid, forming a plasma channel, and a small spark jumps.

WIRE-CUT EDM

Such type of EDM sometimes called travelling wire EDM.Electrical discharge wire cutting is a process that is similar in configuration to band swing except in the case of WEDM the saw is a wire electrode of small diameter.Material removal is affected as a result of spark erosion as the wire electrode is fed through the workpiece.In most cases , horizontal movement of the worktable, is controlled by CNC.

Wire-cutting EDM is commonly used when low residual stresses are desired, because it does not require high cutting forces for removal of material. If the energy/power per pulse is relatively low (as in finishing operations), little change in the mechanical properties of a material is expected due to these low residual stresses, although material that hasn't been stress-relieved can distort in the machining process. Due to the inherent properties of the process, wire EDM can easily machine complex parts and precision components out of hard conductive materials.

IMPORTANT PARAMETERS OF EDM

(a) Spark on time (pulse time or T_{on}): The duration of time (μs) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on time. The energy is really controlled by the peak current and the length of on time.

(b)Spark off time (pause time or $T_{off)}$ 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 wash out from the arc gap. This parameter has to effect the speed and the stability of the cut. Thus, if the off time is too short, it will cause spark to be unstable.

(c) Arc gap (or gap): The arc gap is the distance between the electrode and work piece during the process of EDM. It may called as spark gap. Spark gap can be maintained by servo system.

(d) Discharge current (current**):** Discharge current is directly proportional to material removal rate.

(e) Duty cycle (τ): It is the percentage of the on time relative to the total cycle time. This parameter is calculated by dividing the on time to the total cycle time.

$$\tau = \frac{Ton}{Ton + Toff}$$

(f) Voltage (V): It is a potential that can be measured in volt, it is also effect the material removal rate and allowed to per cycle.

(g) Diameter of the electrode (D): It is the electrode of copper with diameter 11 mm in this experiment.

(h) Over cut**:** It is the clearance per side of the electrode and the work piece after the machining operation

DIELECTRIC FLUID

Since the process of removal of materials(both from work and tool) mainly depends on thermal evaporation and melting, the presence of oxygen in the atmosphere surrounding the spark would lead to formation of metal oxides which adversely affect the continuation of generation of repetive sparks (most of metal oxides are bad conductors).Hence , it is necessary to use a dielectric fluid which contain no oxygen for liberation during the process, to help ionization, without disturbing the process.But the performance of the dielectric to suit the purpose is extremely important.

The failure of dielectric under electric stress, termed as breakdown, is found to spread over a wide range of applied stresses,depending upon its environment and mode of use.

In general, the main basic mechanism of dielectric breakdown in the three state of matter are;
(a)Intrinsic
(b)Thermal
(c)Discharge or Avalanche

FLUSHING METHOD

It is one of most important factor for machining in EDM.The clean and filtered Dielectric is continuously thrown to the spark gap which is developed between the anode and cathode.So this continuous flow of dielectric is possible by the flushing method.

TOOL MATERIAL

The Tool material should be such that it would not under go much tool wear when it is impinged by positive ions. Thus the localized temperature rise should be less by properly choosing its properties or even when temperature increases, there would be less melting. Further, the should be easily workable as complex shaped geometric features are machined in EDM.Thus basic characters of the EDM tool are as follows:

1) High electrically conductivity
2) High thermal conductivity
3) Higher density.
4) High melting point
5) Easily manufactured
6) Cost

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The followings are the different electrode materials which are used commonly in the industry:
1. Graphite
2. Copper
3. Tellurium copper–99%Cu + 0.5%Tellurium

SELECTION OF ELECTRODE MATERIAL

Tool material	Work material	Best application	Limitation
Graphite	Steel	Press tooling, Dies	Carbides (These are tendency of arcing)
Brass	All metals	Holes, Slots	Close tolerances
Copper	All metals	Machining of carbides, slots and micro-machining	Large area,deep slots
Steel	Non-ferrous metals	Through holes	Carbides
Aluminium	Steel only	Forging dies	Through holes

Zinc	Steel	Forging	Through holes
Tungsten Carbide	All metals specially refractory materials	Small slots and holes	Irregular holes

APPLICATION OF EDM

The process is very useful in tool manufacturing due to the ease with which hard metals and alloys can be machined.Other applications include resharpening of cutting tools and broaches,machining of cavities for dies and machining of die cavities without annealing.These are some applications of the process,but it can be perform almost all the conventional machining operations.

ADVANTAGES OF EDM

(a) Enables high accuracy on tools and dies because they can be machined in 'as hard condition'.
(b) Even highly delicate sections and weak materials can be machined without any fear of distortion because there is no direct contact between the tool and the workpiece
(c)Irrespective of its hardness or strength, any material, which is electrical conductor can be machined.
(d)Any shape that can be imparted to the tool can be reproduced on the work.
(e) Fine holes can be easily drilled.
(f) It is a quicker process,even harder materials can be machined at a much faster rate than conventional machining.

LIMITATIONS OF EDM

This process has some distinct disadvantages such as;
(a)Capacity to machine small workpieces only
(b)Unstability for machining of electrical non-conductors
(c)Thermal distortion
(d)Inability to produce sharp corners.

LITERATURE REVIEW

Chen et al. (2013) had utilized the Taguchi design methodology to optimize the EDM processing parameters for the machining of A6061-T6 aluminium alloy. They have taken four EDM parameters, namely; the pulse current , the pulse-on duration, the duty cycle , and the machining duration to observed the Surface Roughness.

Lin et al. (2008) examined the effects of attached magnetic force on EDM machining characteristics such as MRR, TWR, SR using Electrolytic Copper as Tool and work-piece is SKD61 steel. Taguchi's L18 OA was adopted to design the parameters namely p, Ip, pulse duration, high-voltage auxiliary Current (IH), no-load voltage and servo reference voltage (Sv)
.

Nikalje et al. (2013) used Taguchi method to determine the influence of process parameters and optimization of MDN 300 steel in EDM. Important performance measures such as, MRR, TWR, SR and relative wear ratio (RWR).

Das et al. (2012) presented an investigation on the effect and optimization of machining parameters namely, Ton, Toff , Ip and V on Material Removal Rate (MRR)in EDM of EN31 tool steel.

Manikandan and Venkatesan (2012) have shown an investigation the feasibility of micron size hole manufacturing using Micro Electro Discharge Machining (MEDM).This study investigates the effect of machining parameters such as Ip, Ton, Toff on the optimization of machining characteristics namely, Radial Over cut , MRR, Tool Wear Rate for machining in MEDM.

Marafona and Araujo (2009) developed a model using Taguchi methodology with the influence of the hardness of the alloy steel on the MRR and SR. The results shows that MRR and SR are directly dependent on the work-piece hardness.

Ali and Mohammad (2008) had analysed the optimization of the process parameters of conventional WEDM of a copper substrate for micro-fabrication. Statistical models were established to predict the SR and peak-to-valley height (Rt) in terms of Ip, Ton and gap voltage. The SR increased with higher Ip and gap voltage and decreased with increase of Ton.

Kansal et al. (2007) had analysed the effect of silicon powder mixing into the kerosene as dielectric fluid of EDM on machining characteristics of AISI D2 die steel . Six process parameters, namely Ip, Ton and Toff , concentration of powder, gain, and nozzle flushing have been considered. The process performance is measured in terms of machining rate (MR). This study indicated that all the selected parameters except nozzle flushing have a significant effect on the mean and variation in MR. Optimization to maximize MR has also been undertaken using the Taguchi method.

Guleryuz et al. (2013) had investigated the effect of EDM parameters on the SR for machining of Al/SiCp metal matrix composites produced with the Powder Metallurgy (PM). Ip, electrode type, Ton, particle reinforcement weight ratio and V were used as the process parameters. An experimental plan L18 was constituted by using the Taguchi orthogonal design.

TABULATION OF THE LITERATURE REVIEW

NAME OF RESEARCHERS	YEAR	CONTRIBUTION	WORK PIECE MATERIAL	PARAMETERS	
				MACHINING	PERFORMANCE
K.M.Patel	2009	Investigated the determination of an Optimum Parametric Combination Using a Surface Roughness Prediction Model for EDM of Al2O3/SiCw/TiC Ceramic Composite	Al2O3/SiCw/ TiC Ceramic Composite	-	Dischagre current , Pulse on time, Duty cycle, Gap voltage
Saurav Datta	2010	Modeling, Simulation and Parametric Optimization of Wire EDM Process using Response Surface Methodology coupled with Grey-Taguchi Technique	D2 steel	Discharge current, Pulse on time, Pulse frequency, Wire speed, Wire tension, Dielectric flow rate	MRR, SR
Shailesh	2011	Experiment Investigation of Machining Parameters for EDM Using U-shaped Electrode Of AISI P20 Tool Steel	AISI P20 Tool Steel	Pulse on time, Discharge current, Diameter of electrode	MRR, TWR
A. Manjuder	2012	Study of the Effect of Machining Parameters on Material Removal Rate and Electrode Wear during Electric Discharge Machining of Mild Steel	Mild Steel	Supply Current, Pulse on time, Pulse off time	MRR, EW
Anish	2012	Prediction of Surface Roughness in Wire Electric Discharge Machining (WEDM) Process based on Response Surface Methodology	Pure Titanium	Pulse on time, Pulse off time, Peak current, Spark gap voltage, Wire feed, Wire tension	SR

M.R.Shabgarg	2012	Mathematical Analysis of Electrical Discharge Machining on FW4 Weld Metal	FW4 weld metal	Discharge Current, Pulse on time, Voltage	MRR, Stability factor (Sf)
S.Gopalakannan	2012	Modeling and Optimization of EDM Process Parameters on Machining of Al 7075-B4C MMC using RSM	Al 7075-B4C MMC	Pulse current, Gap voltage, Pulse on time, Pulse off time	MRR, EWR, SR
Raj Mohan	2012	Optimization of Machining Parameters in Electrical Discharge Machining (EDM) of (304) stainless steel	Stainless Steel (304)	Pulse off time, Pulse on time, Voltage	MRR
Herpreet Singh	2013	Effect of Pulse on / Pulse off on Machining of Steel Using Cryogenic Treated Copper Electrode	Steel	Pulse on time, Pulse off time	MRR, TWR
SV Subrahmanyam	2013	Evaluation of Optimal Parameters for machining with Wire cut EDM Using Grey-Taguchi Method	H13 Hot Die tool steel	Discharge current, Pulse on time, Pulse off time, Spark voltage, Wire feed, Wire tension, servo feed, flushing pressure	MRR, SR
Prajapati	2013	Effect of Process Parameters on Performance Measures of Wire EDM for AISI A2 Tool Steel	AISI A2 Tool Steel	Pulse on time, Pulse off time, Voltage, Wire feed, Wire tension	MRR, SR
Nikalje	2013	Influence of Parameters and Optimization of EDM Performance Measures on MDN 300 Steel using Taguchi Method	MDN 300 Steel	Discharge current, Pulse on time, Pulse off time	MRR, TWR, RWR
C. D. Shah	2013	Optimization of Process Parameter of Wire Electrical Discharge Machine by Response Surface Methodology on Inconel-600	Inconel-600	Peak current, Pulse on time, Pulse off time, Wire feed	MRR
Chikalthankar	2013	Experimental Investigations of EDM Parameters			MRR, SR

			WPS DIN 1.2379/AISI D2 tool Steel	Current, Voltage, Pulse on time, Pulse off time	
Kumar	2013	Modeling and Optimization of Wire EDM Process	Machining Al-sic (20%)	Pulse on time, Pulse off time, Wire speed, Wire feed	MRR, SR
Geetha	2013	Modeling and Analysis of Performance Characteristics of Wire EDM of SS304	Stainless steel 304	Pulse on time, Pulse off time, Wire tension, Water pressure	MRR, SR
Neeraj Sharma	2013	Multi Quality Characteristics of WEDM Process Parameters with RSM	HSLA	Pulse on time, Pulse off time, Peak current, Servo voltage, Wire tension	MRR, SR
Singaram Lakshmanan	2013	Optimization of EDM Parameters using Response Surface Methodology for EN31 Tool Steel Machining EDM Process	EN31 tool steel	Pulse on time, Pulse off time, Pulse current, voltage	MRR
Sanjay Kumar	2013	Optimization of EDM Parameters using Integrated Approach of RSM, GRA and Entropy Method	-	Peak current, Pulse on time, Pulse off time	MRR, SR ,TWR
Manabhanjan Sahoo	2013	Experimental Investigation of Machining of Tungsten carbide by EDM and Its Mathematical Expression	Tungsten carbide	Discharge current, Pulse on time, Duty cycle	MRR, EWR
Md. Khaja	2013	Effects of Machining Parameters on Surface finish over Hardened Die Steel working on Wire-EDM Machine.	Die Steel (K100 grade)	Pulse on time, Pulse off time, Wire feed, Wire tension, Spark gap, Voltage, Peak current	SR

CONCLUSION

Recent advancements in various aspects of electrodischarge machining that reflect the state of the art in these processes are presented in this review paper. Researcher works on enhancement of material removal rate (MRR), reduction of tool wear rate (TWR), improve Surface Quality (SQ) by experimental investigation[13].

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