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An Overview of Additive mixed EDM

Mahendra G. Rathi*, Deepak V. Mane**

* HOD (Workshop), Government College of Engineering, Aurangabad, Maharashtra, India.

** PG Student, Dept. of Mechanical Engineering, Government College of Engineering, Aurangabad, Maharashtra, India.

Abstract- The objective of this paper is to understand various trends of Electrical discharge machining (EDM) has been widely used as a removal process to produce parts, dies and molds for several decades. In recent years, the surface modification for hardening and depositing some functional materials by EDM has been studied [1].The development of the super tough electrical conductive material such as carbides, stainless steel, nitralloy etc. resulted in development of the nontraditional machining processes. These materials are difficult to machine by conventional machining process & have wide range of applications in industry. In EDM thermal energy is used to machine all electrical conductive materials of any hardness & toughness. Since there is no direct contact between the tool electrode & work piece in EDM, machining defects like mechanical stresses, clattering & vibration do not create problem during machining [2].

In spite of remarkable advantages of the process, disadvantages like poor surface finish and low volumetric material removal limits its use in the industry. In the past few years, Additive mixed Electric Discharge Machining (AEDM) emerges as new technique to enhance process capabilities. In this process, a suitable material in fine powder form (aluminum, chromium, graphite, copper, or silicon carbide, etc.) is mixed into the dielectric fluid of EDM. The spark gap is filled up with additive particles. The added powder significantly affects the performance of EDM process. The electrically conductive powder reduces the insulating strength of the dielectric fluid and increases the spark gap distance between the tool electrode and work piece. As a result, the process becomes more stable, thereby improving machining rate (MR) and surface finish.

Index Terms- Electro Discharge Machining (EDM), AEDM, Electrical conductive Powder, spark, Gap, Machining rate, Surface finish.

I. Introduction

Electro discharge machining is a non-traditional concept of machining which has been widely used to produce dies and molds. It is also used for finishing parts for aerospace and automotive industry and surgical components. This technique has been developed in the late 1940s where the process is based on removing material from a part by means of a series of repeated electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid. The electrode is moved toward the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece. EDM does not make direct contact between the electrode and the work piece where it can eliminate mechanical stresses chatter and vibration problems during machining. Materials of any hardness can be cut as long as the material can conduct electricity.

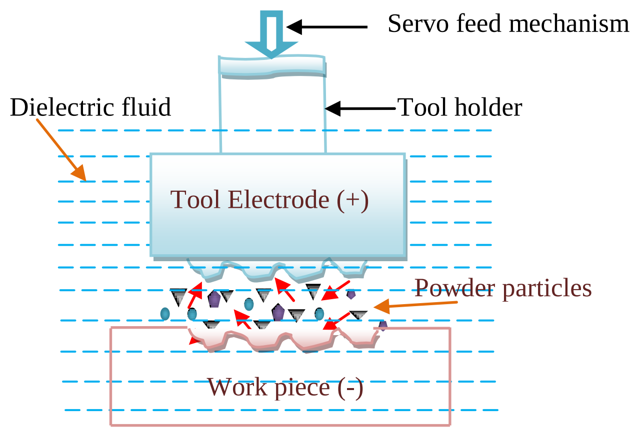

Fig. 1.1 The principle of Additive mixed EDM

When voltage is applied the powder particles become strengthened and act in a zigzag manner. These charged particles are accelerated due to the electric field and act as conductors encouraging breakdown in the gap. This rises the spark gap between tool and the work piece. Under the sparking area, these particles come adjacent to each other and arrange themselves in the form of chain like constructions. The interlocking between the powder particles arises in the direction of flow of current. The chain formation helps in linking the release gap between the electrodes. Since of bridging effect, the shielding strength of the dielectric fluid falls resulting in easy short circuit. This causes early blast in the gap and series discharge' starts under the electrode area. The quicker sparking within a discharge causes sooner erosion from the work piece surface and hence the material removal rate increases. The sparking is evenly spread between the powder particles, hence electric concentration of the spark drops. Due to constant scattering of sparking between the powder particles, narrow craters are formed on the work piece surface. This results in improvement in surface finish.

The basic machining mechanism of AEDM.

Additive_mixed Electric discharge machining has a various machining mechanism from the conventional EDM [3]. In this process, a suitable material in the powder form is mixed into the dielectric fluid either in the same tank or in a separate tank. For better circulation of the powder mixed dielectric, a stirring system is employed. For constant reuse of powder in the dielectric fluid, a modified circulation system (Fig. 1.2) is used.

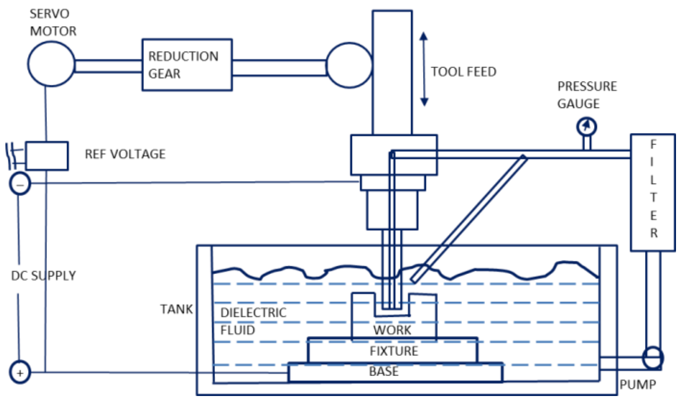

Fig 1.2 Setup of Electric Discharge Machining

A) Major Component of Additive mixed Electrical discharge Machining

1. Power supply: The power supply is an important part of any EDM system. It converts the alternating current from the main utility supply into the pulse direct current (DC) essential to create the spark ejection at the machining gap.
2. Pulse Generator & Control Unit: is likely for providing pulses at a definite voltage and current for precise extent of time. The power supply control the extent of energy spent. First, it has a time control purpose which controls the span of time that current flows during each pulse; this is called "on time." Then it is regulating the volume of current permissible to flow during each pulse. The control unit is control the all function of the machining for example of Ton, Ip, duty cycle, placing the values and maintain the workpiece the tool gap.
3. The servo system to feed the tool: The servo control unit is provided to maintain the pre-determined gap. It senses the gap voltage and relates it with the present value and the different in voltage is then used to control the drive of servo motor to adjust the gap.
4. Tool holder: The tool holder clamps the tool with the process of machining.
5. Circulating Pump: Circulation of powder mixed dielectric.
6. Electrode: The EDM electrode is the tool that fixes the shape of the cavity to be produce.
7. Permanent magnet: Magnetic forces are used to isolate the debris from the dielectric fluid. For this purpose, two permanent magnets are positioned at the bottom of machining tank
8. **Machining Tank:** The system contains of a transparent bath-like container, called the machining tank. It is placed in the work tank of the EDM, and the machining is accomplished in this container.
9. Working tank with work holding device: All the EDM oil preserved in the working tank, it is used to deliver the fluid throughout the process of machining.
10. **X-Y table accommodating the working table:** They are used to the movement of the workpiece from X and Y direction. [3]

II. MAJOR PARAMETERS OF EDM

EDM Parameters mainly classified into two categories.
Process parameter and Response Variable. [12]

Process Parameters: The process parameters in EDM are used to regulate the performance methods of the machining process. Process parameters are generally well-disciplined machining input factors that decide the conditions in which machining is carried out. These machining situations will affect the process performance result, which are gauged using various performance methods.

- ELECTRICAL PARAMETERS
  1. Duty factors
  2. Gap Voltage
  3. Peak Current
  4. Average current
  5. Push on time
  6. Pulse off time
  7. Discharge voltage
  8. Polarity
  9. Pulse Frequency
  10. Pulse waveform
  11. Electrode gap
- POWDER BASED PARAMETERS
  1. Type of powder
  2. Powder size
  3. Powder conductivity
  4. Powder concentration
  5. Powder density
- NON ELECTRICAL PARAMETERS
  1. Type of Dielectric
  2. Working time
  3. Electrode lift time
  4. Nozzle flushing
  5. Gain
- ELECTRODE BASED PARAMETER
  1. Electrode material
  2. Electrode size
  3. Electrode shape

Response variable: These variables measure the various process performances of EDM results.

1. Material removal rate (MRR)
2. Tool Wear rate (TWR)
3. Surface Quality
4. Surface Roughness

TYPES OF DIELECTRIC FLUIDS:

- Mineral Oils: liquid petroleum is a byproduct in the refinement of petroleum.
- Kerosene: was one of the first popular dielectric oils. Its primary advantage is that it has very low viscosity and flushes very well.
- Transformer Oil: is another mineral oil based product that was revised for use in EDMs due to its dielectric properties. Earlier generations of transformer oil were compounded with PCBs. Transformer oil has no current application in EDM.
- EDM Oils: There are currently various choices of mineral oils formulated specially for EDM.
- Synthetic oil: Synthetic oil is oil containing of chemical compounds which were not originally present in crude oil (petroleum)

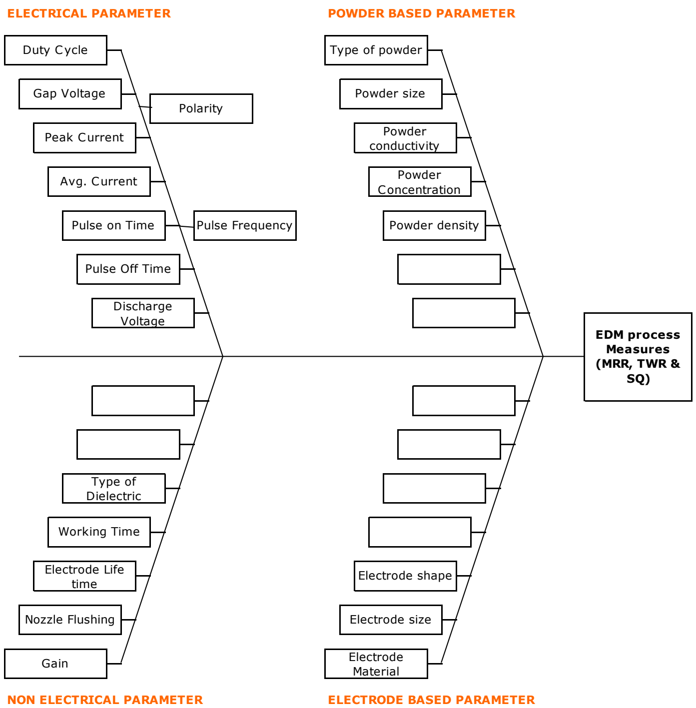

Fig 2.1 Process parameters and Output variables of EDM Process a cause and effect diagram

S No.	Material	Wear Ratio	Metal Removal Rate	Fabrication	Cost	Application
1.	Copper	Low	High on rough range	Easy	High	On all metals
2.	Brass	High	High only on finishing range	Easy	Low	On all metals
3.	Tungsten	Lowest	Low	Difficult	High	Small holes are drilled
4.	Tungsten copper alloy	Low	Low	Difficult	High	Used higher accuracy work
5.	Cast iron	Low	Low	Easy	Low	Used on few materials
6.	Steel	High	Low	Easy	Low	Used for finishing work
7.	Zinc based alloy	High	High on rough range	Easy die casted	High	On all metals
8.	Copper graphite	Low	High	Difficult	High	On all metals

Table 2.1 Types of electrode material

TYPES OF POWDER:

1. Aluminum
2. Silicon
3. Graphite
4. Chromium
5. Aluminum oxide
6. Silicon carbide.

III. Literature Review

Research Contribution year wise as follows:

Erden A., et al., (1980) Reported during the machining of mild steel that the machining rate rises by the adding of powder particles (Al, Cu, iron) in the dielectric fluid of dielectric machining. Here enhancement in the Break Down characteristics of the dielectric fluid is noticed with the addition of powder particles, but after a certain critical concentration of powder short circuiting take place which causes poor machining.

Jeswani M.L., et al., (1981) Study the effect of adding of graphite powder to kerosene used as dielectric fluid in the EDM. He concluded that addition of about 4gm/l of fine powder having average size of particle as 10Hm increases the MRR (Material Removal Rate) by 60% and TWR (tool wear rate) by 15% in electrical discharge machine. Wear ratio is also reduced by 30%. He concluded that there is 30% reduction in the breakdown voltage of kerosene at spark gap of 50Hm was witnessed.

Narumiya H., et al., (1989) Used Si, Al & graphite as powder materials. The concentration range of the powder was between 2gm/l to 40gm/l. Their conclusion showed that the gap distance increases with the powder concentration and is larger for the aluminum powder but there is no direct relation between the surface roughness and the gap distance. The best results about the surface finish were attained for low powder concentrations levels and that also for silicon and graphite powders.

Mohri, et al. (1992) Found that an EDM finishing process using dielectric mixed with silicon powder provides a mirror surface of up to 500 cm2, area. Recently this machining method has been introduced in commercial machine tools and practically applied in industry.

Kobayashi K., et al., (1992) Have concluded that silicon powder mixed in the dielectric improves the surface finish of SKD-61 tool steel. It has also been observed, however, that at specific machining conditions in the EDM of steel the aluminum and graphite powders create better surface roughness than silicon powder.

Yan and Chen (1994) That the powder particles contribute to the reduction of surface cracks and to the smoothness and homogenization of the white layer. The lowest surface roughness levels and a correct balance between the discharge energy density and the discharge rate were observed for a powder concentration within the range of 2 to 5 g/l.

Ming and He (1995) Indicates that some conductive powder can lower the surface roughness and the tendency of cracks in middle finish and finish machining but the inorganic oxide additive does not have such effect.

Wong Y.S., et al., (1998) Study the powder mixed dielectric electric discharge machining (PMD-EDM) by employing a current of 1A and pulse on time as 0.75Hs to produce a near mirror finish on SKH-54 tool steel. The conclusion was that the resulting machining surface was composed of well defined, uniformly sized, smoothly overlapped and shallow craters. The analysis was carried out by varying the silicon powder concentration and the flushing flow rate.

Uno et al. (1998) Observed that nickel powder mixed working fluid modifies the surface of aluminum bronze components.

Nickel powder was purposely used to deposit a layer on an EDM surface to make the surface abrasion-resistant.

Chow et al. (2000) Studied the EDM process by adding SiC and aluminum powders into kerosene for the micro-slit machining of titanium alloy. The addition of both SiC and aluminum powder to the kerosene enhanced the gap distance, resulting in higher debris removal rate and material removal depth.

Furutani K., et al., (2001) Used titanium powder in dielectric fluid (Kerosene) and found that the layer of titanium carbide of hardness 1600HV (Vickers hardness number) on a carbon steel with negative polarized copper electrode, peak current 3A and 2 Hs pulse duration. Titanium and titanium Carbide are found in XRay diffraction (XRD) analysis of machine surface. It was concluded that the breakdown of dielectric takes place and carbon came from it.

Tzeng Y.F., et al., (2001) Examines the effect of powder characteristics on machining efficiency of electrical discharge machining. They reach to a conclusion that 70- 80nm powder suspended in dielectric produces the greatest material removal rate and least increase in the spark gap.

Yan BH., et al., (2001) Studied the electric discharge machining with powder suspended working media and reported that the gap length become shorter regardless of a mixed powder with a decrease of the pulse duration at a duty factor of 0.5.

Peças P, et al., (2003) Investigated the influence of silicon powder mixed dielectric on conventional EDM. The relationship between the roughness & pulse energy was roughly investigated under a few sets of the conditions in the removal process. Still, the effect of the energy was not systematically analyzed.

Kozak J., et al., (2003) Reported that the material removal rate and tool wear rate were decreased by addition of powder. Consequently the machined surface becomes smooth.

Klocke F., et al., (2004) Used HSFC high speed forming camera technique to find out that in comparison to standard electrode, the Al mixed dielectric forms larger plasma channel. It was concluded that discharge energy distribution is on the larger art on the wok piece surface. The type and concentration of the powder mixed in the dielectric fluid also found to have direct effect on the machining performance output.

Biing Hwa Yan et al. (2005) Investigates the influence of the machining characteristics on pure titanium metals using an electrical discharge machining (EDM) with the addition of urea into distilled water. Experimental results indicate that the nitrogen element decomposed from the dielectric that contained urea, migrated to the work piece, forming a TiN hard layer, resulting in good wear resistance of the machined surface after EDM. They have concluded that Adding urea into the dielectric, MRR and EWR increased with an increase in peak current. Moreover MRR and EWR declined as the pulse duration increased. The surface roughness deteriorated with an increase in peak current.

Wu KL., et al., (2005) Study the problem of powder settling by adding a surfactant with Al powder in dielectric fluid and observed that a surface roughness (Ra value) of less than 0.2μm. This is because of more apparent discharge distribution. It was also reported that negative polarity of the tool resulted in better hardness of the surface.

H.K. Kansal et al. (2005) Optimized the process parameters of powder mixed electrical discharge machining (PMEDM) on tool steel using Response surface methodology. Pulse on time, duty cycle, peak current and concentration of the silicon powder added into the dielectric fluid of EDM were chosen as variables to study the process performance in terms of material removal rate and surface roughness. The silicon powder suspended in the dielectric fluid of EDM affects both MRR & SR. They concluded that more improvement in MRR and SR are expected at still higher concentration level of silicon powder.

Kansal H.K., et al. (2006) founds optimum process conditions for PMEDM of Al– 10%SiCP Metal Matrix Composites by an experimental investigation using Response Surface Methodology. Aluminium powder was suspended into the dielectric fluid of EDM.

Bai and Koo (2006) Investigated the effects of kerosene and distilled water as dielectric during electrical discharge surface alloying of super alloys.

Yeo S H., et al., (2007) The experiments were conducted using dielectric with and without additive and at low discharge energies of 2.5μJ, 5μJ and 25μJ, and was observed that a considerable difference in crater morphology is seen between craters in dielectric with and without the powder at low discharge energy of 2.5μJ, 5μJ and 25μJ. More circular shapes with smaller diameters are produced with powder additive as compared to without powder additive. Craters with the additives are smaller and have more consistent depth than in dielectric without additive. They reported that dielectric with additive in it lower the amount of discharge flowing between the work piece and the tool electrode and slows down the rate at which these charges flow.

H.K. Kansal et al. (2007) Have also identified number of issues that need to be addressed in future for implementation of PSD-EDM of this modified process of machining. Few of them are discussed here. Many researchers have shown that powder suspended EDM machining can distinctly improve the SR and surface quality in the finish machining phase and obtain nearly mirror surface effects. Despite the promising results, PMEDM process is used in industry at very slow pace. One of the key reasons is that many fundamental issues of this new development, including the machining mechanism are still not well understood. The complexity of this process, particularly in context with thermo physical properties of the suspended particles deserves a thorough investigation. Secondly, the difficulty in operation of dielectric interchange, the high amounts of powder consumption, the environmental requirements of fluid disposal and its higher initial cost (two to three times higher than the one required for a conventional EDM system) have restricted its frequent use.

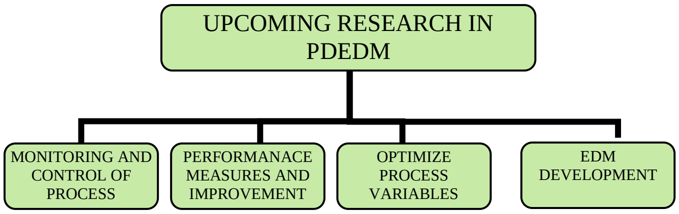

Fig : 3.1 Upcoming research in PMEDM

Norliana Mohd Abbas et al. (2007) Have reported a review on current research trends in electrical discharge machining (EDM). They have observed that Fine abrasive powder is mixed into the dielectric fluid.The hybrid material removal process is called powder mixed EDM (PMEDM) where it works steadily at low pulse energy and it significantly affects the performance of EDM process.

Han-Ming Chow et al. (2008) Have investigated the use of SiC powder in water as dielectric for micro slit EDM machining of titanium (Ti) alloy. They have concluded that SiC powder suspended in pure water causes a larger expanding-slit and electrode wear than those of using pure water alone. Also, pure water and a SiC powder attain a smaller amount of machined burr than that of using pure water alone.

Peças P. et al., (2008) Study the effect of silicon powder particles suspended in dielectric fluid. The powder concentration & flushing flow rate are two input parameters. They reach to a conclusion that even for small level of powder concentration there is evident amount of reduction in crater depth, crater diameter and the white layer thickness. They reported that for a particular experimental configuration used, we can find the powder concentration that generates better surface morphology. It was observed that there is dielectric flow rate that minimizes the surface roughness for each electrode area and for larger flow rates, no positive effect on the surface morphology.

Beri and Anil (2008) Performed experimentation on EDM of AISID2 steel in kerosene with copper tungsten (30% Cu and 70% W) electrode (made through Powder Metallurgy technique) and conventional Cu electrode. An L18 orthogonal array of Taguchi methodology was used to identify the effect of process input factors (viz. current, duty cycle and flushing pressure) on the output factors (viz. material removal rate and surface roughness). It was recommended to use conventional Cu electrode for higher MRR and CuW electrode made through PM for low SR.

Kun Ling Wua et al. (2009) Explored the influence of surfactant on the characteristics of electrical discharge machining (EDM) process on mold steel (SKD61). In this study, particle agglomeration is reduced after surfactant molecules cover the surface of debris and carbon dregs in kerosene solution. The experimental results show that after the addition of Span 20 (30 g/L) to dielectric, the conductivity of dielectric is increased. The machining efficiency is thus increased due to a shorter relay time of electrical discharge. When proper working parameters are chosen, the material removal rate is improved by as high as 40–80%. Although the improvement of surface roughness is not obvious, the surface roughness is not deteriorated since the material removal rate is great.

Kibria G., et al. (2009) relates different dielectrics in micro-EDM machining operation and reported that the machining characteristics are greatly influenced by the nature of dielectric used during micro-EDM machining. From the available literature, it is concluded that the machining characteristics of some hard and difficult to cut material can be studied by suspending powder of some material in the dielectric fluid of EDM.

Prihandana G.S., et al. (2009) Presents a new method that contains of suspending micro-MoS2 powder in dielectric fluid and using ultrasonic vibration during μ-EDM processes. It was detected that the introduction of MoS2 micro-powder in dielectric fluid and using ultrasonic vibration significantly increase the MRR and improves surface quality.

Kung et al., (2009) Reported that the material removal rate and electrode wear ratio in powder mixed electrical discharge machining of cobalt-bonded tungsten carbide by suspending aluminium powder in dielectric fluid. They observed that the powder particles disperses and makes the discharging energy dispersion uniform.

Furutani K., et al., (2009) The conditions for deposition machining by Ti powder suspended EDM was investigated with respect to discharge current and pulse duration in this paper. They concluded that the discharge energy affected the deposit able condition range. TiC could be deposited in the case that both discharge energy and powder density was small. They reported that the hardness of the deposition achieved was 2000Hv. The matrix surface was also hardened.

Kumar S., et al., (2010) Found that significant amount of material transfer takes place from the manganese powder suspended in dielectric fluid to the machined surface under appropriate machining conditions which changes the surface composition and its properties. They reported that percentage of manganese increased to0.95% from 0.52% and that of carbon to 1.03% from 0.82% that result in increase in the micro hardness. For surface alloying favourable machining conditions were found to be low peak current (4 A), shorter pulse on-time (5μs), longer pulse offtime (85μs),

Sharma S. et al (2010) Study the effect of aluminium powder on the machining performance of conventional EDM with reverse polarity. The machining performance is evaluated in terms of material removal rate, tool wear rate, percentage wear rate, surface roughness. Concentration and grain size of aluminium powder are taken as the input powder parameters and its effect are presented on machining performance. It is found experimentally that powder characteristics significantly affect machining characteristics.

Singh P. et al., (2010) investigate the Concentrations of Al powder and grain size of powder mixed in dielectric fluid strongly affects the machining performance of EDM process

Sharma S. et al. (2011) Study the effect of graphite powder on the machining performance of conventional EDM. The machining performance is evaluated in terms of tool wear rate. Concentration of graphite powder, polarity, electrode type, peak current, pulse on time, duty cycle gap voltage and retract distance is taken as the input parameters and their effect are presented on machining performance. Conventional copper electrode and cold treated copper electrodes were used during the experimentation. It is found experimentally that with the addition of the powder particles in the dielectric and the use of cold treated electrode Tool Wear Rate decreased.

SYED K. H. et al., (2012) Investigations on addition of Al metal powder to dielectric fluid in electric discharge machining(EDM). As more stress is given currently to the green manufacturing concept, the present analysis uses distilled water mixed with aluminium powder as dielectric fluid instead of conventional hydrocarbon-based oils. The workpiece & electrode materials chosen for the investigation are W300 die-steel and electrolytic copper, respectively. Taguchi design of experiments is used to conduct experiments by varying the parameters peak current, pulse on-time, concentration of the powder, and polarity. The process performance is measured in terms of material removal rate (MRR), electrode wear ratio (EWR), average surface roughness (Ra), and white layer thickness (WLT). The trial results indicate that the polarity significantly affects the machining performance. Signal-to noise (S/N) ratio and the analysis of variance (ANOVA) are employed to find the optimal levels for the process parameters to achieve maximum MRR, low EWR, Ra, and WLT values. [12].

IV. Conclusion

Electric discharge machining (EDM) has been found to be a promising machining technique for obtaining desired dimensional accuracy and intricacy from hard and tough die steels like high carbon high chrome materials. Powder mixing into the dielectric fluid of EDM is one of the innovative developments that ensure better machining rates at desired surface quality and at reduced tool wear rate.

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Authors

First Author - Mahendra G. Rathi, HOD (Workshop), Government College of Engineering, Aurangabad, Maharashtra, India.
mgrathi_kumar@yahoo.co.in, +91-9049504930

Second Author – Deepak V. Mane, PG Student, Dept. of Mechanical Engineering, Government College of Engineering, Aurangabad, Maharashtra, India.
deepakvmane@gmail.com, + 91-9922504914