



RECENT ADVANCEMENTS IN EDM PROCESS- A REVIEW

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Abstract- Every research is possible due to the advancement of technologies and a lot of researches have been departing in all fields to reach the market demand. In this regard various researches are going on in the development of Electrical Discharge Machining (EDM) to achieve a stable, accurate and efficient machining. Since EDM is an assembly of electrical, physical and mechanical process this paper reviews collaborative research developments and their influence on performance characteristics of variant EDM process in recent years.

Index Terms – EDM, New EDM, Die sinking EDM, wire EDM, Dry EDM, E-jet EDM.

I. INTRODUCTION

Electrical discharge machining is one of the most useful machinery in die and mould making industries. The finished portions of resources of EDM have been used in aero, automotive and nuclear industries and fine machined parts can also be applied in precise equipments of medical and surgical fields [1]. The development of EDM in the past years includes wire EDM, dry EDM, ultrasonic vibratory EDM, rotary EDM, and Powder mixed EDM, and magnetic field assisted EDM and finally the micro EDM and more [2]. Advance developments of EDM in recent years incorporates

the interdisciplinary ideas and thus leads to the emergence of the horizontal EDM [3], E- jet EDM [4] and many more to evolve.

A. Working principle

The general EDM consists of DC power supply, pulse generator circuit, servo control mechanism, Electrodes and dielectric medium. EDM works on the principle of electrical erosion by which continuous removal of material has been done in the presence of dielectric medium. The spark occurs when the dielectric medium reaches its breakdown voltage through decomposition. A crater is formed and grown when continuous discharges occur. There is break between the each discharge in which the dielectric regains its original position and cools the electrodes. The dielectric medium is traditionally of kerosene. Nowadays it has been replaced by other liquids such as de- Ionized water; distilled water etc. and many researches are going on in analyzing the phenomenon occurring in the dielectric medium to flush away the removed material effectively from the spark gap in order to improve the MRR. In Wire EDM the tool has been substituted by a thin strand of electrically charged wire which travels through the work piece sunken

in a dielectric medium. Machining in liquid dielectric medium has the following disadvantages.

1. Causes health hazards due to the collapsing of hydrocarbon oil
2. Disposing this contaminated oil is very difficult and
3. Renewal of dielectric oil is cost consuming.

To overcome these disadvantages, dry EDM is developed in which the liquid dielectric medium has been exchanged by gaseous media.

B. Trends in EDM

Ever since EDM is a thermo-electric process, the performance of EDM is controlled by the process parameters such as electrical, non electrical and other external factors. In the history of years, researches were done on the developmental stage by considering the electrical parameters. Currently the researchers are concentrating on the other parameters such as thermal and physical characteristics of the tool and workpiece, debris uniqueness, plasma personality, bubble expansion etc. Secondly, due to the emergence of new materials, the research trend is tuned to the machining of exotic materials. Third they focus on optimization of parameters and finally they spot on the modeling and controlling systems.

Hence this paper reviews the collection of electrical, physical and mechanical techniques and modeling developed in the EDM and their influence on performance characteristics has been discussed.

II. NOVEL ADVANCEMENTS IN EDM

To achieve a good performance results, novel techniques has been employed, taking the EDM to its new form.

A. E-jet EDM

While performing operations on EDM, the tool as well as the workpiece wears because of continuous erosion electrical discharge. Material removal in workpiece is a most wanted process but wearing of tool is not encouraged because it is an

economic factor in industries to make new tool every time. Many compensation techniques have been adopted to resolve this problem.. Presently the solid tool has been replaced by liquid tool by means of jet. Zhang et al [4] employed a capillary tube to produce a fine jet by the application of high voltage DC power supply between the nozzle and the workpiece. The created tool electrode has no wear and it produces fresh tool at every cycle. It has the ability to work as a micro EDM with both the polarity.

B. Horizontal EDM

The managing capability of the tool has been dropped down when an ultrasonic unit has been attached to its spindle. To overcome these difficulties, Che et al [3] designed separate ultrasonic equipment which has attached to the EDM horizontally. The horizontal ultrasonic (HU) unit induces vibration to the work piece and starts the stirring effect in the dielectric medium which improves the removal of debris. The MRR has been increased by 3 times as the machining depth and reduced the surface roughness from 2.543 μm to 2.050 μm .

III. RESEARCH DEVELOPEMENTS IN DIE SINKING EDM

Die sinking EDM is the one in which die will be sunken in the workpiece during machining. Even though many configurations of EDM are presented, researches in die sinking EDM continues by means of enrichment techniques in various angles.

a) Research made by machining of exotic materials.

Due to the manifestation of new high strength materials such as heat resistance and heat treated steels, carbides, ceramics, composites and super alloys, which are very hard and electrically conductive, machining of these materials is very challenging in practice. The EDM does all the

operations of drilling, milling, grinding and polishing of these new metallic materials which are not possible by conventional machining. And hence EDM is widely used in machining of these high cost materials to satisfy the industrial need. Consequently a number of researches are growing in the machining of these exemplary materials using EDM to achieve intricate shapes by considering its physical properties.

Gangadharudu [5] et al made aluminum/ alumina MMC using sintering technique and the machining was carried out in aluminum powder mixed in kerosene dielectric medium. They have established an empirical model for MRR and surface roughness based on the dimensional and regression analysis. The enhancement in performance characteristics not only depend on the machining parameters but also on the thermo physical properties of the work piece.

b) By applying different actions of tool

Zhao et al [6] constructed a new rotating coring tool electrode in which coring of SiC has been done for maximum material utilization. They have established electrostatic induction feeding method to achieve numerous discharges in a single pulse. The tool electrodes are arranged parallels as well as insulated separately and are connected to power sources by their respective feeding capacitors. This electrostatic multiple discharge method can have advantages of no contacting method of feeding electricity plus it does not require separate switching circuit for the interval between the discharges and finally the increased machining speed and accuracy.

c)

d) Research on Hybrid tool operation

Yan et al [7] used sintered diamond act as a hybrid tool for EDM as well as grinding. The surface topography has been analyzed under various machining parameters. He established a smooth surface of SiC by grinding the recast layer produced during the machining. It enables high efficiency, high precision and low damage micro machining of SiC

e) By analyzing thermal characteristics of tool

Joudivand et al [8] researched thermal diffusivity of tool which has major influence on tool wear rate. They have compared the results of copper alloy, copper-iron alloy, aluminum alloy and graphite as a tool electrode with the numerical simulation of tool erosion developed using Levenberg–Marquardt system and proposed that the tool wear rate decreases with high thermal diffusivity coefficient.

f) Researches on Powder Mixed EDM

Marashi et al [9] investigated the effect of Ti nano powder mixed in hydro carbon dielectric medium under different machining parameters. The addition of Ti powder enhances the surface morphology and reduces the surface roughness of the machined AISI D2 steel. The maximum enhancement of MRR and surface roughness is achieved at pulse on time (T_{on}) of 210 μ s with 6A and 12 A.

Gangadharudu [5] et al carried out their research in machining of sintered alumina MMC with aluminium powder fused in the dielectric media. The result shows that there is a significant reduction in surface roughness.

g) By analyzing the impedance characteristics of dielectric medium

Wang et al [10] examined the impedance individuality and the breakdown process of the spark channel during solo pulse discharge. The breakdown process took earlier in pure kerosene oil and for the powder mixed dielectric it increases with the gap distance and was justified using avalanche ionization. The impedance characteristics have been increased by increasing the expulsion current leads to a stable plasma channel in aluminum powder mixed oil.

h) Influence of EDM debris and bubble

Tomoo Kitamura [11] examined the interesting phenomenon that has taken place in the spark gap with transparent electrodes using high speed video camera. The results showed that almost 70% of the working surface is covered with bubbles after multiple discharges and the sparking occurs not

only in the liquid but also in the bubble and the boundary between the liquid and bubble. The probability of highest discharge occurs at boundary between the liquid and bubble due to the presence of debris particle. Through this observation they have established the relation between the bubbles and the successive discharge locations.

Koyano et al [12] showed that the external hydrostatic pressure has significant effect on Material removal rate. The experiment was conducted inside a pressure vessel. When the external hydrostatic pressure is decreased the pressure inside the bubble was decreased. This decreased pressure increases the deletion quantity of single pulse discharge due to the boiling and evaporating property of heated material. The material removal not only depends on the single pulse ejection but also depends on the bubble pressure.

Murray et al [13] studied the effect of debris particle on the electrical field strength. They have developed a model for debris spark gap using the Lattice Boltzmann technique. The particle size has great influence on breakdown voltage and the diameter has been calculated using the binary images developed by SEM and TEM.

IV. RESEARCHES CARRIED OUT IN DRY EDM

In view of the fact that the dry EDM is an environmental friendly, the reduced tool wear is another advantage. Varieties of researches have been in use on dry EDM due its ease handling and safe environment.

The speed of the machining can be increased by flushing out the debris from the spark gap rapidly. Shen et al [14] achieved very high MRR of 5162 mm³/min in dry EDM through the application of the high pressure and high speed air flow at the spark gap. They determined that the improvement in

MRR is due to the formation of discontinued and thin resolidified layer.

Wu and Zhou [15] developed an adaptive control system to stabilize and fastening the EDM process. They have constituted a minimum variance law which resolves the oscillations of the discharging cycle by following the specific gap state which retains the suitable concentration of chips in the machining gap. This makes the machining fast. To achieve the stabilization of EDM process, preferred poles have been established by making the dynamic response to track the preset reference model. The variance rule is coupled with the pole placement method to form an adaptive control system. To combine these two laws, the next level of the gap state is followed after implementing the variance law. The combined control law makes the EDM process fast and stabilizes upto a depth of 25 mm.

V. RESEARCH CONTRIBUTIONS IN WIRE EDM

In wire electrode EDM, wire tension, wire strength, wire thickness and feed rate are vital factors other than the electrical parameters which needs fine tuning in the machining process. This topic discusses the researches on wire tension and wire degradation parameters and their influence on performance personality.

Wire EDM adopts closed loop control system for wire tension control but in high speed WEDM (HS- WEDM) make use of gravitation force of heavy punch Junjie [16], Yongcheng [17]. With the development of electronic technology and intelligent control system Pratihari [18], Kwon et al [19] developed an expert system for manufacturing technology and the real time control for micro WEDM. But it does not satisfy the wire tension control. Hence Li et al [20], adopted a closed loop control to maintain the wire tension constant by utilizing the characteristics of HS-WEDM. They developed a mathematical model for wire tension control system in which wire tension fluctuation has been reduced by half and the surface roughness is

reduced by 0.6 μm . This adaptive control method improves the machining efficiency and accuracy by reducing the vibration of wire electrode.

Pramanik et al [21] analyzed the effect of machining parameters and wire tension of WEDM on the degradation of wire during the machining of SiC reinforced Al MMCs. They have examined the influence of the size of reinforcement particles on the cross section area of the wire. Due to high temperature there is a downward flow of malleable material which increases the diameter of the wire and the vaporization of wire decreases the diameter.

Habib et al [22] studied the effect wire tension on the amplitude and frequency of vibration of the tungsten wire electrode during fine wire electrical discharge machining. They observed that there is larger amplitude in the machining direction than that in a perpendicular direction. They also have analyzed and cleared up the uncertainties on vibration mode and the amplitude envelope.

VI. RESEARCHES IN MICRO EDM

Micro EDM works on the same principle of EDM, with a difference of the tool dimensions, sparking energy and the diameter of the plasma at micro level. It is developed for its use in precision and accurate machining which is mainly used in electronic, optical and jewel making industries. Throughout the era of MEMS technology, micro EDM plays a remarkable job.

Qian et al [23] observed the alternating current flow in the finishing regime of micro EDM with RC pulse type generator at higher open voltages. They exposed that the reverse current is flowing due to the resonance capacitance in the discharging circuit which increases MRR to a greater extent.

Wang et al [24] implemented a pulse counting method to analyze the alternating current run during discharge to see the effect of reverse current. The reverse current flow helps to polish the edges and to form the crater. Bypassing the reverse current by

connecting the diode between the spark track of the discharging circuit enhances the tool wear with respect to the work piece removal.

Tong et al [25] formed a scheme for roughing and finishing boundaries and online measurement method of micro electrodes for the transformation of roughing and finishing operations by intersecting point electrical contact method between the micro electrode and a standard thin rod and they have achieved accuracy of $\pm 1\mu\text{m}$, R_a of 0.38 μm and increased efficiency of 2.4 times.

A. Meso micro EDM

Here the dimension of the electrode lies between the macro EDM and micro EDM. Very few researchers have made analysis on meso micro scale.

Maradia et al [26], achieved near zero value of electrode wear of graphite electrode in meso micro scale by generating low thermal conductivity with high hardness carbonaceous layer on the electrode face.

Secondly they have analyzed the carbonaceous layer deposited on the electrode face and developed a thermal model to estimate the region of formation of carbon layer on the electrode plane [27]. They have simulated and compared the results of the pulse values at which the carbonaceous layer covers entirely the electrode surface to achieve close zero wear. And set up a new strategy to achieve a low wears in micro scale graphite electrode [28]. They have applied a combination of pulses (ipac) called wear neutral pulse packets to attain near zero wear. The results showed that the electrode wear reduces with longer pulse duration and the pulse duration values depend on electrode size, workpiece and rising current.

VII. NANO EDM

Due to the advent of nano technology, miniaturization of the product is promising and the nano EDM is the highest degree used for ultra

precision manufacturing in the finishing mode. Many challenging developments are hidden in the nano EDM which plays incredible role in future machining processes.

Xiao et al [29] reported a scaling approach to reduce electrode tip size in carbon nano forests to establish a nano EDM. They have experimented micro EDM of CNT forests sample with different electrode tip size and discovered that the reduction of tool tip size affect the breakdown voltage and is an efficient path to decrease the energy of the discharge. This fine discharge is capable of controlled removal of CNTs in the submicron scale leading to a fine patterning with miniaturized electrodes.

VIII. INTER DISCIPLINARY APPLICATION OF EDM

The electrical discharging machining is not only used for machining purpose but for other applications too. EDM can be used, to gather the nano particles from the solution, as an electrolysis process etc.

Somashekhar et al [30] developed the generation of copper nano particles using micro EDM. They have added PVA (Poly Vinyl Alcohol) and PEG (Poly Ethylene Glycol) as a stabilizing agent to prolong the period of deposition of Cu in De Ionized water.

Sahu et al [31] characterized the copper nano fluids which were developed as debris in μ EDM process built by the author Somashekhar [30]. By using Urick and Ament's link the mass concentration of Cu nano particles present in solution has been found and the ultrasonic velocity has been calculated via Pulse Echo system. The result shows that the concentration of Cu nano particles remains same for Cu- DI water and Cu-DI+ PVA nano liquid and there was a reduction in ultrasonic velocity for Cu-DI water+PEG nano fluid than PVA due to smaller particle size and reduced concentration.

IX. FUTURE SCOPE

- ❖ Researches on interdisciplinary relations have been practicable.
- ❖ Online tool manufacturing is realizable.
- ❖ Research on automation for the interface is needy.
- ❖ Research on smart machining is yet to workout.
- ❖ Research on hybrid tool and workpiece is still to exercise etc.

X. CONCLUSIONS

This paper discussed the dissimilar approaches of authors for the development of EDM at various faces. Through the scrutiny of these papers, many authors address the modeling technique, reduction of tool wear and machining of composites and carbides. But only countable researchers analyzed on reverse current flow and adaptive control system. Few authors established novel forms of EDM. Despite a range of experiments carried out in EDM, only very few researchers have started working on the implementation of smart machining. Overall, this paper reviewed the new techniques and strategies and their influence on performance characteristics developed by the researchers in recent years and opened some future scope.

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