A Brief Review on the Machinability of Micro EDM,Wire cut-EDM, and Die Sink EDM

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Abstract

The term "machinability" refers to an easy cutting action that allows for the removal of material with the desired surface finish at a cheaper cost. Working with a material that is well-machinable means that the unwanted material can be removed quickly while using only a small amount of power, with a reasonable level of surface finish and little tool wear. Different engineering materials have varying degrees of machinability depending on the specific machining conditions. a variety of parameters, such as cutting force, power consumption, tool life rating, surface integrity, limiting rate of material removal, tool geometry with the material, and stability of the machine tool, are used to determine the machinability of a certain material. Machinability is a relative concept so influenced by a variety of elements. Consideration must be given to the term machinability index in order to compare relative machinability. However, the machinability of cutting-edge machining techniques like Powder Mixed Electric Discharge Machining (PMEDM) and Electric Discharge Machining (EDM) differs slightly from that of traditional machining. The intricacy of EDM or PMEDM and other aspects affect how machinable it is. Material removal rate (MRR), tool wear rate (TWR), and surface roughness (SR) of the machined item are three crucial characteristics of EDM machinability. As a result, current study into the machinability of EDM or PMEDM has proved interesting. Due to PMEDM's numerous benefits, numerous researchers have concentrated their research on it during the past few decades. The objective of the present work is to review multipletypes of research. In addition, to highlight and summarize the research works in a systematic order and hence, to find out the future scopes in this particular field. It will motivate the researchers for exploring their study in the considered arena.

Keywords: *EDM, WEDM, Dielectric fluid, spark gap, electrode, PMEDM,MicroEDM.*

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1. Introduction

In an unconventional machining method called Electrical Discharge Machining (EDM), there is no physical contact made between the tool and the workpiece. It is used to mill materials whose excessive hardness and brittleness make them challenging to work with through traditional machining. Dimensional precision and form complexity are other important considerations when choosing an EDM technique. The EDM process enables precise machining on electrically conductive and semi-conductive materials. The use of EDM, one of many non-traditional machining processes, is greatly expanding because of its precise machining capabilities across a variety of industries. A relatively new field of study is the machining performance in the context of machinability for PMEDM and EDM. The machinability index is utilized for making a comparison of the machining performance of various engineering materials through the various cutting process. However, the machinability index in a contact type (intimate physical contact in between tool and workpiece) machining can be defined as follows[1–3]:

$$\text{Machinability Index (I)} = \frac{V_i}{V_s} \times 100\%$$

Where, V_i is the Cutting speed of metal under investigation during 20 minutes tool life. and V_s is the Cutting speed of standard steel with 20 minutes operation. It is customary to consider all parameters which evaluate the machinability or rather says relative machinability in contact type machining as follows:Tool life with the type of tool wear for crater wear, wear on flank etc., Size and shape, chip type, inclination towards burr, chip thickness ratio, Cutting forces in combination with associated power consumption, Chip removal rate with efficiency, Surface quality, surface finish in combination with characteristics of the machined surface, The temperature at cutting zones.

Because of this, study into the machinability of EDM or PMEDM has been difficult in recent years, and it may continue to be so in the future. Traditional EDM dielectrics without powder particles, low discharge energy, and small tool-to-workpiece gaps cause issues with gap cleaning and an increase in capacitance effects, which ultimately causes the ignition of the discharge to be delayed. Compared to conventional EDM and wired EDM (WEDM), polishing performance is improved by the controlled addition of powder particles including Si, Cr, Al, Graphite, Cu, SiC, and Al2O3 to an appropriate dielectric. This reduces the size of craters, the thickness of the white layer, and surface imperfections[4–8].

It has already been attempted by several scholars [2–14] to describe the material removal mechanism as a breakdown of dielectric, discharge, and erosion. The performance evaluation of high MRR, reduced TWR, and reasonably acceptable surface quality are thought to be the improved polishing phenomenon against the influence of powder on PMEDM[9–13]. They used the force of the suspended powder particles to significantly increase the spark gap by lowering the insulation resistance of the dielectric fluid. While an appropriate voltage is provided, a strong electric field is being created between the workpiece and tool material. This floating powder particle conducts electricity. In the presence of powder particles that create a bridge between the tool electrode and the workpiece, chains are produced at various points beneath the sparking zone. As a result of which, the voltage across the gap along with the insulating strength of dielectric decreased and subsequently, short-circuiting took place and hence accelerating the explosion process in between the spark gap[8,13–16]. Because of the enhancement in the number of discharges per unit time, faster sparking takes place that may cause rapid erosion from the work surface[11,17–23]. Simultaneously the control addition of powder particles increases the plasma channels for which electric density is reduced, and uniform distribution of sparking may be possible, resulting in uniform erosion on the workpiece surface and improved surface finish. A basic schematic illustration of EDM has been presented in Figure 1.

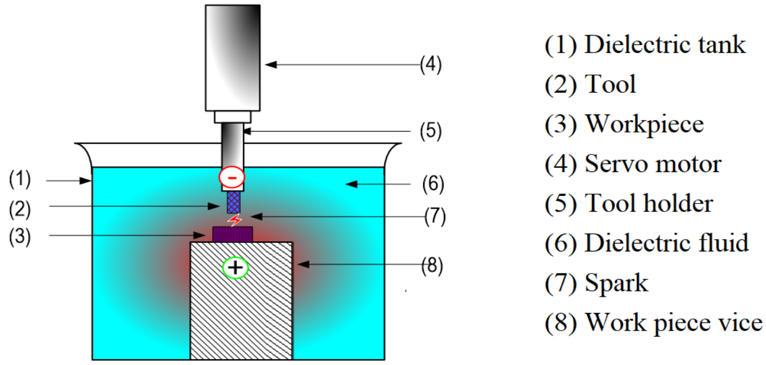

Fig. 1. Basic schematic illustration of EDM

The performance characteristics of machining through PMEDM depend upon the selection of input parameters. Some of the parameters for PMEDM arePeak current, Discharge voltage, Pulse on and off time, Polarity, Electrode gap, Gap voltage, Duty factor, Polarity, Pulse frequency, Pulse waveform, Electric field intensity against applied voltage etc.

2. Literature review

The impact of PMEDM on the machining performance of EDM and WEDM isan exciting area of study. Research work of various researchers relevant to the above-mentioned topic are enumerated and stated in chronological order in the recent past, more than one and half decades as follows:

In the year 2003, EDM research by Ho and Newman[8].related to the improvement of performance measures, optimizing the process variables, monitoring and controlling the sparking process may be considered as an inception to the development of die-sinking EDM process. Schumacheret al.[24]interpreted the EDM process as an ion action which is identified as physical research of discharges in the air or in a vacuum in conjugation with investigations on the breakthrough strength of insulating hydrocarbon liquids. It is further added that the material removal reaction is grouped in an evaporation phase at the start of ignition and later in the ejection of fused material by instantaneous boiling at the discharge spots. The research work carried by Pauloet al. [25]reveals a very significant point in the field of PMEDM. The introduction of Si powder with variable concentration combined with dielectric fluid improves MRR, surface quality produced in the EDM process. Prakash et el.[26],in the year 2013, identified that PMEDM has a significant role on TWR. Jamadar et al.[14]in the year of 2014 investigated the influence of process parameters of EDM like (I_p), (T_{ON}), and Al powder concentration on machining performance of AISI-D3 die steel. Machining characteristics wereanalyzed in terms of MRR, TWR and SR value (R_a) of the AISI-D3 die steel. Saliya et al. [27]reviewed the influence of powder mixed dielectric on the performance of WEDM in the year 2014. Studies have been performed under variation of electrical parameters, and the effect of powder in dielectric on quality characteristics were reported in terms of surface finish, kerfs width in combination with machining time. Choudhary et al. [28]also reviewed current research trends and applications on (PM-EDM) in the same year. An experimental investigation was performed on EN-8 working material, processed by PMEDM into Kerosene dielectric fluid by Prajapati et al.[29]. Performance characteristics of AISI die steel was evaluated against variation of Cr powder concentration, I_P and T_{ON} by Abrol and Sharma [30].Mathapathiet al.[15]analysed the influence of Cr, graphite powder concentration, within Kerosene dielectric against I_P, T_{ON}, T_{OFF}, electrode lift time on MRR and tool electrode life through with SR and TWR. Kumaret al.[31]investigated the influence of Al and Si powder in distilled water on machining characteristics of Nimonic-90 through the WEDM process. A trial was made to find out the value of optimum process parameters such as I_P, T_{ON}, T_{OFF}, SV, WO in different dielectric conditions. Kumaret al.[32],in the year 2018, experimented with the performance of EDM process for machining Inconel 825 alloy through PMEDM process, using Al_2O_3 nano powder with deionized water. The experiment reveals that a maximum MRR of 47mg/min against a minimum Ra value of 1.487µm is obtained, which are 44% and 51% higher in comparison with the conventional EDM process.Sivakumar andBoopathi[33]performed an investigation with the machining of HSS-M2 tool steel material through WEDM using near dry(air-mist/oxygen-mist), replacing liquid dielectric which is considered as eco-friendly machining environment with cooling effect at cutting zone. Sivakumaret al.[34] identified various biomaterials for orthopaedic implant areas and other applications based on considering related metal toxicity, corrosion in the body and biocompatibility for living systems. They did further identify various tool electrodes and work piece (bio-implant) for machining through EDM and WEDM. Chakrabortyet al[21]. in the year of 2020 investigated the performance analysis of eco-friendly machining of Ti6Al4V using powder mixed with different dielectrics in WEDM. Fadhilet al. [35]in the year of 2020 investigated the effect of powder mixed dielectric on EDM process performance. Research reveals that maximum MRR (0.492g/min) is obtained at various process parameters as follows I_p is 24A,T_{ON} is100µs,C_P is 10g/l. Minimum TWR(0.00126g/min) is obtained against at various parameters values as follows I_P is10A, C_p is 10g/l. Better Ra (3.51 µm) against various process parameters I_p is 10A, T_{OFF} is 50 µs, C_P is 10g/l. Debnath et al. [36] studied the variation of response measures with the variation in the input parameters during electric discharge machining (EDM) of 430 stainless steel using brass tool. They usedtap water as the dielectric medium in this study.Baroi et al. [17] investigated the effect of input process parameters on the output parameters during electrical discharge machining (EDM) of titanium grade 2 alloy using deionized water as the dielectric medium.

3. Conclusion

The results of a thorough literature review suggest that modern technology helps with real-time tool wear sensing and adjustment, which in turn increases machining efficiency by reducing the amount of time it takes to complete the task. A thorough evaluation of the literature from the past decades in the field of EDM,WEDM and MicroEDM on machinability led to the following recommendations for further research.

- It is necessary to explore the effects of powder particle, flushing systems, and the shape and size of the dielectric fluid tank.
- The effectiveness of different nano-powder mix dielectrics for the EDM process has received very little research to date.
- Considering eco-friendliness, near dry EDM and WEDM may be one of the challenging areas of future scope in view of working environment safety and health of the operator.
- There are several research worksthat have already been carried out with the concentration of powder particles in the EDM and WEDM processes. But the

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influence of powder shape and size on EDM performance needs to be investigated thoroughly. So, these may be identified future scope for recent days.

- Hybrid machining with EDM and WEDM like ultrasonic-assisted PMEDM may be one of the examples of future research areas.
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The machinability of the contactless machining process needs to be studied thoroughly. Extensive experiments and investigations can only define the machinability index of various engineering materials. So, there is immense scope of research to study the machinability index of EDM in order to find out relative machining efficiency and hence may estimate machining time for various newly discovered engineering materials.Recent development in the field of material Science and technology gifted us extremely hard, newly discovered many metals matrix composite of low electrical conductivity. Machining such newly invented critically important engineering materials through PMEDM and PMWEDM may be the next challenge for manufacturing professionals. So, these may be identified as the future scope in the field of PMEDM.

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