

Improving the Process Capabilities of EDM: A Review

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Abstract: Electrical Discharge Machining is non conventional machining process which works on the principle of thermoelectric energy between the tool and the workpiece. In this there is no direct contact between tool and the workpiece, hence material is removed without the formation of chip without causing any damage to the workpiece. It is capable of machining any electrical conductive material of any hardness. Researchers have explored a number of ways to improve the efficiency of EDM that depart from traditional EDM phenomena. The present research identifies some of major research related to improve the performance efficiency of EDM. In the end of the paper, future scope related to EDM has been highlighted.

Keywords: Electric Discharge Machining, Non conventional, Thermoelectric, Chip, Efficiency

I. Introduction

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive [13].

II. History of EDM

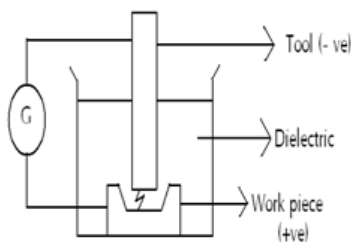
In 1943, Lazzerko and Lazzerko was the first who used the destructive properties of the electrical discharges for the constructive use. Later in 1944, a controlled machining by electrical sparks was introduced by Lazzerko in Russia. In 1960, semi conductor industry permitted considerable improvement in EDM machine [3].

In early 1970, CNC was implemented along with EDM. This provided much control over the tool movement hence EDM became more precise and resulted in improving the performance measures of EDM [24]. During 1980- 1990, efforts were made to improve generator design, servo control system and automation was introduced in field of EDM to large extent and now improvements are still occurring for increasing the efficiency of EDM.

III. Working Principle of EDM

EDM is a thermal process that uses spark discharges to machine the material. A shaped electrode acts as a tool which makes cavities or holes in the workpiece. Electrically conductive workpiece is connected to one pole of pulsed power supply and electrode or tool is connected to another pole of power supply. A small gap is maintained between the electrode and the workpiece to provide electrical resistance in gap.

Fig 1 Working Principle of EDM



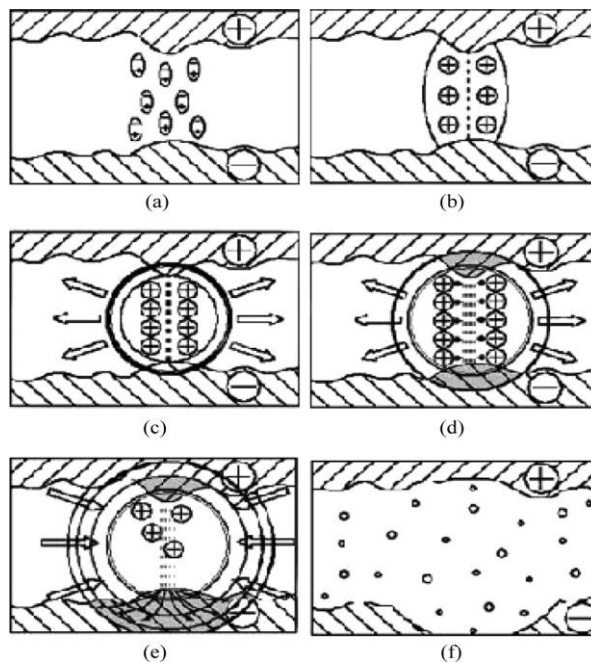
An intensive electric field is created between the tool and the workpiece when a pulse of D.C electricity is delivered. This electric field is created at a point where surface irregularities provide the narrowest gap. As a result of this field, naturally occurring microscopic contaminants suspended in dielectric fluid and the negatively charged particles emitted from the workpiece form a high conductive bridge across the gap. As the voltage

increases in the beginning, the temperature of this bridge increases and formation of spark comes into play between two surfaces. At the mid- point of electrical pulse, voltage is decreased by power supply and current is increased. Due to this, increase in temperature and pressure in the spark channel takes place. Because of this increase in temperature and pressure, small amount of material melts and vaporizes from both electrode and workpiece at the point of spark contact Fed by gaseous by products of vaporization, a bubble rapidly expand outward from the spark channel. The spark and heating are stopped when the electrical pulse is terminated. This causes both the spark channel and the vapour bubble to collapse. The injection of relatively cool dielectric fluid results in an explosive expulsion of molten metal from both surfaces, resulting in the formation of small crater in both surfaces. The entire sequence takes place in only microseconds to miniseconds. As there is no contact between the tool and the workpiece, so there is no force generated during machining.

IV. Material Removal Mechanism in EDM

In EDM, material is removed from the workpiece and the electrode by the series of sparks at the closest point which decrease the distance between the electrode and the workpiece. The next spark occurs at the next closest point. Material at the closest point is heated. This results in vaporization of material due to origination and termination of spark. Whole sequence of material removal mechanism is shown in following figures

Fig 2 Mechanism of Material Removal [28]



In fig 2(a) due to the strong applied electrical field, the positive and negative ions are accelerated. As the dielectric strength of the dielectric in the gap increases above the natural limit, electrons strike the cathode and the anode form the discharge channel fig 2(b). The kinetic energy of the striking electron causes the melting or vaporization of both tool and the workpiece at the discharge point. This results in the formation of the high pressure plasma channel fig 2(c). This high pressure in plasma channel exerts the force on the discharge channel boundaries to expand which results in the formation and growth of bubbles fig 2(d). When the pulse voltage ceases, superheated molten cavities explode violently into the dielectric due to decrease in the pressure of plasma channel fig 2(e). All the molten material is carried out by the dielectric fluid leaving behind crater on the workpiece surface fig 2(f). In this way material is removed from the workpiece in EDM.

V. Improving Material Removal Rate

Material Removal Rate (MRR) in Zinc mixed dielectric EDM largely depends on power concentration, Peak current and the interaction of both. Pulse off time and tool electrode diameter has no significant effect on MRR [32]. Among the three flushing gases i.e carbon dioxide, nitrogen and oxygen used in EDM, oxygen results in higher material removal rate [9]. Material Removal occurs during or just after the discharge duration while the bubble is expanding but no debris particle is removed while the bubble is contracting [30]. For high MRR, frame type tooling is preferred for linear or axial symmetrical swept surfaces shapes of the work-piece due to better flushing conditions for such type of tooling [25]. EDM process in water based medium possesses higher thermal stability, resulting in much greater increases in the MRR [18]. Introducing ultrasonic vibration to the tool improves the flushing conditions and hence facilitates higher material removal rate [12]. By making the

workpiece to vibrate, there is a better flushing and hence high MRR [11]. Providing vibration and rotation to the tool resulted in increase in MRR by 35% as compared to only introducing vibratory EDM [10]. There is an increase in MRR by 60% by adding graphite powder in the dielectric fluid of EDM [14]. It was found that adding copper, diatomite and aluminium powders in the dielectric during machining of mild steel using graphite electrode causes the MRR to increase with increase in powder concentration but to decrease with further increase in powder concentration [21]. Adding the SiC and Aluminium powder into the kerosene oil increased the gap distance, resulting in higher material removal rate and depth [6]. Multi spark system increases the MRR [17]. Design of the electrode used for multi spark system was based on the "Ref. [23]" concept in which tool electrode was divided into multiple electrodes. Plate type tool gives better removal rate in comparison to 3d form tool. For low TWR and high MRR, tool shape is in circular in shape followed by triangular, rectangular and square cross section [34]. Optimum process conditions are carried out in rough machining phase using Taguchi method with graphite powder. It was found that addition of appropriate amount of powder into the dielectric causes considerable improvement in MRR [15]. With dry milling EDM, MRR found to be six times more than that of oil EDM milling [38].

VI. Reducing Tool Wear

Electrodes prepared by powder metallurgy results in lower TWR and higher MRR than Cu and Graphite electrodes [35]. Better machining performances for tungsten carbide can be obtained with electrode as the cathode and workpiece as anode. Tool with negative polarity lowers tool wear and better surface finish [20]. There was decrease in electrode wear when EDM of mild steel was done with ZrB₂- 40 wt % Cu tool as compared to Cu tool [16]. Addition of small size powder particle led to low TWR as compared to large size particle [29]. It was found that addition of graphite powder in the dielectric and the use of cold treated Cu electrode as compared to conventional Cu electrode is the favorable conditions for reducing the electrode wear [31]. It was concluded that tool wear rate is also affected by the concentration of debris. Higher the concentration of debris, higher will be the tool wear [7]. Application of wear inhibitor carbon layer on the electrode surface by adjusting the settings of the process parameters prior to normal EDM condition resulted in reduction of TWR to large extent [22]. A uniform tool wear machining method was introduced to compensate the longitudinal tool wear by applying an overlapping to and fro machining motion [39]. Evaluation of the reduction of tool length was done on the basis of pulse analysis and subsequently compensated the tool wear by controlling the machining downward feeding movement [5]. Addition of powder in dielectric resulted in decreasing the wear of the electrode [1].

VII. Improving Surface Quality

Suspending the micro-MoS₂ powder in the dielectric fluid and using ultrasonic vibration in micro EDM resulted in providing high surface quality and MRR [27]. Using powder tungsten electrode made by powder metallurgy technique provides lower surface roughness as compared to conventional Cu electrode. Low thermal conductivity of powder metallurgically prepared electrode produce less cracks on the workpiece surface [4]. Among the two parameters namely powder concentration and flushing flow rate, it is the powder concentration that provides the better surface morphology. It is the flow rate of dielectric that minimizes the surface roughness [26]. Silicon powder mixed in the dielectric improves the surface finish of SKD-61 tool steel. However, at specific machining conditions in the EDM of steel, the aluminium and graphite powders generate better surface roughness than silicon powder [19]. It was found that in order to increase the surface abrasion resistant of aluminum bronze component, working dielectric has to be mixed with nickel powder as it deposit a layer on the EDM surface [36]. Aluminium electrode gives best surface roughness as compared to graphite and copper electrode when machining Titanium alloy using kerosene as a dielectric fluid [2]. Negative polarity of tool electrode is desirable lowering of surface roughness. Increasing pulse on time leads to produce more rough surfaces. Addition of powder particles in dielectric fluid decreases surface roughness of specimen in EDM process [33]. Workpiece rotary motion improves the circulation of the dielectric fluid in the spark gap and temperature distribution of the workpiece yielding better SR [25]. It was concluded that copper tungsten electrode with negative polarity are suitable for the planetary EDM surface micro finishing of the die steel (AISI H13). High voltage and negative polarity exhibit low MMR and TWR but good surface finish [8]. A low pressure and low temperature technique was developed to produce Cu-Cr composite electrode in hot mounting machine. It was found that corrosion resistance properties of the surface increases after EDM with these electrodes as these helps in the formation of modified surface layer [35]. Using EDM machine tool and kerosene as the dielectric a new ceramic layer of TiC with titanium electrode was developed on the workpiece surface by electro discharge coating technique. The hardness of the ceramic layer was found to be six times more than the base body and the hardness changes gradually from the surface to the body [37].

VIII. Remarks and Future Trends

The objective of the review article has been aimed to report the work of various researchers in the field of improving the performance measures of EDM. After an elaborate scrutiny of the published work, the following remarks emerge from the existing published work:

1. Most of the work is carried by using aluminium, silicon, zinc powder for enhancing performance measures. Powders like chromium, vanadium are still to be used.
2. Dry EDM emerges as new technique for improving the performance measures. Materials like composite is still to be investigated using Dry EDM.
3. Very little work is done using vibro rotary EDM for different materials.
4. Most of the work is done by using single material electrode like Copper, graphite and brass. Composite material electrodes are still to be used.
5. Electrodes prepared by powder metallurgy provide low tool wear and improve the surface properties but there is limited published work regarding the performance of such electrodes. The performance of such type of electrodes should be investigated in future.
6. Performance of water based dielectric is still to be investigated for carbides and composites.
7. There is negligible published work available on comparative analysis of various EDM techniques of MRR improvement with same/different work materials in EDM.

IX. Abbreviations Used

- MRR- material removal rate
- TWR - tool wear rate
- SR- surface roughness
- EDM- electric discharge machining
- CNC-computer numerical control.

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