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REVIEW ON EFFECTS OF PROCESS PARAMETERS IN WIRE CUT EDM

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Abstract - *WEDM (Wire electrical discharge machining) is a precision machining method for cutting electrically conductive materials. It is an unconventional machining process that produces precision parts that match the dimensional tolerances of our designs within the range of ±0.0001mm. As the residual stress results in premature failure of parts, the WEDM is preferred for hard to machine materials such as Inconel, Nickel, and other Super alloys. In the present paper, earlier and recent work was reviewed, segregated and evaluated on the effect of wire material, diameter, dielectric fluid, wire wear, pulse on and off times and machining characteristics such as kerf size, machining efficiency, material surface characteristics, etc. This paper also focused on hybrid and ultrasonic-assisted WEDM used for machining of different materials. This paper discussed the major research studies in WEDM.*

Key Words: Wire Electrical Discharge Machine, Wire EDM, WPS D2 Steel, Pulse on time, Pulse off Time, Peak Current, Servo Feed.

1. INTRODUCTION

Machining process plays a major role in manufacturing industries where quality and cost are taken as a benchmark. WEDM is the most influential machining processes overall unconventional machining processes for difficult to machine materials (such as tungsten carbide, graphite, molybdenum, tool steel, titanium, zirconium, copper, aluminum, Waspaloy, Inconel, Hastelloy, conductive ceramics, polycrystalline diamond compacts, metal matrix composites etc.) which are widely used in manufacturing industries such as aerospace, nuclear reactors, automobiles, etc. In WEDM, the material removal process will take place with the help of heat generated by electrodes made of electrically conductive metals.

The machining process takes place without contact between the wire tool and the workpiece, and therefore the cutting is done without residual stress, since the workpiece cannot be subjected to cutting pressure. This type of advantages makes WEDM an exemplary method for machining precision parts as well as machining complex and hard workpieces with complicated profiles and shapes that are difficult to machine on conventional machines. WEDM is a potential thermoelectric machining technique and it is a non-contact machining process i.e., the wire electrode does not come in contact with the workpiece electrode, this technique was invented for the purpose of better machining accuracy. The material was eroded by a series of controlled sparks between two electrodes. Both electrodes are connected to a DC pulse power source and immersed in a dielectric liquid; the liquid behaves as an electrical conductor, which behaves as an electrical insulator until the time of ionization.

Spark discharges occur in the small gap between the electrodes with a frequency of thousands of sparks per second. At each spark moment with a period of approx. 10-4 –10-6 s, the liquid medium is deionized and ionized. The vicinity of the cutting area is heated to 10,000-20,000 ºC and the dielectric medium around this area evaporates, especially when the pressure increases. In addition, a small amount of workpiece material and wire liquefies and vaporizes, creating smaller craters on the surface of the workpiece. After the spark stops and the starting moment begins, the pressure drops lead to the condensation of the metal balls that have been discharged by the flowing dielectric medium.

2. LITERATURE REVIEW

- Literature reviews were categorized based on process parameters, electrode wire, material surface, machining efficiency, hybrid WEDM, pulse, kerf, dielectric fluid, ultrasonic assisted WEDM, discharging systems, dry WEDM and Thermal. Process parameters: There are four major parameters, which affect the WEDM process. Selection of the correct parameters for WEDM to get better performance is an important task.

- **Peak Current:** Maximum supplied current for each regular pulse from the generator/power supply. Gap voltage: A proper gap is necessary to generate sparks between the workpiece and the wire electrode. Therefore, WEDM discharge gap is about 0.005 to 1.0 mm.
- **Servo Feed:** The servo feed system provides balanced operation even at machine running conditions. (P off time > P on time)
- **Pulse on Time:** Metal removal rate is correlative to the amount of power supplied during the pulse on time. The longer the pulse, the more the material will be removed.
- **Pulse off Time:** One cycle will finish when required pulse off time maintained prior to starting of the coming cycle. Pulse off time influences the stability and accelerates the cut.

Table -1: Liturature Review

Sr. No.	Author	Title	Tool / Workpiece Material & Specification	Processing Parameter	Significant Results
1	Deepak Kumar Gupta, Avinash Kumar Dubey	Multi-process parameter optimization of wire EDM on shape memory alloy (Ni54.1Ti) using Taguchi approach	1. Workpiece Material - Nickel-based Titanium 2. Tool Electrode - Co Cu alloy	1. Pulse on Time (Ton) - 18, 22, 26 2. Pulse off Time (Toff) - 40, 48, 56 3. Ip Peak Current (A) - 160, 180, 200	1. Pulse on time is the most significant parameter, MRR increases with increase Ton 2. Optimal parameters for better MRR are zinc coated brass electrode Ton 26us, Toff 48us, and Ip 200A 3. The roughness of the surface increases with the increase of Ton 4. Results parameter better for surface finish
2	M. Arunadevi, C.P.S. Prakash	Predictive analysis and multi-objective optimization of the wire-EDM process using ANN	1. Workpiece Material - Aluminum alloy (Al7075) 2. Tool Material - Alumina (Al2O3)	1. Voltage (Volt) - 75, 100 2. Pulse on Time (Ton) - 40, 30, 20 3. Pulse off Time (Toff) - 9, 12, 15 4. Current (I) - 2, 4, 6 5. Bed Speed (um/s) - 50, 150, 250	The influence of input parameters such as pulse-on, Voltage, pulse-off, current, and bed speed on MRR and SR is studied by modeling the experimental data using Artificial Neural Network
3	Sadananda Chakraborty, Souren Mitra and Dipankar Bose	Experimental investigation on enhancing die corner accuracy during powder mixed wire EDM of Ti6Al4V	1. Workpiece Material - Ti6Al4V (Titanium- based alloy) 2. Electrode - Ezeecut plus wire electrode	1. Peak current (Ip) - 1, 2, 3, 4 2. Pulse on Time (Ton) - 30, 50, 70, 90 3. Pulse off Time (Toff) - 2, 5, 8, 11 4. Powder types - B4C, graphite, silica, and Al2O3	A prominent methodology namely Taguchi analysis is applied to evaluate the process parameters and determine the most significant parameters
4	Divya Marelli, Sateesh N., and Ram Subbiah	Review on multi-objective optimization of wire cut EDM process parameters using grey relational analysis	1. Workpiece Material - Inconel 825 2. Electrode - AISI D3	1. Pulse on Time (Ton) - 2. Pulse off Time (Toff) - 1, 3, 5 3. Peak current (Ip)	It is demonstrated that the quality characteristics considered in the present investigation are of both smaller the-better type (SR and kf) and larger the-better type (MRR) and

				- 4, 8, 12 4. Servo voltage -	subsequently conflicting with one another
5	Ozan Can Ozaner, Gokhan Dursun, Guray Akbulut	Effects of wire-EDM parameters on the surface integrity and mechanical characteristics of additively manufactured Inconel 939	1. Workpiece Material - Inconel 939 2. Electrode - Thermo Tex copper wire	1. Pulse on Time (Ton) (us) - 0.1, 0.4, 0.6 2. Pulse off Time (Toff) (us) - 3, 6, 12 3. Voltage (V) - 80, 120, 200	1. The surface properties of Inconel 939 are considerably affected by Wire EDM parameters as the main inputs such as pulse on, pulse off and voltage leads to noteworthy change 2. In addition to examining the Wire EDM parameters individually, it was found that surface integrity is affected by the ratio with pulse off and pulse on
6	Sahil Sharma, Umesh Kumar Vates, Amit Bansal	Parametric optimization in wire EDM of D2 tool steel using Taguchi method	1. Workpiece Material - D2 steel (D2 tool steel)	1. Pulse on Time (Ton) - 113, 116, 119 2. Pulse off Time (Toff) - 30, 35, 40 3. Peak current (Ip) - 170, 200, 230 4. Wire tension - 8, 10, 12	1. Using Taguchi technique for Ton initially decreases and further increases 2. Value of MRR for Toff constantly reduces 3. The value of MRR for Ip increases by increasing level
7	Ranjit Singh, Ravi Pratap Singh, Mohit Tyagi, Ravinder Kataria	Investigation of dimensional deviation in wire EDM of M42 HSS Using cryogenically treated brass wire	1. Workpiece Material - M42 HSS	1. Pulse on Time (Ton) - 110, 115, 120 (mu) 2. Pulse off Time (Toff) - 45, 50, 55 (mu) 3. Spark Gap Voltage (SV) - 40, 50, 60 (V) 4. Wire Feed (WF) - 3, 5, 7 (m/min)	1.The pulse on time (Ton) and pulse off time (Toff) have more discernible impacts on the dimensional deviation of the processed M42 work material
8	M. Fakkir Mohammed and K. Lenin	Optimization of Wire EDM process parameters using Taguchi technique	1. Workpiece Material - Aluminum Alloy (AA 6082-T6)	1. Pulse on Time (Ton) (us) - 33, 36, 39 2. Pulse off Time (Toff) (us) - 5, 7, 10 3. Current (A) - 1, 1.5, 2	In Taguchi Analysis Surface Roughness versus Pulse on, Pulse off and Current has carried out an average of every level in terms of S/N ratios area
9	Ranu Maurya, Rajesh Kumar Porwal, Vinod Kumar	Experimental investigation & modeling of wire EDM process during machining of Nicrofer 5716	1. Workpiece Material - Nicrofer 5716	1. Pulse on Time (Ton) (us) - 8, 10, 12 2. Pulse off Time (Toff) (us) - 57, 60, 63 3. Servo feed (Sv) - 7, 10, 13	The factor pulse on time has a great impact on both the performance characteristics as compared to the other two machining factors. It has been observed that as Tn increases Mr increases while there is subsequent degradation in surface quality and vice versa.
10	Ashish Goyal, Adithya Garimella, Priyanka Saini	Optimization of surface roughness by the design of experiment techniques during wire EDM machining	1. Workpiece Material - Nimonic 80A	1. Peak current (A) - 6, 7, 8 2. Pulse on Time (B) - 0.7, 0.9, 1.1 3. Pulse off Time (C) - 4, 5, 6 4. Feed rate (D) - 5, 7, 9	The Taguchi's method has been employed in evaluating the influence of surface roughness due to four input parameters as process parameters

11	Umang Maradia, Eric Filisetti, Moritz Wiessner, Sebastian Schneider, Marco Boccadoro	The Influence of energy input characteristics of surface integrity in wire EDM	1. Workpiece Material - Tungsten Carbide WC - CO (RGM30)	1. Peak current (Ip) - 216, 210, 300, 242 2. Pulse Duration (te) - 0.85, 1.53, 1.41, 1.75 3. Pulse Energy (E) - 2.34, 4.09, 5.39 4. Pulse Frequency (f) - 90, 51, 10, 26.7	A comprehensive analysis of discharge energy characteristics in wire EDM of tool steel and tungsten carbide identifies the applied power as the most significant factor for productivity and pulse duration for surface integrity
12	Ayush Owhal, Nandam Srinivasa Rao, Umashankar Gupta, Murlidhar Mahajana	Extension of Wire-EDM Capability for Turning Titanium Alloy and an Experimental Study for Process Optimization by Grey Relational Analysis	1. Workpiece Material - Titanium Alloy	1. Pulse on Time (Ton) (us) - 8, 9, 10 2. Pulse off Time (Toff) (us) - 50, 50, 50 3. Work feed (Sv) - 6, 10, 14 (m/s)	The main effects on individual performance parameter, where MRR increases with Ton as energy discharge rate increases, but decreases with RPM and WF
13	Nancharaiah Tata, Ravi Kumar Pacharu, Sameer Kumar Devarakonda	Multi response optimization of process parameters in wire-cut EDM on INCONEL 625	1. Workpiece Material - Inconel 625 2. Tool - Brass wire electrode	1. Pulse on Time (Ton) - 125, 130, 135 (sec) 2. Pulse off Time (Toff) - 30, 35, 40 (sec) 3. Supply voltage (V) - 15, 20, 25 (volts)	The effects of the input parameter, i.e., Discharge current, Pulse on time and voltage on MRR, surface roughness (SR) of Inconel 625 machined workpiece were calculated with brass Wire tool using Taguchi method
14	B. Selva Babu, S. Sathiyaraj, Anantha Krishnan P. Ramesh, B.A. Afridi, K. Kristo Varghese	Investigation of machining characteristics of aluminum 6061 by wire cut EDM process	1. Workpiece Material - Aluminum 6061 2. Tool - Brass wire electrode	1. Pulse on Time (Ton) (us) - 32, 34, 36 2. Pulse off Time (Toff) (us) - 6, 7, 8 3. Peak current (Ip) - 1, 2, 3	The effect of process parameters on the process performance by performing different experiments. WEDM of AI6061 indicate peak current and Pulse on having a significant effect on MRR and SR
15	Malaya Kumar Debta, Ravi Mishra, Manoj Mahanta	Experimental investigation on the machining performance of AZ91D (90% Mg) alloy by wire-cut EDM	1. Workpiece Material - AZ91D (90% Mg) Alloy	1. Pulse on Time (Ton) (us) - 100, 105, 110 2. Wire Feed - 5 m/mi 3. Peak current (Ip) - 110 A 4. Servo voltage - 22 V 5. Pulse frequency - 2100 Hz	At constant wire tension with increased Ton the cutting velocity increases gradually
16	P. Sivaprakasam, P. Hariharan, S. Gowri	Experimental investigations on nano powder mixed Micro-Wire EDM process of Inconel-718 alloy	1. Workpiece Material - Inconel 718 Alloy	1. Voltage (V) - 80, 90, 100 2. Capacitance (uF) - 0.0001, 0.01, 0.1 3. Concentration (g/kg) - 0, 0.25, 0.5	Machining parameters such as voltage (A), capacitance (B), powder concentration (C), the interaction of voltage & capacitance (AB), and capacitance & powder concentration (BC) have a significant influence on material removal rate of powder mixed Micro-Wire EDM process

17	K. Hareesh, K.V. Nalina Pramod, N.K. Linu Husain, K.B. Binoy, R. Dipin Kumar, N.K. Sreejith	Influence of process parameters of wire EDM on the surface finish of Ti6Al4V	1. Workpiece Material - Ti6Al4V of Titanium Alloy	1. Voltage - HV, LV 2. Wire Speed - 2, 3, 2, 3 3. Feed Rate - 30, 60, 90, 120, 150 (Hz)	The process parameter such as wire speed, voltage, and feed rate are optimized for wire electric discharge machining of Ti6Al4V
18	P.M. Abhilash and D. Chakradhar	Failure detection and control for wire EDM process using multiple sensors	1. Workpiece Material - Inconel 718 2. Electrode - Zinc coated electrode	1. Pulse on Time (Ton) (us) - 105, 110, 115 2. Pulse off Time (Toff) (us) - 30, 40, 50 3. Input current Ip (A) - 40, 10	Machining failure is defined when either of the following cases occurs: (a) when the process fails to perform the required function, or (b) when a breakdown event causes an interruption
19	Tirupati Kadam, Rohan Mohammad Abdul, Balram Yelamasetti	An Experimental Study on roundness error in wire EDM for Fero materials	1. Workpiece Material - Ferro materials	1. Tension (N) - 6 2. Wire Feed (m/min) - 12 3. Flushing Pressure (kg/cm2) - 4 4. Current (A) - 100	1.The thickness of workpiece dimensions of the blunder, Spout separation affecting cutting rate 2. The result was found a variety of blunders dimensionally 0.004

3. CONCLUSIONS

From the study, it was found that all the input parameters significantly affect the Wire EDM process. Among the significant factors, pulse on time, pulse off time, and peak current have the maximum influence on the whole process. Wire feed, wire tension, and water pressure have minimal effects on the process. Therefore, it is necessary to optimize the process parameters to achieve the desired results.

Here are some points that should always be kept in mind while doing research work on WEDM process parameters:

1. The higher the current value, the greater the intensity of the spark, and the result is a high rate of material removal.
2. Surface roughness can be improved by reducing pulse duration and discharge current.
3. Increasing pulse duration and open-circuit voltage increase the wire wear ratio, while increasing wire speed decreases it.
4. The newly developed high-speed wires can greatly increase the production speed compared to the commonly used brass wire and galvanized surface wire.

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