A Comprehensive Study on Electric Discharge Machining

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Abstract

Electric Discharge Machining (EDM) is an unconventional manufacturing process that would help make components made of hard-to-machine materials. EDM is capable of high degrees of accuracy. The only requirement is that the EDM process can be used with conductive material. EDM process can able to make components having complex geometries. An effort has been made in the current research work to study the different dimensions of EDM, such as materials that can be machined using EDM, machining parameters, process details, advantages, limitations, and directions for future works.

Keywords
Electric Discharge Machining, EDM, Un-conventional machining, Dry EDM, Spark erosion

1. Introduction
Components used in Aerospace and Nuclear domains demand materials that have a high strength compared to their weight. But these materials are difficult to machine by conventional manufacturing techniques. Electric discharge machining (EDM) shapes components of difficult-to-machine material, such as tungsten or carbide. In 1770 Joseph Priestley discovered the ability of electric sparks to erode materials. EDM process was proposed in 1943 by B. R. Lazarenko and N. I. Lazarenko. Only electric sparks are used in metal removal, and cutting force is not used during the EDM process. In this way, the EDM process is different from conventional machining. In non-conventional processes, alternative energy sources such as sound, light, electrical chemical, and mechanical energy are used. Dielectric fluid is used during the EDM process as it improves the erosion of the workpiece. The process is capable of shaping any component that is made from electrically conductive materials. Another advantage of EDM is that complex geometry is possible on parts. The electrode is positioned at a small distance from the workpiece during the EDM process. The electrodes are set at a distance to initiate a spark that erodes the work and causes material removal by melting and vaporizing. Many researchers have been working for the last few decades to study machining parameters' effect on process performance. They have proposed schemes for enhancing the MRR and the quality or surface roughness during the shaping of the component. In 1970 CNC driven EDM came into practice.

2. Literature review
EDM machine uses the following components: a. workpiece: Any conductive material is worked by EDM process; b. In EDM shape of the electrode will determine the shape of the cavity in the workpiece; c. Dielectric fluid: While performing the EDM process, the electrodes are kept in a dielectric fluid tank; d. servomotor would help maintain the constant distance between the electrodes, by proper tool feed; e. power supply AC from the mains is converted into DC supply for generating the electric sparks between the electrodes, and f. pulse generator: used for supplying electric pulses for a specific amount of time.

EDM makes use of the erosion effects of electric spark on the electrode. Thus, the tool will be positioned at a small distance from the work during the process. In EDM, electric sparks will be created between two electrodes within the dielectric fluid, such as water or oil. The EDM process requires work must be a conductive material. During the EDM process, electrical discharge not only melts the work material in small amounts but also vaporizes the metal. During EDM, every electric spark would remove 10^6-10^4 mm^3. The exact process would be repeated approximately 10000 times per second.

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During the process, voltage (200V) is established between the workpiece and the tool. The dielectric starts breaking down when the tool begins moving toward the work. The voltage will drop at the instant of the breakdown, and the current rises immediately. A plasma channel will be created between the work and the electrode at this moment. The workpiece will start melting and then starts to vaporize. The distance between the electrodes is generally maintained between 10 to 100 µm. Both voltage and current are shut down by the end of the cycle. The metallic particles will not be allowed to settle between the work and the electrode, leaving a crater on the workpiece. The dielectric would not only help cool the electrode but also would help in taking the molten metal out when plasma collapses. The dielectric is made to flow between the electrodes to enhance material removal from a workpiece. Pulsing the electrode would also improve the space between the electrodes. The material removal rate during the EDM process depends upon (i) materials of the electrodes, (ii) polarity of the electrodes, (iii) duration of the discharge (iv) discharge current.

Process variables govern the EDM process: peak current, gap voltage, discharge voltage, polarity, pulse frequency, pulse on time, pulse waveform, pulse off time, and the distance between the electrodes. In addition, the dielectric type, nozzle flushing, powder conductivity, and power density. The EDM process maintains no contact between the work and the electrode. There are no vibrations, chatter, and residual stresses.

2.1 EDM Variants

2.1.1 Die-sinking EDM

Die sinking is also called cavity EDM. During the process, the electrode and the work are kept within a tank containing the dielectric fluid such as oil. Electric potential is maintained between the electrodes. The dielectric will break down when the tool is near the workpiece, forming a plasma channel. Also, a spark jump happens. As the work wears out, the tool will be moved to maintain the distance between the electrodes (Figure 1).

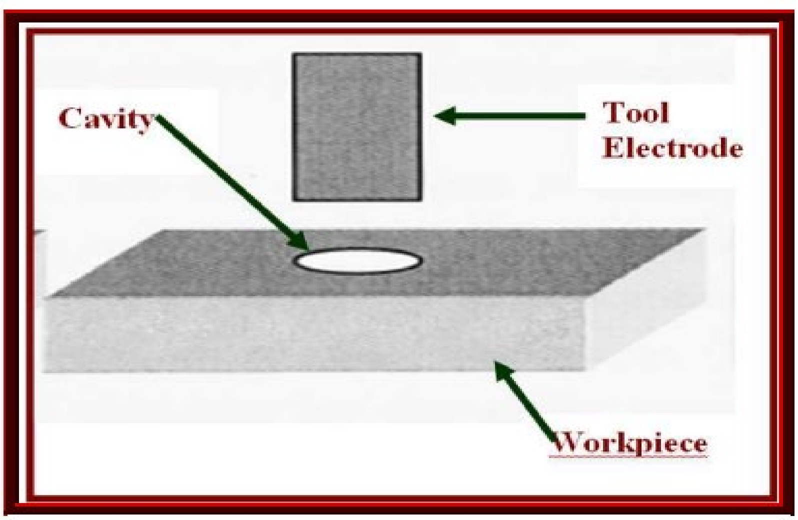

Figure 1. Working principle of a Die-Sinking process

2.1.2 Wire-cut EDM

In the Wire cut EDM process, a thin Brass wire and de-ionized water are made to cut through the workpiece using the heat energy released during spark generation. The workpiece is submerged in dielectric solution during the process. A thin wire is supplied through the workpiece during the process. The process can cut 300 mm thick metal plates. This capability would manufacture punches and dies made out of tough materials. This process is helpful as it produces components with very low residual stresses. This is mainly because it does not use high cutting forces. As there is no change in the mechanical properties in the workpiece, during the process, the processing used to machine hard-to-machine, electrically conductive materials with a detailed profile to the highest accuracies. Figure 2 shows the working principle of a wire-cut EDM process.

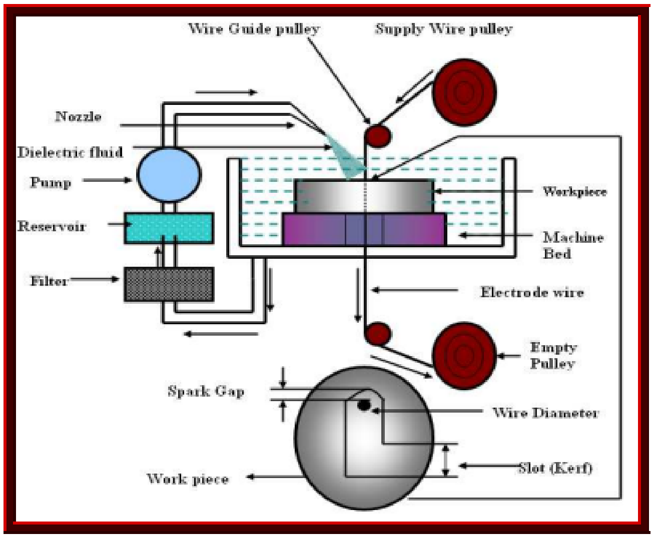

Figure 2. Working principle of a Wire-cut EDM process.

2.1.3 Vibro-Rotary EDM

Sato et al. (1987) used EDM to make micro-hole boring. They made electrodes to rotate for performing flushing and achieved high material rates. Murti and Philip (1987) conducted a series of experiments and have noted a significant improvement in MRR and surface roughness with the addition of ultrasonic vibrations. But the tool wear rate also has increased considerably. Soni and Chakraverti (1997) used rotary disc electrodes while conducting EDM. They faced a large amount of debris between the electrodes. They also observed lower material removal rates during the process. They identified arcing during the process. Zhang et al. (2002) explored using ultrasonic frequency DC power in place of the usual pulse power supply. The relative motion between the electrodes would result in Pulse discharge. Guo et al. (1997) could achieve better material removal rates by using ultrasonic frequencies during EDM, mainly because of better removal or cleaning of the debris between the electrodes. Soni and Chakraverti (1997) studied electrode rotation's effects on MRR and compared the results with that of the stationary electrode. They observed very little tool wear but achieved a better surface finish.

Egashira (1999) explored conducting EDM using the vibrating workpiece. They used quartz and could produce a micro-sized hole of 5µm in the presence of vibration. The tool wear rate was high when using a sintered diamond tool. Yan et al. (2000) studied EDM using disc electrodes and workpieces made of Al_2O_3/6061 Al composite material. One investigation revealed that using the Taguchi technique, pulse duration, peak current, and gap voltage would significantly affect performance parameters such as wear rate, surface roughness, and the MRR. Ghoreishi et al. (2002) explored using the electrodes' high and low axial frequency on factors like tool wear rate, MRR, and surface finish. It was found that MRR would be increased to 35%. Zhang et al. (2004) observed that reasonable material removal rates could be achieved with increased open voltage, pulse duration, ultrasonic vibration amplitude, and decreased pipe wall thickness.

Mohan et al. (2004) studied EDM using a centrifugal force and found that the MRR was better. Also, the centrifugal force has made the dielectric fluid fill the gap between the electrodes, creating a better surface finish on the component. Kuo et al. (2004) did experiments using series-pattern microdisk electrodes to achieve simultaneously slits having widths less than 8 µm. Zhang et al. (2005) concluded that the MRR in the UEDM process with gas is more than EDM in gas but lower than the typical EDM. This is true for achieving the same surface quality. Prihandana1 et al. (2011) studied the EDM process using a vibrating workpiece and concluded that the presence of vibration has resulted in higher material removal rates. This was mainly due to the high amplitude, high frequency, and effective flushing of dielectric flowing between the electrodes.

Chattopadhyay et al. (2008) studied the EDM process using EN-8 steel workpiece and the electrode made using copper. The work was carried out using the rotary electrode. It was found that reduced electrode rotation, peak current increase, and decreased pulse time would result in increased material removal rates.

Han et al. (2009) conducted EDM experiments using a satisfying arc. They generated the moving arc using a rotating electrode of copper and work connected to a DC power source. They observed that the MRR in this process is four times that of conventional EDM. They attributed this increase in MRR to the heavy-duty cycle in the process. Xu et al. (2009) studied EDM using ultrasonic vibrations in a gas medium. The study revealed that ultrasonic-assisted vibrations would help in enhancing the material removal rate. Prihandana1et al. (2011) found that using low-frequency vibrations on the workpiece would help improve the MRR during the EDM process. They concluded that introducing pulses improves debris removal and thereby increases surface finish on the workpiece.

2.1.4 Water-assisted EDM process
The use of hydrocarbon oil such as Kerosene would release carbon monoxide or methane into the atmosphere. These are very harmful not only to the environment but also to the operators. Many researchers have attempted to employ water as dielectric fluid while performing EDM to make the work environment safe for the operators. Jeswani (1981) studied the EDM process using distilled water as dielectric and reported an increase in material removal rate compared to the standard EDM process using kerosene. Tariq et al. (1984) explored using tap water while performing the EDM process. The study has reported increased wear and zero tool wear rates when using Copper as an electrode with opposing polarity and water as a dielectric medium. Koenig et al. (1987) studied EDM using aqueous water as a dielectric and concluded the dielectric possesses excellent thermal stability and makes the work environment safe for operators. Also, I observed that the process would be free from fire hazards. Koenig et al. (1993) studied the EDM process using a water-based dielectric medium and concluded that the process becomes more economical compared to other processes.

Kruth et al. (1995) studied the EDM process and concluded that water-based dielectric would cause decarbonization on the surface, providing a safe working environment. Chen et al. (2008) studied the EDM process. They concluded that using the water-based dielectric would increase the MRR and cause a reduction in wear rate compared to the EDM process using the Kerosene dielectric.

2.1.5 Dry EDM
In dry-EDM, the dielectric will be in the form of a gas. The process uses gas at high pressure through a tubular electrode. The high velocity of gas would help remove debris during the EDM process. The gas would also help remove heat and prevent heating of the electrodes. The process uses a rotating electrode that would help remove the debris. The process is environmentally friendly. Many researchers also found that the process considerably reduced the wear rate of the tool. And the MRR in dry EDM was significantly higher when compared to the regular EDM. The schematic of Dry EDM processes is shown in Figure 3. Kunieda et al. (1991) conducted the EDM process using oxygen gas as the dielectric medium. They concluded that the MRR was significantly higher when compared to the usual EDM process using the liquid dielectric medium.

2.1.6 Powder-assisted EDM
Mixing metallic particles in the dielectric fluid increased the MRR and the smoothness of the work surface during the EDM process. This was because adding metal powder will improve the dielectric breakdown even at the increased distances between the electrodes. This would help flush the debris between the electrodes (Tzeng et al. 2001).

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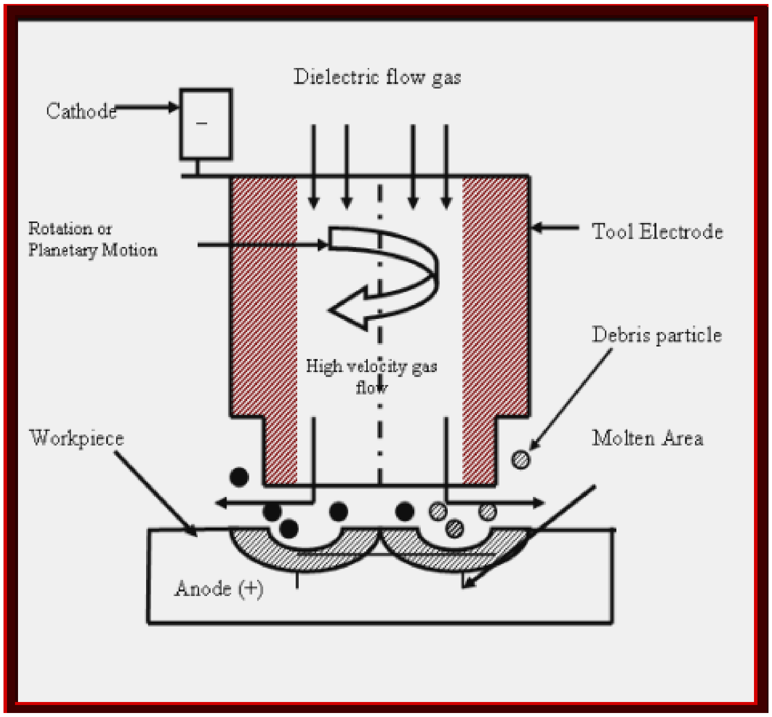

Figure 3. Schematic of Dry EDM process

Conclusion

EDM is a nonconventional manufacturing process. Many researchers have proposed slight modifications to the regular EDM process, such as Die sinking EDM, Wire-cut EDM process, Vibro-Rotary EDM process, Water-assisted EDM process, and Dry EDM process. The dry EDM process is environmentally friendly compared to the other variants of EDM processes. Much research is expected in the fields such as (i) improving MRR and surface finish, (ii) reducing tool wear rate, (iii) Exploring using EDM with new materials and electrodes, and (iv) optimizing the selection of the process variables.

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Biography

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