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Effect of Various Process Parameters in Wire-Cut EDM- A Review

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Abstract: Wire-Cut Electric Discharge Machining (EDM) process is renowned for its high accuracy in cutting conductive materials with intricate profiles. This process is widely used in industries such as aerospace, marine, automotive, and electronics. This review paper broadly examined the impact of various input process parameters of Wire-Cut EDM such as pulse-off time, pulse-on time, voltage, current, wire tension, and servo feed on machine performance, including material removal rate (MRR), wire wear, and roughness. Various types of electrodes have been developed to meet machining needs. The transition from traditional brass wires to innovative coated wires has been analyzed, revealing enhancements in thermal conductivity, improved cutting speeds, and reduced erosion while maintaining accuracy. It was found that the relationship between electrical and non- electrical parameters shows that higher currents boost material removal rates but compromise surface finish. The review also highlights how hybrid wires and eco-friendly materials address cost and sustainability concerns. The aim of this review paper is to serve as a guide for researchers and practitioners seeking to understand the Wire-Cut EDM process and optimize input process parameters.

Keywords: *Wire-Cut EDM Process, Pulse On/Off Time, Voltage, Current, MRR, Surface Roughness, Optimization.*

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I. INTRODUCTION

In 1770s, British scientist Joseph Priestley discovered the EDM techniques, established the beginning of the technology's history. He noticed in his examinations that the electrode lost material because of the electrical discharge. Soviets examined the removal of erosion effects on electrical contacts and made a decision to take benefit of the damaging effects of electric discharges to establish a controlled metal approach.

Soviet scientists announced in 1943, that the first sparks had been created for EDM machine, and used as spark power source, EDM technology that has been created commercially was applied to machine tools [3].

Wire EDM is known as Spark EDM is a thermal and electrical process that permits thin metal brass wires to use heat from the wire metal to the voltage. State-of-the art EDMs of wires are usually used when low residual stress is required. Due to this reasons, more cutting force is not required to cut the material [4]. Wire- CUT EDM is generally used to cutting of max size of 300 mm plate and cutting of hard and high strength material. The sparks between the workpiece and the wire electrode is generated by the, WEDM process which is used to removes the material. The wires and workpiece are submerged in a dielectric liquid, which is electrically non-conductive and generally acts as a coolant to cut the material. With WEDM, the work part and the wire do not come into contact directly. Therefore, the level of hardness can be controlled by processing methods, and clamping pressure must be used to maintain the workpiece in position. Sparks get generated by these discharges, and temperatures increase gradually to approximately 10,000°C [5].

II. PRINCIPLES OF WEDM

This is also known as wire- DM or MEDM. The mechanism of material removal is similar to the process of electrical discharge, with the erosion effect being produced by a series of electrical sparks, continually surrounded by a machining zone between the workpiece and the electrode [1]. However, in WEDM, thin wires made of copper, brass, etc. are used as electrodes. A wire cut EDM is an ejector that uses CNC movement to

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generate the desired contour or form.

As with EDM, no special shape of electrodes is required, but the electrodes use vertical lines where the vertical wires move continuously under tension. The diameter of the electrodes of the wire cut EDM is very small, and its path is controlled by a machine computer to create the shapes needed to create the shapes needed to create the shapes needed. During this process, the wire trip goes down vertically, the table movement becomes horizontal and is controlled by the CNC controller [2].

The workpiece is held on the table with the help of a device that does not cause blockages in the wire path. Wire diameter. Usually 0.25 mm. The difference in voltage between this wire creates a spark between the wire and the workpiece. There is always a minimum gap between the workpiece and the wire. Dielectric fluid keeps the workpiece and wire surrounded. The impulse of electrical energy is sent through wires that evaporate the material from the workpiece. Rinse the tiles and used wires in the scrap zone seductive fluid. Screen Voltage, cable rate, and other input parameters can be set as needed by changing-the values from the display system [6]. There are mainly important parameters of wire cut EDM machining such as pulse off time, on time, peak current, dielectric pressure, spark gap voltage, wire feed and wire tension.

III. EFFECT OF DIFFERENT PARAMETERS ON MRR, RA

- *Pulse on Time Effects on MRR and Surface Roughness*

Researchers have found that the MRR is extended straightly with increment in pulse on time. This might be that the pulse on time increases, delivering more life on the work piece and allowing the top layer of fabric disintegrate and vanish. [7]. It ceases to liquefy more sum of surface which makes a difference to make a bigger and more profound cavity. This impacts the increment in surface unpleasantness [8][9]. The increment in surface unpleasantness was watched with expanded pulse on time. Usually since of expanded beat on time which produce bigger release vitality between terminal and the work piece.

- *Pulse off Time Effects on MRR and Surface Roughness*

The beat OFF time starts vitality increments as a result of the increment within the esteem of Ton, the rate of fabric expulsion increments when the esteem of Ton is less. Fabric evacuation rate diminishes as the esteem of Ton, M.R.R. is raised since the associate electrode gap and vitality exchange hiders are hindered, coming about in a drop-in fabric evacuation rate. Ton, M.R.R. could be a steady esteem, As the current increments, the fabric evacuation rate increments due to the expanding start escalated, and the fabric is evacuated by dissolving and vaporization [10][11]. surface harshness (SR) rises with an increment in current, and a lower sum of current recommends a lower level of surface harshness. This happens as a result of an increment in start concentrated, which comes about in a gigantic release vitality and an increment in surface roughness [10][11].

- *Peak Current Effects on MRR and Surface Roughness*

When top current increments the MRR increments and beat on moreover increments but has a few variety and MRR diminish within the period of pulse off time. This could have been the result of a rise in release vitality and a rise in beat on and crest current, which enhanced the MRR. Since the gaps between beats were a bit longer, there are less releases in a particular time frame, causing in a lesser MRR [07]. When the top current fails, the surface roughness value improves. As the peak current and duration rise, the release vitality also grows [07]. Increased IP values lead to increase the pulse load energy and increase the reduction rate also. The biggest latest - as the value of MRR, RA, and WWR increases. The top stream is the main factor affecting the surface roughness [14].

- *Effect of Wire Feed Rate*

With the variance in the wire feed input, the material evacuation rate keeps relatively constant. Surface roughness reduces as the feed rate increases because idle wire quickly comes into touch with the material. Increases in wire feed result to more wire consumption; decrease in speed create wire failure and enhance machining costs [12][13].

- *Effect of Dielectric Flow Rate*

It's very important for correct processing and the use of dielectric fluid rate. This fluid assists in pushing waste out of the editing area. Area provided increases rate of wear and surface roughness in the flow. High fluid tends to lowers MRR [12].

- *Effect of Wire Tension*

The wire stays in place instantly if the tension is sufficient adequate; if not, it wires drags behind. The result makes simpler to maintain the wire loose from vibrating. The improper tension in the wire leads the wire to vibrate, which will impact the accuracy. The tension wire can significantly improve the slicing accuracy and speed [12].

- *Effect of Voltage*

MRR increment is seen with raise of voltage and then decreases. This is due to an increase in Servo voltage, which increases the emission energy per Spark due to the strong ionization of the dielectric between the working gaps. Therefore, the MRR increases [3] [15]. Servo voltage has the greatest effect on dimension deviation, and follows from the pulse-off time and wire feed in this order [16].

IV. RECENT ADVANCEMENTS

WEDM is an advanced machining process used for precise and accurate cutting of conductive materials, particularly in aerospace, medical, and tooling industries. Recent advancements have focused on improving

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machining efficiency, surface integrity, sustainability, and automation. This paper reviews key developments in WEDM, including hybrid machining techniques, intelligent control systems, sustainable dielectrics, micro-WEDM, and additive manufacturing integration.

➢ *Hybrid WEDM Processes*

Hybrid WEDM techniques combine conventional WEDM with auxiliary energy sources to enhance machining performance. Ultrasonic-Assisted WEDM (UWEDM) - Ultrasonic vibrations (UV) are applied to the workpiece or wire to improve debris removal and reduce recast layer formation. It was demonstrated that UWEDM reduces surface roughness by up to 30% when machining Ti-6Al-4V. The vibrations enhance dielectric flushing, minimizing micro-cracks and improving fatigue life [17]. Powder-Mixed WEDM (PM-WEDM) is the addition of conductive or semi-conductive powders (e.g., SiC, Al_2O_3, graphene) to the dielectric fluid improves sparking efficiency and surface finish. It is reported that nano-powder additives reduce tool wear by 25% and enhance machining stability in hardened steel [18]. Laser-Assisted WEDM (LA-WEDM) is a pre- heating laser softens the workpiece, reducing cutting forces and improving wire life. A study showed that LA-WEDM increases cutting speed by 18% when machining tungsten carbide [19].

➢ *Hybrid WEDM Processes*

Bio-Dielectrics, Traditional hydrocarbon-based dielectrics are being replaced with biodegradable alternatives. It was found that sunflower oil-based dielectrics reduce carbon emissions by 40% without compromising machining accuracy [20]. Dry WEDM, the compressed air or gas dielectrics eliminate the need for liquid dielectrics, reducing waste disposal issues. It was reported that dry WEDM achieves comparable precision while being more sustainable [21].

➢ *Micro-WEDM and Additive Manufacturing Integration*

Micro-WEDM is used for micro-scale features in medical devices and MEMS. It was achieved sub-micron precision in stainless steel coronary stents using a 20 µm tungsten wire [22]. Hybrid WEDM-Additive Manufacturing (AM)Combining WEDM with 3D printing allows for complex geometries with minimal post-processing. It was demonstrated that hybrid WEDM-AM reduces production time for aerospace components by 35% [23-25].

V. CONCLUSIONS

In this study, all input parameters have a significant impact on the wire-EDM process. Among the key factors in pulses, the trigger and top current have the greatest impact on the entire process. Wire attempts, wire voltage, and water pressure have minimal impact on the process. Therefore, it is important to optimize the process parameters to achieve the desired results. Recent advancements in WEDM have significantly improved machining precision, sustainability, and automation. Hybrid techniques, AI-driven optimization, and eco-friendly dielectrics are key trends. Future research should focus on.

- High current values, increased spark strength, and material removal speed.
- Reducing both pulse duration and discharge current can improve surface roughness.
- Increased pulse time and open circuit voltage increase the increase in wire speed, but increases the increase in wire speed.
- AI-based adaptive control systems for Industry 4.0.
- Advanced wire materials to minimize breakage.
- Integration with renewable energy sources.

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