A Review on Effect of Process Parameter on Performance Measurement in WEDM

Viahvas Patel[1], VAIBHAV JAVALE[2]

[1] Research scholar, Mechanical Engg. Dept., Aadishwar College of Technology-Gandhinagar, Gujarat, India

[2] Asst. Prof. Vaibhav Javade, Mechanical Engg. Dept., Aadishwar College of Technology-Gandhinagar, Gujarat, India

ABSTRACT

With the development of technology, the scientists and technologists in the field of manufacturing are facing more and more challenges. Technologically advanced industries such as aeronautics, nuclear reactors and automobiles have been demanding high strength temperature resistant (HSTR) materials having high strength to weight ratio. Researchers in the area of materials science are developing materials having higher strength, hardness, toughness and other diverse properties. This also needs the development of improved cutting tool materials so that productivity is not hampered. Hence the increased use of nonconventional machining methods in manufacturing continues to grow at an accelerated rate, Wire electrical discharge machining (WEDM) is one of the important nontraditional machining processes. This is used for machining of difficult to machine materials and intricate profiles. Being a complex process, it is very difficult to determine optimal parameters for improving cutting performance. Wire electrical discharge machining (WEDM) is extensively used in machining of conductive materials when precision is of prime importance. Wire electrical discharge machining (WEDM) allowed success in the production of newer materials, especially for the aerospace and medical industries. This paper reviews the notable research work done by various researchers in the field of wire electrical discharge machining.

Keyword: - *Wire electrical discharge machining (WEDM), Material removal rate (MRR0, Surface roughness*

1. INTRODUCTION

Machining removes certain parts of the work pieces to change them to final parts. Machining nowadays has been classified in two types: (1) Traditional Machining; (2) Non-traditional Machining. Traditional Machining, also known conventional machining requires the presence of a tool that is harder than the work piece to be machined. This tool should be penetrated in the work piece to a certain depth. Moreover, a relative motion between the tool and work piece is responsible for forming or generating the required shape. The absence of any of these elements in any machining process such as the absence of tool-work piece contact or relative motion, makes the process a nontraditional or non-conventional one [1].

Non-conventional machining processes are well established in modern manufacturing industries as they are capable of machining hard materials. Nonconventional machining processes are classified according to the machining action

which helps in material removal from the work piece. The material removal mechanism, machining system components, process variables, technological characteristics, and industrial applications are different for all these processes [1].

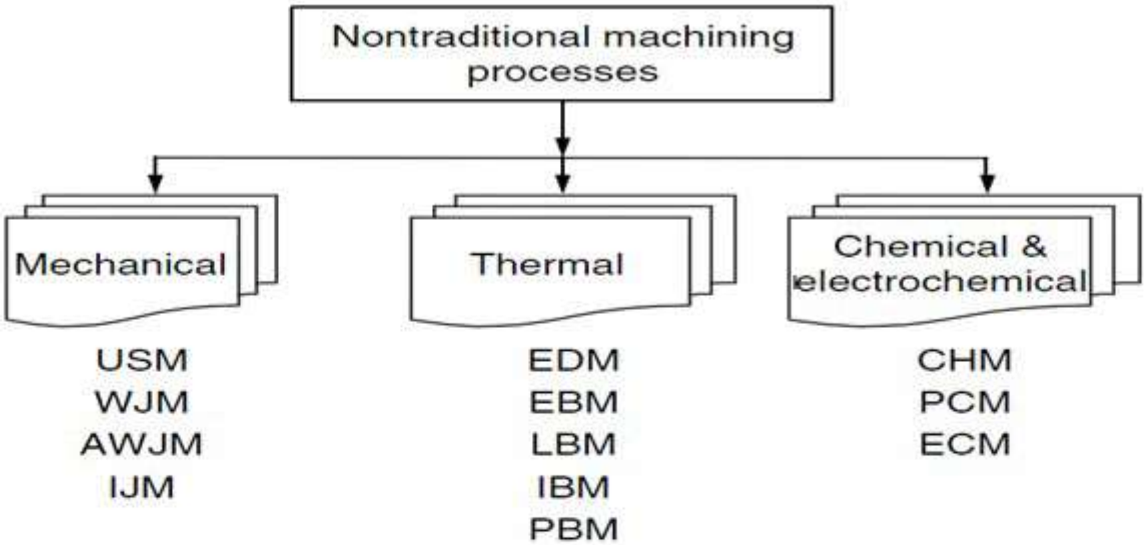

Fig. 1.1 Classification of Non-Traditional processes [1]

1.2 Historical background

The phenomenon of erosion of metals by electric spark was first noticed by Joseph Priestily in 1878 but this was not used for machining of metals until 1930s. Controlled machining of metals by electric sparks was first done by Lazarenko in Russia in 1944 [2].

One of the most widely used Non-Conventional Machining process in industry is Electrical Discharge Machining (EDM). Electric Discharge Machining is a nontraditional concept which is based on the principle of removing material by means of repeated electrical discharges between the tool termed as electrode and the work piece in the presence of a dielectric fluid [3]. Electrical Discharge Machining (EDM) uses thermal energy to achieve a high-precision metal removal process from a fine, accurately controlled electrical discharge. The electrode is moved towards the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric [1]. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece. EDM does not make direct contact between the electrode and the work piece thus it can eliminate mechanical stresses, chatter and vibration problems during machining [3, 4].

EDM is commonly used for machining very hard and tough materials such as tool steels and carbides and for finishing parts for aerospace, automotive industry and surgical components. It is also used to produce complex shapes and small diameter holes, which are difficult or impossible to machine using conventional methods. Since EDM uses an electric discharge to cut the material, its use is limited to conductive materials [1, 3-5].

1.2 Wire Electric Discharge Machining (WEDM)

WEDM is considered as a unique adoption of the conventional EDM process which comprises of a main worktable, wire drive mechanism, a CNC controller, working fluid tank and attachments. The work piece is placed on the fixture table and fixed securely by clamps and bolts. The table moves along X and Y-axis and it is driven by the DC servo motors. Wire electrode usually made of thin copper, brass, molybdenum or tungsten of diameter 0.05-0.30 mm, which transforms electrical energy to thermal energy, is used for cutting materials. The wire is stored and wound on a wire drum which can rotate at1500rpm. The wire is continuously fed from wire drum which moves though the work piece and is supported under tension between a pair of wire guides located at the opposite sides of the work piece. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining. Also the work piece and the wire electrode (tool) are separated by a thin film of dielectric fluid that is continuously fed to the machining zone to flush away the eroded particles. The movement of table iscontrolled numerically to achieve the desired three-dimensional shape and accuracy of the work piece [8].

1.2.1 WEDM Process

WEDM is a process which erodes and removes material by using the channel of plasma generated by electric sparks between two conductive materials (i.e. electrode and the work piece), this channel of plasma converted into thermal energy at a temperature range of 8000 to 12000º C at a pulsating direct current supply of 20000 to 30000 Hz. The electrode and work piece are separated by a small gap being immersed in dielectric fluid, an electric spark is produced in between this small gap and the work piece material is eroded, as the pulsating current is turned off, the plasma breaks down which leads to sudden reduction in the temperature and the eroded material is flushed away with the help of dielectric fluid in the form of microscopic debris. With each electric spark discharge a small crater is formed on both the work piece and the electrode which is a prime decider in the final surface quality [3, 9]. The taper can ranging from 15º for a 100 mm thick to30º for a 400 mm thick work piece can be obtained on the cut surface material [10]. A WEDM schematic is shown in Fig. 1.2.

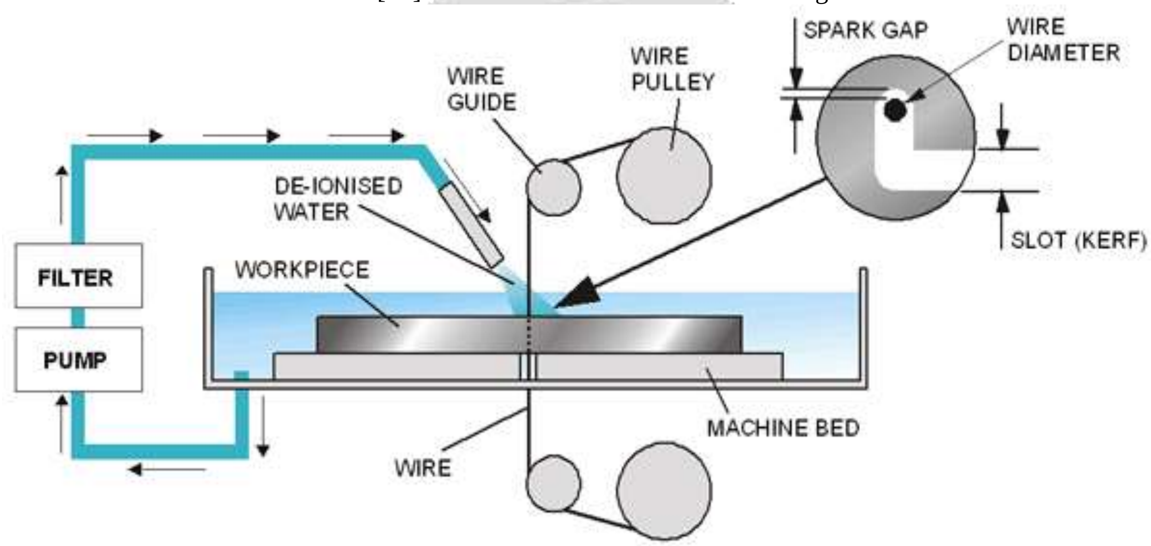

Fig.1.2 Schematic Diagram of WEDM process [10]

Deionized water is used as the dielectric as it is the purest form of water and it acts as an insulator. Normal tap water contains minerals which may be too conductive for Wire EDM, in order to control the water conductivity; water is deionized by passing it through a resin tank which eliminates the conductive elements of water. This deionized water is circulated with the h e l p of a pump. As the machining operation is performed, conductivity of water rises and it is again re-circulated through the resin tank [6]. The purpose of deionised water is to stabilise the spark erosion path and to act as the dielectric medium which is forced into the cutting gap to flush out the eroded metal. There is virtually no cutting force on the part of the machine because the wire electrode and work piece never make contact [3].

WEDM process is usually used in conjunction with CNC and will only work when a part is to be cut completely through. The melting temperature of the parts to be machined is an important parameter for this process rather than strength or hardness. The surface quality and material removal rate (MRR) of the machined surface by wire EDM will depend on different machining parameters such as applied peak current, and wire materials. WEDM process is commonly conducted on submerged condition in a tank fully filled with dielectric fluid; nevertheless it also can be conducted in dry condition. This method is used due to temperature stabilization and efficient flushing in cases where the work piece has varying thickness (10).

2. LITERATURE REVIEW

U. A. Dabade, S. S. Karidkar et al.[1] have analyse the machining conditions for Material Removal Rate (MRR), Surface Roughness (SR), kerf width on WEDM for Inconel 718 using DOE such as Taguchi methodology. The experimental analysis is carried out using Minitab 16 software and it was observed that pulse-on-time is the most influential factor for all the response variables such as MRR, SR, Kerf width. Along with this, peak current was observed to be next significant parameter for kerf width whereas for MRR and SR servo voltage was observed to be the next significant parameter.

A. Dey, V.R.Reddy Bandi, K.M.Pandey et al.[2] had worked on experimental investigations of the effect of machining parameters (pulse-on time, pulse-off time, wire speed) on the performance measure like cutting speed (CS), kerf width(KW) and surface roughness(SR) on wire electrical discharge machining (WEDM) for AA6061. Response surface methodology is employed to analyse the effects of significant machining parameters on the performance characteristics. The main significant factors that affect the Cutting speed is pulse on time. The CS increases with an increase in pulse on time. The pulse on time have statistical significance on both KW and SR. pulse off time and wire speed on SR are not that much significant. The SR decreases with an increase in pulse on time (Ton) whereas with increase in wire speed it increases slightly.

Sreenivasa Rao M, Venkaiah N et al.[3] an attempt has been made to investigate the effect of WEDM process parameters such as pulse on time, pulse off time, peak current and servo voltage in machining of Nimonic-263 alloy. Response Surface Methodology (RSM) has been used for experimental plan. The significance of process parameters are estimated by ANOVA analysis. It was found from the ANOVA results that, pulse on time, peak current and interaction effect of pulse on time and peak current are more influencing parameter. Whereas for SR it was found that pulse on time, peak current, servo voltage.

Prajapati and Patel et al.[4] evaluates the effect of pulse On-Off time, voltage, wire feed and wire tension on MRR, SR, kerf in Wire EDM. The experiments were carried out on wire-cut EDM machine (ELEKTRA SUPERCUT 734) using AISI A2 tool steel as work piece in form of square bar. Based on control factors and their levels L27 orthogonal array was selected. Analysis of data optimization and performance is done by Response Surface Methodology (RSM).

Ravindranadh Bobbili, V. Madhu, A.K. Gogia et al.[5] use a Taguchi method coupled with Grey relational analysis is planned for wire-EDM operations on ballistic grade Aluminum alloy. Experiments have been performed with four machining variables: pulse-on time, pulse-off time, peak current and spark voltage. Experimentation has been planned as per Taguchi technique. Three performance characteristics namely material removal rate (MRR), surface roughness (SR) have been chosen for this study. Results showed that pulse-on time, peak current and spark voltage were significant variables to Grey relational grade. The confirmation tests have also been performed to validate the results obtained by Grey relational analysis and found that great improvement with 6% error is achieved.

Aniza Alias, Bulan Abdullah, Norliana Mohd Abbas et al.[6] evaluates the influence of three different machine rates which are 2 mm/min, 4 mm/min and 6 mm/min with constant current (6A) with WEDM of Titanium Ti-6Al-4V. The effects of different process parameters on the kerf width, material removal rate and surface roughness are also discussed. The best combination of machining parameter viz. machine feed rate (4 mm/min), wire speed (8 m/min), wire tension (1.4kg) and voltage (60V) were identified. The paper highlights the importance of process parameters and different machining conditions on kerf width, MRR, surface roughness (Ra) and surface topography. The machine feed rate increases, the kerf width decreases. By increasing machine feed rate, the MRR will increases simultaneously. Smoother surface can be obtained with low setting of machine feed rate. Machine feed rate have been proven to play an important role in this experimental work. Since the low kerf and the high MRR are equally important goals in WEDM, equal machine feed rate are recommended.

Amrish Raj. D , Senthilvelan.T et al.[7] optimize the cutting conditions of Wire-EDM for better surface roughness and material removal rate for Titanium alloy. The cutting parameters taken for study in this work includes pulse-on time, pulse off time and wire feed rate. The measured response includes surface roughness and material removal rate. Box-Benkhen approach has been used as the experimental strategy. The results shows that pulse on time and pulse off time are the important parameters that influences the surface roughness whereas the pulse off time has major influence on material removal rate (MRR).

V. Chengal Reddy, N. Deepthi, N.Jayakrishna et.al[8] investigate the effect of various process parameters such as pulse on time, pulse off time, wire tension, current for Aluminum HE30. The experimentation has been completed with the help of Taguchi grey relational analysis. Grey relational analysis is used to optimize the process parameters on Material removal rate, surface finish and kerf width. Grey Relational Analysis (GRA), for finding the optimal parameters affecting MRR, Surface Roughness and Kerf Width are found to be Pulse on time = 112µs, Pulse off time=61µs, Current=11Amp, Wire tension=780gm. Higher MRR value of 0.153mm³/min, lower Surface Roughness value of 2.861µm and lower Kerf Width value of 0.257mm.

G.Ugrasen, H.V.Ravindra, G.V.Naveen Prakash, Y.N.Theertha Prasad et al.[9] study on the optimization of process parameters in the wire EDM. HCHCr was selected as a work material. This work material was machined using different process parameters based on Taguchi method. Parameters such as pulse-on, pulse-off, current and bed speed was varied. The response variables measured for the analysis are surface roughness, material removal rate. ANOVA has been carried out to know the magnitude of factor affects. Further the verification experiment has been carried out to confirm the performance of optimum parameters. It was found that, each control factors are affecting the response variables to different extent. Comparing the ANOVA table for the HCHCr material, for the surface roughness and MRR it is concluded that, the control factor pulse on time is having more effect on it. The verification experiment was conducted using the optimized process parameters and the performance characteristics Surface roughness and MRR. The values were improved from 2.105µm to 2.055µm for surface roughness, 11.899 mm3/min to 12.23132mm3/min for MRR. After the confirmation experiment, it was concluded that, the optimized parameters have shown good results, so these parameters can be used to achieve good surface finish, higher MRR.

Aniza Alias, Bulan Abdullah, Norliana Mohd Abbas et al.[10] aims to investigate the influence of feed rate on the performance of WEDM on Titanium Ti-Al-4V. Brass wire was employed as the electrode for the investigation. The results on kerf width and material removal rate are graphically tabulated. The best combination of machining parameter viz. machine feed rate (4 mm/min), wire speed (8 m/min), wire tension (1.4kg) and voltage (60V) were identified. The selection of parameters depends on the requirements based on a better surface roughness or a maximum material removal rate. Hence an appropriate combination of variables can be selected accordingly. Furthermore, this combination can contributes to increase production rates perceptibly by reducing machining time. The outcome of this study will help in improving the quality of Titanium Ti-6Al-4V products as well as minimizing the machining cost to realize the economic potential to the fullest.

Vikram Singh, S.K. Pradhan et al.[11] investigate the effects of various WEDM process parameters such as pulse on time, pulse off time, servo voltage and wire feed rate on the Material Removal Rate (MRR), Surface Roughness (SR) and cutting rate. Secondly, to obtain the optimal settings of machining parameters at which the Material Removal Rate (MRR) and cutting rate are maximum and the Surface Roughness (SR) is minimum in a range. In the present investigation, AISI D2 steel specimen is machined by using brass wire as electrode and the response surface methodology (RSM) is used for estimate the optimum machining condition to produce the best possible response within the experimental constraints. From the experiment it is found that the two main significant factors that affect the Cutting rate are Pulse on time and Pulse off time respectively. The two main significant factors that affect the Surface Roughness are pulse on time and Servo voltage respectively. The two main significant factors that affect the Material Removal Rate are Pulse on time and Pulse off time respectively. The optimum parameters of combination setting is Pulse on time 112.99 µs, Pulse off time 45µs, Servo Voltage 20 volts, and Wire feed 4.85mm/min for maximizing MRR and Cutting, minimize the SR.

Brajesh Kumar Lodhi, Sanjay Agarwal et al.[12] optimize the machining conditions for surface roughness based on Taguchi methodology. Experiments were carried out under varying pulse-on-time, pulse-off-time, peak current, and wire feed. Analysis of variance (ANOVA) were employed to the study the surface roughness in the WEDM of AISI D3 Steel. It was observed that the discharge current was the most influential factors on the surface roughness.

P. Sivaprakasam, P. Hariharan, S. Gowri et al.[13] investigate the influence of three different input parameters such as voltage, capacitance and feed rate of wire electrical discharge machining (WEDM) performances of material removal rate (MRR), Kerf width (KW) and surface roughness (SR) using response surface methodology. The experiments are carried out on titanium alloy (Ti-6Al-4V). The machining characteristics are significantly influenced by the electrical and non-electrical parameters in WEDM process. Analysis of variance (ANOVA) was performed to find out the significant influence of each factor. The model developed can use a genetic algorithm (GA) to determine the optimal machining conditions. The optimal machining performance of material removal rate, Kerf width and surface roughness are 0.01802 mm3/min, 101.5 mm and 0.789 mm, respectively, using this optimal machining conditions viz. voltage 100 V and feed rate 15 mm/s.

Amitesh Goswami, Jatinder Kumar et al.[14]uses Taguchi method for wire electrical discharge machining (WEDM) of Nimonic-80A alloy. The machining characteristics that are being investigated are material removal rate (MRR) and surface roughness (SR). The study makes use of experimentation planned and executed as per Taguchi methodology. The Investigation indicated that material removal rate and surface roughness increases with increase in pulse-on time and decreases with increase in pulse-off time. Significant interactions have been found between pulse-on time and pulse-off time, pulse-on time and peak current , pulse-off time and peak current for material removal rate; and pulse-on time and peak current for surface roughness.

G. Selvakumar, G. Sornalatha, S. Sarkar, S. Mitra et al.[15] aims at the selection of the most optimal machining parameter combination for wire electrical discharge machining (WEDM) of 5083 aluminum alloy. Based on the Taguchi experimental design method, a series of experiments were performed by considering pulse-on time, pulse-off time, peak current and wire tension as input parameters. The surface roughness and cutting speed were considered responses. The influence of the input parameters on the responses was determined. The optimal machining parameters setting for the maximum cutting speed and minimum surface roughness were found using Taguchi methodology. An experimental investigation on wire electrical discharge machining of 5083 Al alloy was presented. ANOVA test was performed to determine the level of significance of the parameters on the cutting speed and surface roughness. ANOVA revealed that the CS was independent on wire tension and *R*a was independent on pulse-off time and wire tension.

3 CONCLUSION

Wire-cut electrical discharge machining is one of the most emerging non conventional manufacturing processes for machining hard to machine materials and intricate shapes which are not possible with conventional machining methods. This is more efficient and economical for machining hard to machine materials. The effect of various parameters and setting of various parameters at their optimal levels is very much required for manufacturers. From the literature, the parameters and their effects observed are given as under :

- Higher the pulse-on time, higher will be the energy applied there by generating more amount of heat energy during this period. Material removal rate and wire wear rate increase with increase in pulse on time where as surface finish will decrease.
- Reducing pulse off time can increase cutting speed, by allowing more productive discharges per unit time. However, reducing Off time, can overload the wire, causing wire breaks and instability of the cut by not allowing enough time to evacuate the debris before the next discharge.
- Servo voltage acts as the reference voltage to control the wire advances and retracts. At higher value of SV the gap between workpiece and wire becomes wider and it decreases the no of sparks, stabilizes electric discharge and the rate of machining slows down. Whereas at smaller value of SV, the mean gap becomes narrow which leads to an increase in number of electric sparks, speed up the machining rate and unstable discharge results in wire breakage.
- Peak current is the amount of power used in discharge machining and is measured in unit of amperage. The current increases until it reaches a preset value during each pulse on time, which is known as peak current. Peak current is governed by surface area of cut. Higher peak current is applied during roughing operation and details with large surface area. MRR directly increases with increased peak current.
- Gap voltage is also called open circuit voltage and specifies the supply voltage to be placed on the gap, greater this value, the electric discharge becomes greater. If the gap voltage increases, the peak current will also increases, which leads to higher MRR.
- Dielectric flow rate is the rate at which the dielectric fluid is circulated. Flushing is important for efficient machining.
- As the wire feed rate increases, the consumption of wire and cost of machining will increase. Low wire speed will cause wire breakage in high cutting speed.
- If the wire tension is high enough the wire stays straight otherwise wire drags behind. Within considerable range, an increase in wire tension significantly increases the cutting speed and accuracy. The higher tension decreases the wire vibration amplitude and hence decreases the cut width so that the speed is higher for the same discharge energy. However, if the applied tension exceeds the tensile strength of the wire, it leads to wire breakage.

From the literature it has been observed that most of the researchers concentrated on Electrical parameters, Electrode Parameter for find effect of this parameter on output parameter in WEDM. Intensive work has been carried out on various materials as well as different process parameters. Pulse on time, Pulse off time, servo voltage, wire tension, peak current, are the most significant and effective parameters of MRR, Surface Roughness, Kerf width in WEDM. Very few researchers have worked on Aluminium material as work material. Wire material is most important parameter for the WEDM but most of the researchers work on soft brass wire material.

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