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# *A Review on Wire Cut EDM Process*

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***Abstract***

*Wire cut electric discharge machining process (WCEDM) is one of the rapidly growing non-contact machining process. This process is much more suitable technique for complex shapes that would otherwise be difficult to produce with conventional cutting tools and also very small work pieces, where conventional cutting tools may damage the part from excess cutting tool pressure. There is no contact between tool and work piece, thus separate sections and weak materials can machined without any difficulty. This paper discusses the literature review on wire cut EDM (WCEDM) process. It encompasses process parameters, tool material, and mode of dielectric medium used and also reviews about the data analysis technique used and finally explains the future trends of WCEDM in research.*

***Keywords:*** *Process parameters, tool and work piece material, data analysis technique, dielectric, Review, Wire cut EDM.*

## 1. INTRODUCTION

Machining processes is one in which a piece of raw material is cut into a defined shape and size by a controlled material removal process. The two main machining process are conventional and non-conventional machining processes. Electrical discharge machining (EDM) is one of the most widely used non-conventional machining processes.The main attraction of EDM traditional machining processes, is that this technique utilizes thermoelectric process to erode undesired materials from the work piece by a series of discrete electrical sparks between the work piece and the electrode. There are various types of EDM process found in machining process, among those types, wire cut EDM is the most preferred method in all industries.

Wire cut EDM (WCEDM) process, in which a thin single-strand metal wire in conjunction with de-ionized water (used to conduct electricity) allows the wire to cut through metal by the use of heat from electrical sparks.The world's first wire cut EDM (WCEDM) machine was produced by the Swiss firm Agie in 1969. These early machines were extremely slow. Nowadays, these machines are equipped with an automatic wire threading and can cut over 20 times faster, Carl Sommer and SteevSommer [1].

The effectiveness of this whole process stands on the number of input parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire feed and wire tension, different process response parameters such as material removal rate (MRR), surface roughness (Ra), Kerf width, wire wear ratio (WWR), surface integrity factors and also the tool and work piece material, mode of dielectric medium and other factors followed in WCEDM.

**PRINCIPLE OF WIRE CUT EDM**

The mechanism of material removal in EDM process, in which erosion effect is produced by the series of electrical sparks produced between the work piece and the electrode surrounded by dielectric fluid. But in the case of WEDM, thin wire of copper, brass etc., is used as electrode. The electrode in WCEDM has a very small diameter whose path is controlled by computer to produce the required shape. During this process the wire travel's downward or sidewise, and table movement is horizontal which is controlled by the CNC controller. Work piece is held on table with the help of fixtures. As this wire travels,a spark is produced between wire and work piece, because of voltage difference. A minimum gap should be there between the work piece and wire. The work piece and wire is surrounded by dielectric fluid, this eliminates the electric pulse created by wire.

 

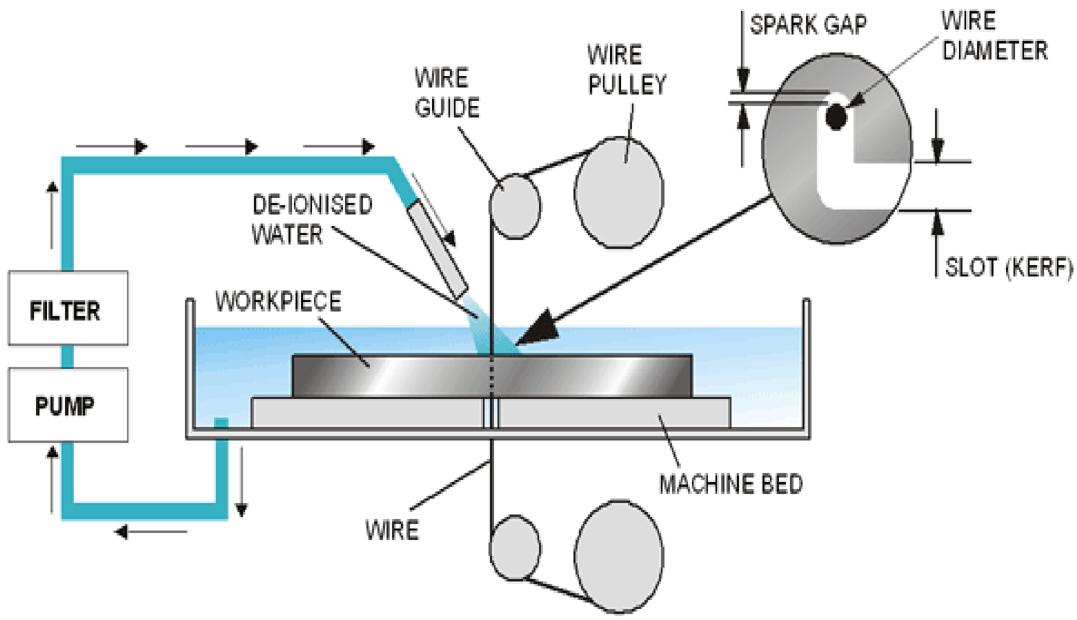


*Fig. 1: Schematic diagram of Wire Cut Electro Discharge Machining*

## 3. PROCESS PARAMETERS

### *Pulse-On Time*

Pulse-on time is the time duration for which the voltage pulse is applied. The voltage is applied between the work piece and the electrode, therefore producing discharge. If the pulse-on time is higher, then the energy applied will be higher, thus more amount of heat energy is produced during this period. The material removal rate depends upon the amount of energy applied during this time. It is expressed in micro seconds [25].

### *Pulse-Off Time*

Pulse-off time is the time gap in which discharges energy is released. It has no effect on discharge energy. Increase in pulse-off time decreases the cutting speed, thus the pulse-off time is kept low in order to obtain increased cutting speed. But during the reduction of pulse-off time there may be overload in the wire tool, causing breakage in wire.

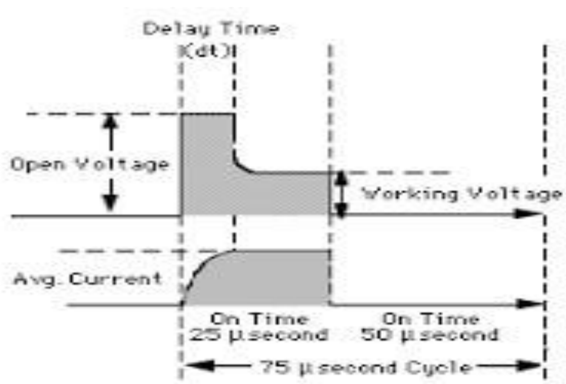


*Fig.2. Schematic diagram of WCEDM pulse*

***Servo Voltage***

Servo voltage acts as the base voltage to control the wire fluctuation. The smaller value in servo voltage set leads to an increase in number of electric sparks, resulting in higher machining rate. However, the state of machining at the gap may become unstable resulting in wire breakage.

***Peak Current***

Peak current is the amount of power used in discharge machining. The current increases until it reaches a pre-set value during each pulse-on time. Peak current is subjected by surface area of cut. There should be a higher peak current during roughing operation and details with large surface area.

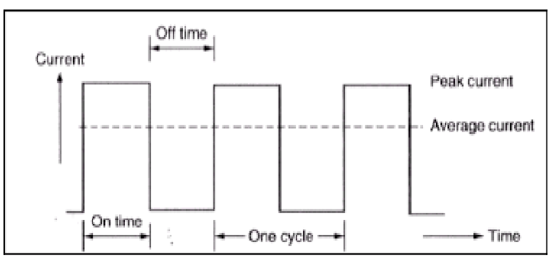


***Fig.3. sketch of peak current amplitude***

***Dielectric Flow Rate***

The rate at which the dielectric fluid is circulated is termed as dielectric flow rate. Flushing is an important for efficient WCEDM process. It is one of the important factors in a successful WCEDM operation.

Four methods of flushing:
1. Normal flow
2. Reverse flow
3. Jet flushing
4. Immersion flushing

***Wire Feed Rate***

If the wire feed rate increases, the consumption of wire and cost of machining will increase. Low wire feed will cause wire breakage in high cutting speed [23].

***Wire Tension***

For a straight and narrow wire, wire tension should be high. Otherwise, wire drags behind. An increase in wire tension increases the cutting speed and accuracy. Higher tension in wire decreases the wire vibration amplitude and thus decreases the cut width from which the speed is higher for the same discharge energy. However, when the applied tension is higher than the tensile strength of the wire, it leads to wire breakage [22].

## 4. RESPONSE PARAMETERS

### *Material Removal Rate (MRR)*

Material removal in WCEDM mainly occurs due to intense localized heating by point heat source for a small time frame. Such heating leads to melting and crater formation. No two sparks take place at the same side. They occur completely randomly so that one gets uniform average material removal over the whole tool cross section. Taper cut can be prevented with proper insulation of the tool. Over-cut cannot be prevented, because it is different to the EDM process.

### *Surface Roughness (RA)*

Surface roughness plays vital role in all machining process. It affects the functional attributes such as friction, wear and tear, light reflection, heat transmission, ability of holding a lubricant, coating etc. Thus, the desired surface finish is specified and appropriate processes are required to maintain the roughness quality. There are many roughness parameters in use. But, Ra is the most common roughness parameter. Many works has been done by different researchers on better surface roughness with various approaches. It is mainly affected by pulse-on time, peak current and cutting speed. Among these, pulse on time is found to be the most predominant parameter affecting the surface roughness.

### *KERF Width*

Kerf is the basic performance measures in WCEDM. It is the measure of the amount of material that is cutted-off during machining. It affects the accuracy of the dimension of the finished part. Kerf width depends on the gap voltage, pulse on time, pulse off time, wire feed and flushing pressure.

### *Wire Wear Ratio (WWR)*

WEDM is a thermo- electrical process in which material is eroded by sparks between the work piece and wire electrode. Along with this, some other particles from wire also gets erode, this phenomenon is called wire wear. This should be kept at minimum level. Wire failure occurs in WCEDM process due to the wire wear rate [29].

### *Surface Integrity*

Surface integrity is the condition of the surface of the work piece after being modified by a manufacturing process. The surface integrity changes the material's properties of a work piece or item. Surface integrity has a great impact on a parts function [24].

Amitesh Goswami [2] indicates the trim cut potential for high surface finish when compared to rough cut machining. In trim cut machining, pulse-on time has found to be the major factor that affecting the MRR (52.31%) and SR (74.69%).Very high value of surface finish can be obtained in trim cut machining. The best value of SR is obtained at pulse-on time: 0.3ls, pulse-off time: 26ls, peak current: 60A and wire offset: 0.12mm. Highest MRR and SR were obtained at pulse-on time: 0.6ls, pulse-off time: 14ls, peak current: 90A, wire offset: 0.10mmandpulse-ontime:0.45ls,pulse-offtime:14ls,peak current: 120A, wire off-set: 0.12mm respectively.S K Rajesh Kanna [3] in his research on WCEDM in stainless steel says that the values of optimum electrical process parameters among the existing parameter combinations are pulse on time 5 µ, pulse off time 8 µs, gap voltage 60 V, wire feed rate 8 mm per min has given the better multiple response.Jay M. Pujara1 [4] details the process parameter optimization for MRR and Surface Roughness during Machining LM6 Aluminum. The improved result in MRR is noted as high as 0.3845 gm/min while for the SR it has been noted at 0.1222 µm. Thus this method has reduced SR and increased MRR for the process. G.Ugrasena [5] says that each control factors are affecting the response variables to different extent. Dara Sudhakara [6] carried out an experiment on Parametric Optimization of Wire Electrical Discharge Machining of Powder Metallurgical Cold Worked Tool Steel. It says that the optimum levels for getting minimum surface roughness is ON = 108 ls, OFF = 63 ls, IP = 11 A, SV = 68 V and WT = 8 g. Yingmou Zhu [7] conducted Machining of Micro Rotational Parts with Wire EDM Machine. The experimental results showed that the maximum MRR can reach up to 3.09 mm3/min when the radial in-feed was 50Pm.Y. Zhaoa [8], Experimental Investigations into EDM Behaviors of Single Crystal Silicon Carbide tells about the cutting speed of foil EDM of sic can be improved by increasing the discharge current and using thinner foil electrode. Thermal cracks caused by thermal stress are considered to be one main mechanism of the removal of the material in EDM process of sic.

## 5. TOOL AND WORK PIECE MATERIALS

More researches has been done in the field of wire cut EDM, to increase material removal rate, tool life, surface finish and to minimize the time consumed for the process. For high speed cutting and highly accurate machining, a wire electrode should have physical properties such as high conductivity, tensile strength, elongation, melting point etc. The wire electrode is given negative polarity. It is made up of several materials such as copper, brass, bronze, coated wires, composite materials etc [15] [17].

Kamlesh Joshi [9] in his work onUltra-thin silicon wafer slicing using wire-EDM. For, slicing of ultra-thin wafer of 10mm thickness and 30 mm height without wire breakage, this response methodology is adopted. It minimize the wafer thickness and kerf-loss while maximizing the slicing rate shows that that the least wafer thickness of 140.5 µm is obtained with kerf-loss of 130 µm and slicing rate 0.96 mm/min. Wafer thickness of 150 µm can be obtained at high slicing rate of 1.05 mm/min and minimum kerfloss of 121 µm. M. Zulafif Rahim [10] explains the Wire-cut EDM of sisic-preliminary investigation in machining parameter. Sisic requires high sparking power due to the higher electrical resistivity and thermal conductivity of material. In this research, high peak current was needed to initiate and stabilize the spark. High thermal conductivity of material caused to the heat loss due to the conductivity. Yasuhiro Okamoto [11] details the use of brass coated steel wire tool. The brass coated steel wire electrode with track-shaped section of aspect ratio 1:2.0 could perform the smaller vibration and the sable running up to 300 m/min. The brass coated steel wire electrode with track-shaped section could accomplish the uniform and straight kerf shape by increasing the wire tension. Atsushiitokazu, Takashihashim oto [12] conducted experiment on Wire Electrical Discharge Slicing For Silicon Carbide. Wire electrical discharge slicing (EDS) method is applied to 100 mm-square sic polycrystalline block. We successfully obtained the average thickness of 385 µm for nine sliced plates by ten-wires EDS. The thickness variation was measured to be less than 11.2 µm. This is the first demonstration of ten-wires EDS for 100 mm-square sic material. A.B. Puria [13], Modelling and analysis of the wire-tool vibration in wire cut EDM, explains that higher the thickness of the work piece, the larger will be the maximum amplitude of vibration for a given span of the wire between the guides and a0. Thus, minimization of imprecision and inaccuracy due to wire-tool vibration will find potential industrial application for manufacturing jobs with ultra-precision contours [28].

## 6. MODE OF DIELECTRIC MEDIUM

Dielectric medium is a liquid which should be non-conductive. This medium provides two main functions: it drives away the chips and prevents their sticking to work piece and tool. It increases the intensity of discharge after getting ionized and thus accelerates metal removal rate. Dielectric medium should have enough strong dielectric resistance. Kerosene and demonized water is the main dielectric medium used in WCEDM [15] [16] [17].

There are various modes of dielectric medium used in WCEDM process such. Among those modes, flushing is widely used in this process [18] [26]. Flushing of dielectric, plays a very important role in the maintenance of stable machining and the achievement of close tolerance and high surface quality. Four methods of flushing are,

1. Normal flow
2. Reverse flow
3. Jet flushing
4. Immersion flushing

***Normal Flow***

In normal flow, the dielectric is introduced with high pressure through one or more passages. It is forced to flow through the gap between tool and work piece. The flush holes are generally placed in areas where the cuts are deepest. Normal flow is, sometimes, undesirable because it produces a tapered opening in the work piece [27].

***Reverse Flow***

Reverse flow is useful in machining deep cavity dies, where the taper produced using the normal flow mode can be reduced. The gap is submerged in the dielectric. Instead of pressure being applied, a vacuum is created in the flow line. There is no side sparking in reverse flow flushing, thus no taper is produced.

***Jet Flushing***

The defined machining can be done by using spray or jet of fluid directed against the machining gap. Machining time is much longer in jet flushing than with the normal and reverse flow modes.

***Immersion Flushing***

For shallow cuts or perforations of thin sections, simple immersion of the discharge gap is sufficient. Cooling and debris removal can be done during immersion cutting by giving relative motion between tool and work piece. Vibration or cycle interruption comprises periodic reciprocation of the tool relative to the work piece to effect a pumping action of the dielectric [14].

## 7. DATA ANALYSIS TECHNIQUE

In today's digital era, learning data gathered from different software systems have a great impact on the quality of the interaction experience. There are two main directions that comes to enhance the emerging research domains of Intelligent Data Analysis (IDA) and Human Computer Interaction (HCI). In WCEDM process, various analysis software's are used such as ANOVA, Taguchi's method, orthogonal array, multiple linear regression mode, cut-cell method, AI etc., to analysis the data acquired from WCEDM process [19] [20] [21] [30].

## CONCLUSION

From the present study, it is found that all of the input parameters affect the Wire cut EDM process. Among the significant factors pulse-on time, pulse-off time and peak current has the maximum influence on the entire process. Wire feed, wire tension and water pressure has minimum effect on the process. Thus, it is essential to optimize the process parameters to achieve better results. The tool materials used for WCEDM process plays a vital role in the efficiency of cutting process. It increase material removal rate, tool life, surface finish and to minimize the time consumed. And various data analysis techniques are discussed. Here are somepoints which is always remembered during research work on WEDM process.

- High value of current results in increased intensity of spark and results in high Material Removal Rate.
- By decreasing pulse duration and discharge current, Surface Roughness can be improved.
- Increased pulse duration and open circuit voltage, increases the wire wear ratio.
- The newly developed analysis software such as ANOVA, Taguchi's method, AI etc., are used to eliminate the data calculation time.

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