Review on Effects of Process Parameters in Wire Cut EDM and Wire Electrode Development

Jaskarn Singh
M. Tech Student
Department of Mechanical Engineering
Northwest Institute of Engineering & Technology
Dhudike(Moga),Punjab – India

Mr. Rishavraj Singh
Assistant Professor
Department of Mechanical Engineering
Northwest Institute of Engineering & Technology
Dhudike(Moga),Punjab – India

Mr. Rakesh Kumar
Head of the Department
Department of Mechanical Engineering
Northwest Institute of Engineering And Technology Dhudike(Moga),Punjab – India

Abstract

Wire cut Electrical Discharge Machining (WEDM) is a non-traditional machining process which is based on thermoelectric energy between the workpiece and an electrode. The increase in the demand of higher surface finish and increased material removal rate requires newer and better techniques which are more efficient. Wire Electrical Discharge Machining is one such type of process which can which is used to manufacture geometrically intricate shapes with great accuracy and good surface finish that are difficult to machine with the help of conventional machining processes. It works on the principle of spark erosion and is capable of machining the materials irrespective of their hardness and toughness. WEDM is used in tool and die making industries, automobiles, aerospace, nuclear, computer and electronics industries. Brass wire is used extensively as a wire electrode in WEDM. Various high performance electrodes like zinc coated, diffusion annealed, coated steel core wires etc. have been developed to satisfy the machining needs. This paper reviews the effects of various WEDM process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire speed, wire tension on different process response parameters such as material removal rate (MRR), surface roughness (Ra), wire wear ratio (WWR) and work related development in wire electrode's materials.

Keywords: Wire cut EDM, Process Parameters, Diffusion Annealed, Ra and WWR

I. INTRODUCTION

The history of EDM techniques goes as far back as the 1770's when it was discovered by English scientist, Joseph Priestly. He noticed in his experiments that electrical discharges had removed material from the electrodes. Although it was originally observed by Priestly, EDM was imprecise and riddled with failures. During research to eliminate erosive effects on electrical contacts, the soviet scientists decided to exploit the destructive effect of an electrical discharge and develop a controlled method of metal machining. In 1943, soviet scientists announced the construction of the first spark erosion machining. The spark generator used in 1943, known as the Lazarenko circuit, has been employed for several years in power supplies for EDM machines and improves form is used in many application. Commercially developed EDM techniques were transferred to a machine tool. This migration made EDM more widely available and a more appealing choice over traditional machining processes [3].

A. *Need of Non Traditional Processes:*

High accuracy, better surface integrity, high cutting rates and the demand for more precise shapes brought the word non-traditional into existence. Moreover, with the development in the material science, a number of advanced engineering materials came into existence. These advanced materials are such as super alloys, composites and ceramics. These materials were quite hard and tough, which caused obstruction in the machining of such kind of materials [4]. These materials were difficult to machine with the traditional machining processes like turning, milling, drilling and grinding. The main problems that occurred in machining these advanced materials were such as low material removal rate, poor surface finish and high wear of the tool. These problems lead to the generation of non-traditional processes which provides better accuracy and more precision as compared to the traditional processes. Non-traditional machining techniques are being successfully utilized for machining advanced materials, complex or difficult shape and size. Such kind of materials can be easily machined by WEDM [5]. Wire Electric Discharge Machining is successfully used in a wide area of applications because of its better results. It is used in tool and dies manufacturing, medical treatment, military equipment manufacturing, aerospace, manufacturing industries and electronic equipment industries [1].

B. Introduction of Wire Cut EDM:

Wire EDM Machining (also known as Spark EDM) is an electro thermal production process in which a thin single-strand metal wire (usually brass) 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. Wire-cutting EDM is commonly used when low residual stresses are desired, because it does not require high cutting forces for removal of material [4]. Wire-cut EDM is typically used to cut plates as thick as 300mm and to make punches, tools, and dies from hard metals that are difficult to machine with other methods. WEDM is a thermo-electrical process in which material is removed by a series of sparks between work piece and wire electrode (tool). The part and wire are immersed in a dielectric (electrically non-conducting) fluid, usually deionized water, which also acts as a coolant and flushes the debris away. The material which is to be cut must be electrically conductive. In WEDM, there is no direct contact between workpiece and tool(wire) as in conventional machining process therefore materials of any hardness can be machined and minimum clamping pressure is required to hold the workpiece. In this process, the material is eroded by a series of discrete electrical discharges between the workpiece and tool. These discharges cause sparks and result in high temperatures instantaneously, up to about 10000º C [6].

II. PRINCIPLE OF WIRE CUT EDM

This is also called as Wire EDM or WEDM. The mechanism of material removal is similar to the Electric Discharge machining process in which erosion effect is produced by the series of electrical sparks produced between the work piece and the electrode surrounded by stream of dielectric fluid continuously flowing in the machining zone [1]. But in case of WEDM, a thin wire made of copper, brass etc. is used as an electrode. The wire-cut EDM is a discharge machine that uses CNC movement to produce the desired contour or shape. It does not require a special shaped electrode as in the case of EDM, whereas it uses a continuous-traveling vertical wire under tension as the electrode. The electrode in wire-cut EDM has a very small diameter whose path is controlled by the machine computer to produce the required shape to produce required shape. During this process the wire travel's vertically downward and table movement is horizontal which is controlled by the CNC controller [2]. Work piece is held on table with the help of fixtures which does not cause any obstruction in the wire path. The wire dia. is generally 0.25mm. As this wire travels a spark is produced between the wire and work piece because of voltage difference. A minimum gap is always there between work piece and wire. A dielectric fluid keeps the work piece and wire surrounded. Pulses of electric energy are sent through wire which vaporizes the material from the work piece. Dielectric fluid flush the debris and used wire is gathered in scrap zone. The wire tension, wire feed rate and other input parameters can be adjusted according to the need by changing the values from the display screen [7].

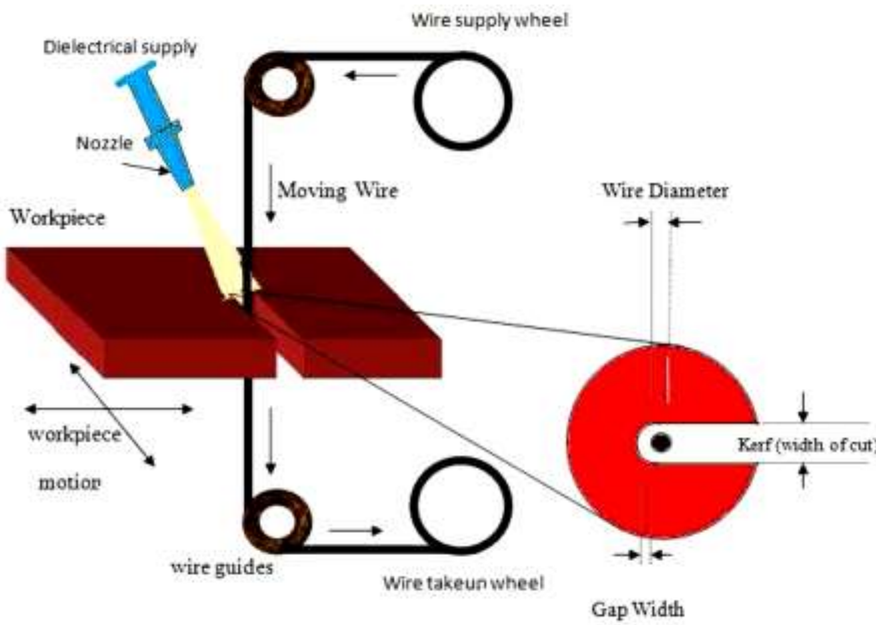

Fig. 1: Schematic diagram of Wire Cut Electro Discharge Machining [8]

III. IMPORTANT PARAMETERS IN WIRE CUT EDM

1) Pulse on Time - It is the duration of time for which the current is allowed to flow in each cycle. It is denoted as Ton and expressed in micro seconds (µs).
2) Pulse off Time – It is the duration of time between two simultaneous sparks. It is also called pulse interval. It is denoted as Toff and expressed in micro seconds (µs).
3) Spark Gap - It is the distance between the electrode and the work-piece during the EDM process.

4) Peak Current - It is the maximum value of the current passing through the electrodes for the given pulse. It is denoted by IP and expressed in amperes (A).
5) Spark Gap Voltage - It gives the specific voltage for the actual gap between the work piece material and the wire. The spark gap voltage is also known as open circuit voltage. It is denoted by SV and expressed in volts (V).
6) Wire Feed - The rate at which the wire travels along the wire guide path and is fed for generating the sparks is called wire feed rate.
7) Wire Tension - How much the wire is to be stretched between upper and lower wire guides is determined by the wire tension.
8) Pulse Peak Voltage - Pulse peak voltage setting is for selection of open gap voltage.
9) Dielectric Pressure - Dielectric Pressure is the pressure of the dielectric fluid which surrounds the work piece and the wire. It is the rate at which this fluid is circulated in the tank.

IV. EFFECT OF VARIOUS PARAMETERS ON MRR, RA AND WWR

A. *Effect of Pulse on Time:*

MRR is directly proportional to the amount of energy applied during pulse on time. Higher the value of pulse on time, higher will be the energy produced and this will lead to the generation of more heat energy. With higher values of Ton, Surface Roughness (Ra) tends to be higher [6].The higher value of discharge energy may also cause wire breakage. Material removal rate and wire wear rate (WWR) increases with increase in the pulse on time [9]. Wear rate of brass wire increases with increase in input energy, leading to wire breakage [10].

B. *Effect of Pulse off Time*

With a lower value of T off, there is more number of discharges in a given time, resulting in increase in more amount of material removal rate. The MRR decreases when pulse off time is increased as with long pulse off time the dielectric fluid produces the cooling effect on wire electrode and work material, Hence decreases the cutting speed. Surface Roughness improves with increase in pulse-off time. The Surface Roughness is high at low value of pulse-off time; this is due to because with a too short pulse-off time there is not enough time to clear the melted small particles from the gap b/w the wire electrode and work-piece. It is observed that surface roughness first decreases with increase in pulse-off time and then increases with increase in pulse-off time. This is because more energy is required to establish the plasma channel and therefore there is higher electrode wear and higher surface toughness [3], [6].

C. *Effect of peak Current*

Increase in the IP value will increase the pulse discharge energy which in turn can improve the cutting rate further. With increase in the value of peak current MRR, Ra and WWR increases. Peak current is found to be the major factor affecting the Surface Roughness [11].

D. *Effect of Servo Voltage*

The MRR increases with increase in servo voltage and then it starts to decrease. This is due to increase in servo voltage result in higher discharge energy per spark because of large ionization of dielectric between working gap; hence the MRR increases [3]. The factors investigated in the study, best SR (0.16 micron) was obtained at higher values of pulse-off time: 54 µs, spark gap set voltage: 70 V, wire feed: 10 m/min and lower values of pulse-on time: 106 µs, input current: 80 A, wire tension: (1260 g). [12] Servo voltage has the greatest effect on dimensional deviation and is followed by pulse off time, and wire feed in that order [13].

E. *Effect of Wire Feed Rate*

The material removal rate remains nearly constant with variation in the wire feed. Surface Roughness decrease with increase in wire feed rate, because new wire comes in contact rapidly when wire feed rate increases. Low wire speed tends to breakage of the wire. But with the increase in wire feed, the consumption of the wire increases and the machining cost also increases [9], [14].

F. *Effect of Dielectric Flow Rate*

It is very important for good machining. This fluid helps to carry away the debris from the machining area. Within required range of flow it improves the quality of surface and reduction in wire wear rate. Excess flow of fluid reduces the MRR [9].

G. *Effect of Wire Tension*

If the wire tension is high enough the wire stays straight otherwise wire drags behind. This helps to keep the wire free from vibration. It is because if there is improper tension, it will produce vibration in the wire, which will further lead to in accuracy of the process. Wire breakage may also arise due to improper wire tension. Within considerable range, an increase in wire tension significantly increases the cutting speed and accuracy [9].

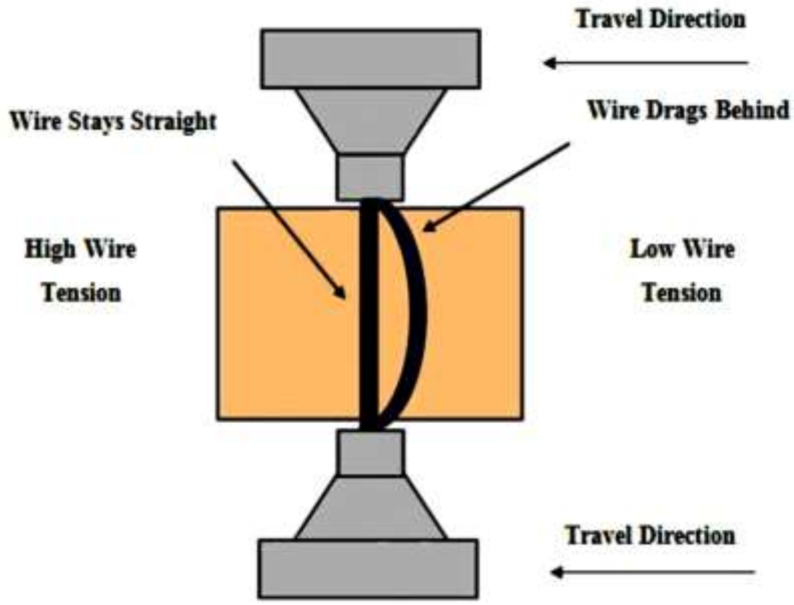

Fig. 2: Relation between Wire drag and wire tension [15]

V. DEVELOPMENTS IN WIRE ELECTRODE MATERIALS

Excessive Research has been done during the last few years in the field of wire EDM, to increase material removal rate, tool life, surface finish and to minimize the time consumed for the process etc. some of the recent developments are discussed here. 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. [16].

A. Copper:

It was the original material first used in wire EDM. Although its conductivity rating is excellent, its low tensile strength, high melting point and low vapor pressure rating severely limited its potential [15].

B. Brass:

It was the first logical alternative to copper when early EDM users was looking for better performance? Brass EDM wire is a combination of copper and zinc, typically alloyed in the range of 63–65% Cu and 35–37% Zn. The addition of zinc provides significantly higher tensile strength, a lower melting point and higher vapor pressure rating; it is now commercially available in a wide range of tensile strengths and hardness [15], [16].

C. Coated Wires:

In 1979 researchers discovered that wire electrodes coated with low vaporization temperature metal or alloy gives more protection to the core of the wire from thermal shock. They discussed the use of a wire electrode which includes a core wire having high thermal conductivity, then a layer of low boiling point metal or alloy and outermost layer of a metal/alloy having high mechanical strength, which ultimately results in increasing the machining speed. In recent years, high performance coated wires, having high conductivity and better flush ability have been developed and used for machining, resulting in better surface finish and improved cutting speeds. But these wires are costly as well as cause many impurities in dielectric fluid and also some environmental hazards [17]. Aoyama et al. had described the development of coated wire electrode to achieve high speed cutting and accurate machining. The new wire electrodes consist of a thin copper zinc alloy layer and core material with high resistance and high electrical conductivity. Two types had been developed: one is called “High – Falcon” (HIF) and is a copper alloy coated with a single phase brass layer. It is applicable when users want high cutting speed and accuracy.

The other is called “High- Eagle” (HIE) and is a copper alloy coated with a double-phase brass layer. It is applicable for widespread use when users want faster cutting, but do not require as high accuracy [18]. U.S Pat. No. 0,138,091 developed a method of manufacturing a zinc-coated electrode wire for electro discharge machining using a hot dip galvanizing process by subjecting a wire to the series of processes of firstly surface forming, pre-coating, main-coating, secondly surface forming, heat treating and drawing, which is advantageous in terms of uniformly coating zinc on the wire by the hot dip galvanizing process and thus reducing Manufacturing cost, thereby achieving economic benefits [19]. U.S Pat. No. 0,295,695 suggested an EDM wire having an outer coating of epsilon phase brass and a process for manufacturing the EDM wire is provided. The process includes coating a copper bearing metallic core with zinc. The zinc coating is then converted to epsilon phase brass by heat treating the wire at a temperature low enough to minimize or eliminate any resulting changes in the mechanical properties of the wire. The coated core wire may be drawn to a finish size prior to heat treatment which will result in a wire with a substantially continuous epsilon phase coating [20].

D. Diffusion Annealed Wires:

If Zinc has such great flush ability one would think that a pure Zinc coating would produce the ultimate wire. Zinc coating has proved to be the ultimate coating for better performance. Zinc has low meting point and requirement of wires of high zinc content coating and high melting point led to the development of diffusion annealed wires. It was disclosed that the outer layers of coated wire has rich zinc alloy. The encased wire is then annealed at such temperature until alloy extends from outer surface to the core. The wire so produced has a structural composition in its outer coating having much greater resistance with respect to erosive wear than common eroding electrode. Another attempt was made to improve the mechanical strength of electrodes while maintain their benefits such as heat shield effect, elimination of shot circuits. Production rates are also increased with this invention. The resulting EDM wire cuts faster and better surface finish than conventional EDM wire electrodes, or is capable of producing a superior finish at competitive metal removal rates [16]. Antar et al. find that an increase in productivity of ~40% for Udimet 720 and ~70% for Ti6246 was possible when replacing standard uncoated brass wire with diffusion annealed coated wires under the same operating parameters [21]. Navjot et al. find that material removal rate was found to be more with cryogenically treated zinc coated diffused brass wire as compare to cryogenically treated plain brass wire [14].

VI. CONCLUSION

From the present study, it is found that all of the input parameters significantly affect the Wire 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 the minimum effect on the process. Therefore it is essential to optimize the process parameters to achieve the desire results. So here are some points which always kept in mind during research work on WEDM process parameters

- Higher the value of current, intensity of spark is increased and results in high Material Removal Rate.
- The Surface Roughness can be improved by decreasing both pulse duration and discharge current.
- The increasing pulse duration and open circuit voltage increase the wire wear ratio whereas the increasing wire speed decreases it.
- The new developed high cutting speed wires can increase the production rate by a significant amount as compared to generally used brass wire and zinc coated wire.

REFERENCES

[1] P.C. Pandey and H.S. Shan, "Modern Machining Processes", Tata McGraw-Hill Publishing Company, 1980, page 79-80.
[2] Hassan Abdel Gawad EI Hofy, "Advanced Machining Processes", Tata McGraw-Hill Publishing Company, 2005, page 115-139.
[3] Kumar Sandeep,"Current Research Trends in Electrical Discharge Machining: A Review" Research Journal of Engineering Sciences, Vol. 2(2), (2013) page 56-60.
[4] Bijo Mathew, Benkim B.A, J.Babu "Multi Process Parameter Optimization of WEDM on AISI 304 using Utility Approach" International Conference on Advances in Manufacturing and Materials Engineering, vol. 2, (2014), page 45-50.
[5] Rajeev Kumar and Shankar Singh "Current Research Trends in Wire Electrical Discharge Machining: An Overview" International Journal on Emerging Technologies 3(2012): page 33-40.
[6] Pujari Srinivasa Rao, Koona Ramji, Beela Satyanaraayana "Experimental Investigation and Optimization of Wire EDM parameters for Surface Roughness, MRR and White layer in machining of aluminum alloy" International conference on Advances in Manufacturing And Materials Engineering, AMME vol. 5, (2014), page. 2197-2206.
[7] M. Durairaj, D. Sudharsun, N. Swamynathan "Analysis of Process Parameters in Wire EDM with Stainless Steel using Single Objective Taguchi Method and Multi Objective Grey Relational Grade" International Conference On design and manufacturing, IConDM, Procedia Engineering 64, (2013), page 868 – 877.
[8] Parveen Kr. Saini, Mukesh Verma "Experimental Investigation of Wire-EDM Process Parameters on MRR of Ti-6al-4v Alloy" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, vol.4, (2014), page16-20.
[9] Sreenivasa Rao and Venkaiah "Review on wire cut edm process" International journal of advanced trends in computer science and engineering vol. 2, (2013), page 12-17.
[10] Ravindranadh Bobbili, V. Madhu, A.K. Gogia "An experimental investigation of wire electrical discharge machining of hot-pressed boron carbide" Science Direct, Defence Technology 11, (2015), page 344-349.
[11] Brajesh Kumar Lodhi, Sanjay Agarwal "Optimization of machining parameters in WEDM of AISI D3 Steel using Taguchi Technique" 6th CIRP International Conference on High Performance Cutting, HPC2014, Procedia CIRP 14, (2014), page 194-199.
[12] Amitesh Goswami, Jatinder Kumar "Optimization in wire-cut EDM of Nimonic-80A using Taguchi's approach and utility concept" Engineering Science and Technology, An International Journal, (2014), page 236-246.
[13] Pradeep Singh, Arun Kumar Chaudhary, Tirath Singh, Amit Kumar Rana "Experimental Investigation of Wire EDM to Optimize Dimensional Deviation of EN8 Steel through Taguchi's Technique" International Research Journal of Engineering and Technology (IRJET) ISSN: 2395 -0056 Vol. 02, (2015), page 1753-1757
[14] Navjot Singh, Parlad Kumar, Khushdeep Goyal "Effect of Two Different Cryogenic Treated Wires in Wire Electrical Discharge Machining of AISI D3 Die Steel", Journal of Mechanical Engineering, Vol. ME 43 No. 2, (2013), page 54-60.
[15] Danial Ghodsiyeh, Abolfazl Golshan, Jamal Azimi Shirvanehdeh "Review on Current Research Trends in Wire Electrical Discharge Machining", Indian Journal of Science and Technology, Vol. 6, (2013), page 4128-4140
[16] Jatinder Kapoor, Dr. Sehijpal Singh, Dr. Jaimal Singh Khamba "Recent Developments in Wire Electrodes for High Performance WEDM", Proceedings of the World Congress on Engineering, Vol. 2, (2010)
[17] Manpreet Singh, Harvinder Lal, Ramandeep Singh "Recent Developments in Wire EDM: A Review", International Journal of Research in Mechanical Engineering & Technology. Vol. 3, (2013), page 150-152.

[18] S. Aoyama, K. Tamura, T. Sato, T. Kimura, K. Sawahata and T. Nagai, High-Performance Coated Wire Electrodes for High-Speed Cutting and Accurate Machining, Hitachi Cable Review,18 (1999), page 75- 80.
[19] J.C. Lee, U.S. Pat. No. 0,138,091 (2006)
[20] D. Tomalin, U.S. Pat. No.0,295,695 (2007)
[21] M.T. Antar, S.L. Soo, D.K.Aspinwall, D. Jones, R. Perez "Productivity and workpiece surface integrity when WEDM aerospace alloys using coated wires", 1st CIRP Conference on Surface Integrity (CSI), Procedia Engineering 19, (2011), page.3-8.

