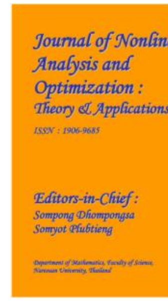
Journal of **N**onlinear **A**nalysis and **O**ptimization
Vol. 12, No. 1, (2021),
ISSN : **1906-9685**



AN EFFICIENT PRODUCTION METHOD THAT USES EDM TECHNOLOGY TO HANDLE POWDER MIXING WITH GREAT ACCURACY

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Abstract
Regardless of the mechanical characteristics of all electrically conductive materials, electric discharge machining (EDM) is one of the most effective production techniques. It is a non-contact thermal energy method used in a variety of industries, including aerospace, automotive, tools, moulds and dies, and surgical implements. It is particularly effective for cutting difficult-to-cut materials with simple or complicated forms and geometries. One of the process's early large-scale applications was to moulds, tools, and dies. These products are particularly challenging to mill because they are constructed of difficult-to-machine materials, have extremely complicated, highly accurate forms, and have surface properties that are delicate to machining conditions. The review of this kind with an emphasis on tool and die materials is extremely useful to relevant professions, practitioners, and researchers. This review provides an overview of the studies related to EDM with regard to selection of the process, material, and operating parameters, the effect on responses, various process variants, and new techniques adopted to enhance process performance. This paper reviews research studies on the EDM of different grades of tool steel materials.
Key words: EDM, PMEDM, MRR, SR

INTRODUCTION

Rapid advancements in recent years in the transportation, medical technology, aerospace, and many other industrial sectors have raised the demand for innovative materials with advantageous properties. Most contemporary materials require sophisticated production techniques in addition to having distinctive properties that make them easy to manufacture. Most of these materials are often challenging to cut using standard production techniques. These materials' distinctive properties expand their uses, which encourages manufacturers to research novel machining techniques that are both affordable and precise. One of the most cutting-edge manufacturing techniques, electric discharge machining (EDM), is used to successfully manufacture conductive materials that are challenging to cut. Modern companies frequently employ EDM as the preferred method to manufacture difficult-to-cut materials in order to promote precise machining, complicated form machining, and better surface integrity. The process is utilized to machine electrically conductive materials by applying repetitive sparks between electrode and workpiece. Unlike in mechanical machining, no deforming force is required between the electrode and the workpiece, and the machining takes place without actual contact between them. There are a large number of variants of the EDM process such as sinking EDM, wire EDM, micro-EDM, powder-mixed EDM, and dry EDM; all of these possess work on the same mechanism of material removal.

Developments of variants make the process more versatile and suitable for relatively big and micro-scale machining areas.

Therefore, it is important to have in-depth knowledge of this subject and, hence, the aim of this research paper is to provide comprehensive information and details of this process. It is important for review articles such as this one to bring out the intricacies of processes, parameter–response co-relations, and critical analysis of their response to better utilize them. This will prove to be of great use to understand failures, as well as in-service performance issues, of tools and tooling. The present article aims to provide an overview of the significant contributions of EDM to machining of tool steels. This paper gives the state of the art on current research studies conducted in all EDM variants for machining different grades of tool materials

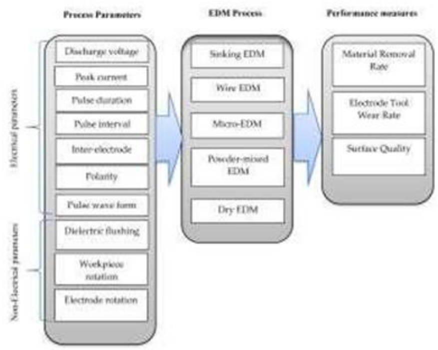

Figure 1: EDM Process parameters, Processes and Performance Measures.

EDM Process:

In EDM machine the material is removed by rapidly recurring (repeating) discharges of current in between the electrodes. The electrodes are separated by dielectric liquid and a high voltage is applied across it. It is used to machine those materials which are difficult to machine and have high strength temperature resistance. EDM can be used to machine only electrically conductive materials. Otherwise it cannot be used. One of the electrodes is called as tool and other is called as workpiece. Here the tool is connected with the negative terminal of the power supply and the workpiece is connected with the positive terminal.

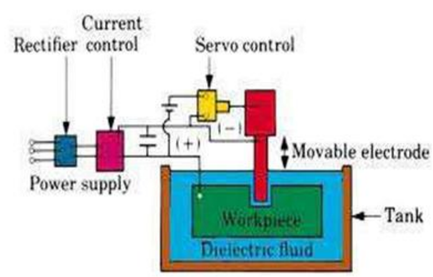

Figure 2: Electrical Discharge Machine

http://doi.org/10.36893/JNAO.2021.V12I1.117-123

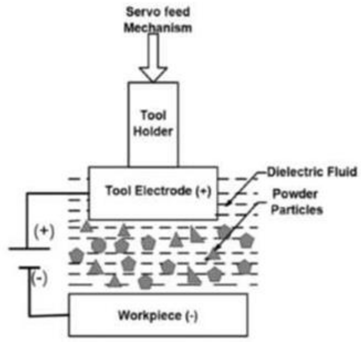

Figure 3: Powder Mixed Electrical Discharge Machine[1]

In Electrical discharge machining, a potential difference is applied across the tool and w/p in pulse form. The tool and workpiece must be electrically conductive and a small gap is maintained in between them. The tool and workpiece is immersed in a dielectric medium (kerosene or deionized water).
As the potential difference is applied, electrons from the tool start to move towards the workpiece. Here the tool is negative and w/p is positive. The electrons moving from the tool to the w/p collide with the molecules of dielectric medium.
Due to the collision of electrons with the molecule, it gets converted into ions. This increases the concentration of electrons and ions in the gap between the tool and workpiece. The electron moves towards the w/p and ions towards the tool.
An electric current is set up in between the tool and w/p and called as plasma. As the electrons and ions strikes the w/p and tool, its kinetic energy changes to heat energy. The temperature of the heat produced is about 10000 degree Celsius. This heat vaporizes and melts the material from the workpiece. As voltage is break down, the current stops to flow between the tool and w/p. And the molten material in the w/p is flushed by circulating dielectric medium leaving behind a crater. The spark generation is not continuous because constant voltage is not applied across the electrodes. The voltage is applied in pulse form.

Recent research in powder mixed EDM:

GangadharuduTallaet al (2015) did research by incorporating aluminium powder in kerosene dielectric, aluminum/alumina MMC can be machined using EDM. In comparison to conventional EDM, the results revealed an increase in MRR and a decrease in surface roughness (Ra). Using a hybrid strategy of dimensional and regression analysis, semi-empirical models for MRR and Ra based on machining parameters and significant

thermal physical properties were developed. To find the best choices of process parameters for the largest MRR and the least Ra within the experimental range, a multi response optimization utilizing the principal component analysis-based grey approach (Grey-PCA) was also carried out. Powder concentration (Cp), peak current (Ip), pulse on time (Ton), and duty cycle (Tau) have been recommended to be the appropriate process parameter settings for the proposed process. These values are 4 g/l for Cp, 3 A for Ip, 150 ms for Ton, and 4 g/l for Cp[1].
Shalini Mohanty et al (2017)studiedthat the input variables on which certain machining characteristics, such as material removal rate (MRR), surface roughness (Ra), and tool wear rate (TWR), were analyzed are low voltage current (LVC), high voltage current (HVC), pulse-on time (Ton), pulse-off time (Toff), and flushing pressure (FP). AlSiCp12% metal matrix composite (MMC) was cut using an EDM with a 99.98% pure copper electrode that had a 12 mm diameter. The trial run was planned using a Box Behnken design. As a multi- objective optimization strategy, the desirability approach was used to

optimize the parameters in order to determine their significance. Furthermore, particle swarm optimization (PSO) was used to forecast the outcomes, leading to the error analysis of the set of tests. A confirmatory test was also performed [2].

Shailesh Dewangan et al (2015) studied to improve the surface integrity features of EDM of AISI P20 tool steel, so the best settings for the process parameters are determined using a hybrid optimization technique based on grey-fuzzy logic. Response surface methodology (RSM) was used to design the experiment, with the following process factors taken into account: discharge current (Ip), pulse-on time (Ton), tool work time (Tw), and tool lift time (Tup). Their work effort takes into account a number of surface integrity criteria, including white layer thickness (WLT), surface crack density (SCD), and surface roughness (SR). Grey fuzzy reasoning grade was calculated using grey relational analysis (GRA) and fuzzy logic (GFRG). According to their research, the best possible outcome is Ip $^{1/4}$1 A, Ton $^{1/4}$10 ms, Tw $^{1/4}$0.2 s, and Tup $^{1/4}$ 0.0.Analysis of variance (ANOVA) results clearly indicated that Ton was the most contributing parameter followed by Ip, for multiple performance characteristics of surface integrity[3].

Analysis of variance for GFRG.

Source	DOF	SS	MS	F	P	% Contribution
Regression	3	0.12399	0.041329	24.48	0.000	73.86
Linear	2	0.08248	0.041240	24.43	0.000	49.13
Ip	1	0.04765	0.047655	28.23	0.000	28.39
T_{on}	1	0.03482	0.034822	20.63	0.000	20.74
Square	1	0.04151	0.041508	24.59	0.000	24.73
$T_{on}*T_{on}$	1	0.04151	0.041508	24.59	0.000	24.73
Residual error	26	0.04389	0.001688			26.14
Lack-of-fit	5	0.01370	0.002739	1.91	0.135	8.16
Pure error	21	0.03019	0.001438			17.98
Total	29	0.16788				100.00

Table 1: Analysis of Variance for GFRG

Comparison of results obtained under initial and optimal machining condition.

Levels	Initial machining parameters level	Optimum machining parameters level	
	Ip = 3 A, T_{on} = 90 μs, T_w = 0.6 s, T_{up} = 0.75 s	Ip = 1 A, T_{on} = 10 μs, T_w = 0.2 s, T_{up} = 0.0 s	
		Predicted	Experimental
WLT (μm)	12.452		6.954
SCD (μm/μm^2)	0.0210		0.0202
SR (μm)	4.8800		2.06
GFRG	0.5612	0.7953	0.7731
Improvement in the GFRG		0.2341	0.2119

Table 2: Comparison of results obtained under initial and optimal machining condition

Shih-Fu Ou1 et al (2017) studied the machining of titanium and titanium-tantalum alloy-based orthopaedic implant materials using bioactive hydroxyapatite (HA)-powder suspension as the dielectric. Investigations were done into how the composition of the workpiece and the powder particles affected machining performance. When titanium is machined with water, the surface is rougher (Ra 2.4 m) and the recast layer is near to 10 m. However, when titanium is machined with a suspension dielectric containing 5 g/L HA, the surface is smoother (Ra 2.1 m) and the recast layer is smaller (9 m).Additionally, compared to water, the MRR of titanium machined in the HA-powder suspension dielectric (6.4x10-4 gmin-1) was significantly lower (28.6x10-4 gmin-1). However, as the HA content

http://doi.org/10.36893/JNAO.2021.V12I1.117-123

was raised, the MRR, electrode wear rate (EWR), surface roughness, and recast-layer thickness all gradually increased. Under PMEDM, the MRR, EWR, and surface roughness of alloys made of titanium and titanium-tantalum showed an inverse relationship with the alloy's melting point and thermal conductivity. Additionally, calcium 2 and phosphorus were added to the recast layer, and as the discharge current was raised, their concentrations declined[4].

Mohammadreza Shabgard et al (2017) conducted experiments where copper electrodes were used in the EDM process together with a mixture of dielectric and CNTs to increase the efficiency of machining Ti-6Al-4V alloy. The current study also attempted to investigate the impacts of CNT mixed dielectric on the work piece's surface characteristics, tool wear ratio, and material removal rate (MRR). Scanning electron microscopy (SEM) analysis of the work pieces' surfaces showed that surface microcracks were diminished in the presence of CNT particles in the dielectric. Additionally, it was mentioned that adding CNTs to the dielectric showed notable benefits in machining stability, which decreased MRR and TWR. The study's findings clearly showed that including these particles had reduced surface roughness [5].

Shalini Mohanty et al conducted experiments On Ti6Al4V sheets, the experiments were conducted utilising tungsten tools and tungsten disulphide (WS2) powders suspended in deionized water as the dielectric medium. Melting happens as a result of sparks that fly between the tool electrode and the work piece gap in the local area. As a result, the dielectric fluid and the particles dispersed inside it become dissociated and go through the alloying process. The tests were conducted using the Taguchi method, and the process parameters were taken as a L9 array. Voltage, duty factor, and powder particle concentration were the chosen for parameter settings. The EDM alloyed samples are subjected to EDS examination using a self-contained field emission scanning electron microscope (FESEM). Additionally, the micro-hardness, material removal rate, and surface roughness were examined. In order for the alloy created to have some self-lubricating qualities, lubricating particles must be used in the dielectric fluid. The lubricating properties of the alloyed material were improved by the creation of a recast layer (RL) across the surface of the Ti6Al4V work piece, according to the results[6].

Modi, M.a et al (2019) The productivity of electro discharge machining (EDM) of the Nimonic 8OA alloy was examined in relation to theuse of various powders. Chromium (Cr) and Aluminium (Al) powders were utilized in the study, despite the fact that they have quite different thermophysical properties. In research. The impact of surface roughness (SR), material removal rate (MRR) and machining process mechanism with the mixing of these powders in dielectric fluid has been investigated. The volumetric proportion of powders, molecule size, density, electric resistance and heat conductivity of additives were all important factors that collectively influenced the productivity of the powder mixed electro discharge machining (PMEDM) process, it was discovered after reviewing the results of experiments. When the proper ratio of powders are added to the dielectric fluid, the material removal rate is increased and the surface roughness is subsequently decreased. The powder's minute suspended molecule size caused the maximum material removal rate under similar molecule volumetric proportion tests, which in turn raised the surface roughness[7].

M.Ashok et al (2021) studied that the dielectric liquid was appropriately diluted before micro or nano particles are added. Lowering the dielectric breakdown characteristics, widening the spark gap, flushing homogeneity, and stability in spark were the key PMEDM functions. Process parameter optimization was used to increase machining productivity. To solve issues in science and engineering, Taguchi is a common optimization tool. However, it is limited in how it deals with single outputs and their analyses. But in practise, the issues facing the engineering sector have many different outcomes. As a result, the Taguchi technique must be used with other strategies in order to solve problems with numerous objectives. Typically, the Taguchi approach is combined with utility concept, desirability analysis, and grey relational analysis [8].

S R Fadhil et al (2020) were studied,

the transformer oil was combined with equa l parts of the powders of graphite and silico n carbide to serve as the dielectric medium. The purpose of this study is to determine h ow certain process variables, such as peak c urrent, pulseon duration, and powder conce ntration, affect the rates of material remova l, tool wear, and surface roughness when hi ghspeed steel (HSS)/(M2) is being machine d (Ra).

By using a facecentered central composite design, experiments havebeen designed and analysed using the Response Surface Meth odology (RSM) technique (FCCD).It has been discovered that, under various circumstances, adding graphite-silicon carbide mixing powder to the dielectric fluid improved the MRR and Ra as well as decreased the TWR. Maximum MRR was achieved at peak current of 24 A, pulse on time of 100 s, and powder concentration of 10 g/l; minimal TWR was achieved at 10 A, pulse on time of 100 s, and powder concentration of 10 g/l; and improved Ra was achieved at 10 A, pulse on time of 50 s, and 10 g/l [9].

Jagadeep Sing et al (2016) concentrated on surface modification and characterization of tungsten carbide (WC), a material that is difficult to machine (DTM), using a powder mixed EDM method. In order to conduct the tests and examine the two main surface characteristics, namely micro-hardness (µ-H) and surface roughness, L27 orthogonal array design is employed. The four main input parameters are pulse-on time, pulse-off time, current, and particles (SR). Powders of alumina (Al_2O_3) and graphite (C) are dissolved in the working fluid. An initial quantitative investigation reveals that adding C powder to the working fluid in EDM improves the µ-H findings by 12.31% and the SR results by 5.61%. When compared to a straightforward EDM procedure, alumina powder exhibits better surface polish and micro-hardness values in this investigation.This demonstrates that adding abrasives to the working fluid enhances the efficiency of the EDM process. The findings of the multi-objective optimization of the powder mixed EDM of WC are primarily used to choose three samples for analysis. Using the scanning electron microscope (SEM) for microstructure analysis, the X-ray diffractometer (XRD) to demonstrate material transfer and the phases of various present elements, and the EDS to quantitatively confirm the results of XRD, these samples are used to perform the qualitative analysis to confirm the results of the quantitative analysis [10].

S Thripathya et al (2016) The current study looks into how process variables affect the micro-hardness of H-11 die steel during electro-discharge machining (EDM) and powder mixed electro-discharge machining (PMEDM). The experiments with chromium powder mixed dielectric fluid were carried out using Taguchi's L27 orthogonal array, and variables included "powder concentration (Cp), peak current (Ip), pulse on time (Ton), duty cycle (DC), and gap voltage (Vg)." The ideal environment has been identified through the use of analysis of variance (ANOVA). A predictive empirical model has been created for micro-hardness. Maximum micro-hardness was determined to be best achieved with the following set of parameters: Cp = 6 gm/l, Ip = 9 amp, Ton = 150 s, DC = 80%, and Vg = 50 V. A confirmatory test revealed a relative error between the experimental and anticipated values of 1.95%micro-hardness values Using a scanning electron microscope (SEM) and energy dispersive spectroscopy, material migration from the tool to the machined surface, conductive powder, and dielectric fluid have been studied (EDS) [11].

CONCLUSIONS

Following a thorough study of several recent technical studies, it has been shown that the addition of powders or nanopowders enhances MRR, surface integrity, and decreases surface roughness. Additionally, additional performance metrics, such as Recast Layer Thickness and Microhardness, will improve. However, these rely on the ration at which particles are added to the dielectric medium. However, there is still room to advance the study by including other nanopowders and combinations of two or more nanopowders into the dielectric medium.

REFERENCES

1. GangadharuduTalla, Deepak Kumar SahoO, S. Gangopadhyay, C.K. Biswas, “Modeling and multi-objective optimization of powder mixed electric discharge machining process of aluminum/alumina metal matrix composite”, Engineering Science and Technology, an International Journal 18 (2015) 369e373.
2. Shalini Mohanty, Ankan Mishra, B.K.Nanda, B.C. Routara, “Multi-objective parametric optimization of nano powder mixed electrical discharge machining of AlSiCp using response surface methodology and particle swarm optimization”, Alexandria Engineering Journal (2017) xxx, xxx–xxx, ttp://dx.doi.org/10.1016/j.aej.2017.02.0 06
3. Shailesh Dewangan, Soumya GangopadhyaY,, Chandan Kumar Biswas, “Multi-response optimization of surface integrity characteristics of EDM process using grey-fuzzy logic-based hybrid approach”, Engineering Science and Technology, an International Journal 18 (2015) 361e368
4. Shih-Fu Ou1, Cong-Yu, Wang, “Effects of bioceramic particles in dielectric of powder-mixed electrical discharge machining on machining and surface characteristics of titanium alloys”, Journal of Materials Processing Technology,
5. Mohammadreza Shabgard, Behnam Khosrozadeh, “ Investigation of carbon nanotube added dielectric on the surface characteristics and machining performance of Ti–6Al–4V alloy in EDMprocess”,Journalof Manufacturing Processes 25 (2017) 212–219.
6. Shalini Mohanty, Vishnu Kumar, Rashi Tyagi, Shakti Kumar, Brij Bhushan,Alok Kumar Das, Amit Rai Dixit, “Surface alloying using tungsten disulphide powder mixed in dielectric in micro-EDM on Ti6Al4V”, DOI:10.1088/1757-899X/377/1/012040.
7. Modi, M.a, Agarwal, G.b, “ Effect of aluminium and chromium powder mixed dielectric fluid on electrical discharge machining effectiveness”, Advances in Production Engineering & Management, Volume 14 | Number 3 | September 2019 | pp 323–332.
8. M.Ashok, T.Niranjan, S.Chokalingam and B.Singaravel, “Investigation of powder mixed electrical discharge machining and process parameters optimization using Taguchi based overall evaluation criteria”, IOP Conf.Ser.: Mater. Sci. Eng. 1057 012075.
9. S. R. Fadhil and S. H. Aghdeab, “Effect of powder-mixed dielectric on EDM process performance,”Engineering and Technology Journal, Vol. 38, Part A, No. 08, pp. 1226-1235, 2020.
10. Jagdeep Singh* & Rajiv Kumar Sharma, “ Study the surface modification and characterization for powder mixed electrical discharge machining of tungsten carbide”, Indian Journal of Engineering & Materials Sciences Vol. 23, October 2016, pp. 321-335
11. S.Tripathya, D.K.Tripathy, “An approach for increasing the micro-hardness in electrical discharge machining by adding conductive powder to the dielectric”, ICMPC 2016, Materials Today: Proceedings 4 (2017) 1215–1224

http://doi.org/10.36893/JNAO.2021.V12I1.117-123