A Systematic Review on Powder Mixed Electric Discharge Machining (PMEDM) Process

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Abstract *The electric discharge machining is also called as spark eroding mechanism. The use of thermoelectric source of energy in developing the non-traditional techniques has greatly helped in achieving an economic machining of the extremely low machinability materials and difficult jobs. The process of material removal by controlled erosion through a series of electric sparks, commonly known as electric discharge machining. Thermal energy gets produced as a result of applied electrical energy in EDM. Therefore, to enhance the process efficiency there should be improvement in different process parameters and also there should be improvement in the performance of different major component of process. The study discusses about having an overview of the EDM mechanism, its process parameters, and how to improve performance of dielectric fluid by adding various additives in it. After reviewing, according to results it has been observed that process efficiency can only be improved by optimizing the process parameters and addition of additives to the dielectric fluid.*

***Key Words*: EDM, PMEDM, mechanism, electrode, dielectric**

1. INTRODUCTION

Electric discharge machining (EDM) is an unconventional machining process which is mainly used for hard material which is difficult to machine by conventional methods like hardened steel, carbide, Inconel based super alloys etc. EDM is non-contact machining operation which is used in industry for high precision products especially in manufacturing industries, aerospace and automotive industries, communication and biotechnology industries [1-7].

No relative hardness between tool and work piece is required as there is no contact between tool & work piece. Due to this non-contact nature there is no force and vibration during machining process [8]. And this force free nature of machining process allows a soft and easy to machine electrode materials to machine a very hard, fragile or thin work pieces [9-11].EDM is a thermal process which makes use of spark discharges to erode material from the work piece surface [5, 12, and 13].

EDM is a high precision process in which the replica of tool can be achieved on the work piece. The general limitation of the process is that it is applicable only for conductive or some semi conductive work piece & tool materials [4, 5]. EDM machine has broad application in the production of die cavities and other pr�ised complex parts.

Material removal takes place due to repetitive produced sparks between tool and work piece. The produced sparks are non-continuous in nature and a series of sparks occurs within a short span of time. The tool and electrode both are submerged in dielectric like kerosene, paraffin oil, unionized water etc. [5, 14, 15].

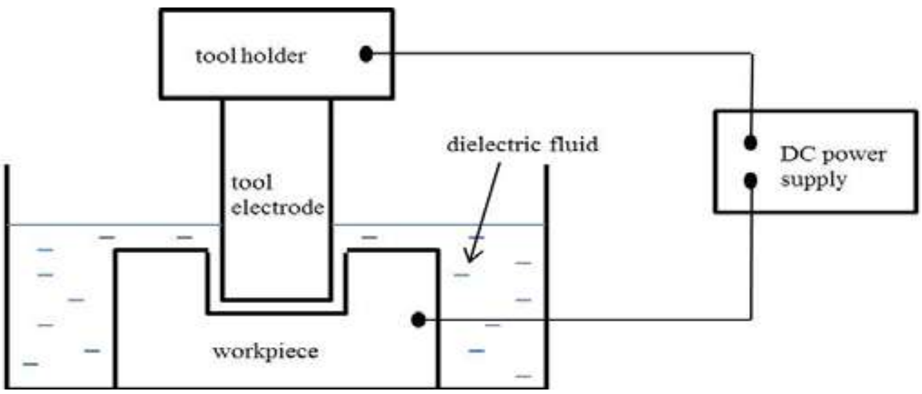

Fig -1: Schematic diagram of EDM.

2. Principle of EDM

EDM process is based on the principle of thermal energy in which hard but electrically conductive material can be machined easily by local melting and vaporization of small area of surface of the work piece by the application of series of sparks between tool and work piece [16]. The volume of material eroded in a single spark is less, which is in the range of 10_6–10_4 mm3. Then this simple procedure is frequently constant normally 10,000 times/sec [17].

By the application of voltage an electric field gets generated between the electrodes (w/p & tool) at the position of least resistance due to breakdown of dielectric medium ionization occurs which results in the drop of the voltage and the flow of current occurs [18].

Further results in migration of electron and ions to the anode and cathode respectively at very high current density. Now due to this a formation of column of vapors begins and localized melting of work commences. This discharge channel continues to expand along the increase of temperature and pressure. Thus, enormous amount of thermal energy gets generated which results in high rise in temperature in the range of 80,000C and 120,000 _C which results in vaporization or erosion of material from the work piece surface and forms a small cavity [19].

Dielectric fluid is used in the further processing step to flushed away residual debris along with the products of decomposition of dielectric fluid. Therefore, dielectric fluid is used to for mainly four eliminatory functions ionizations, insulation, cooling and removal of debris from the gap between tool and work piece [20].

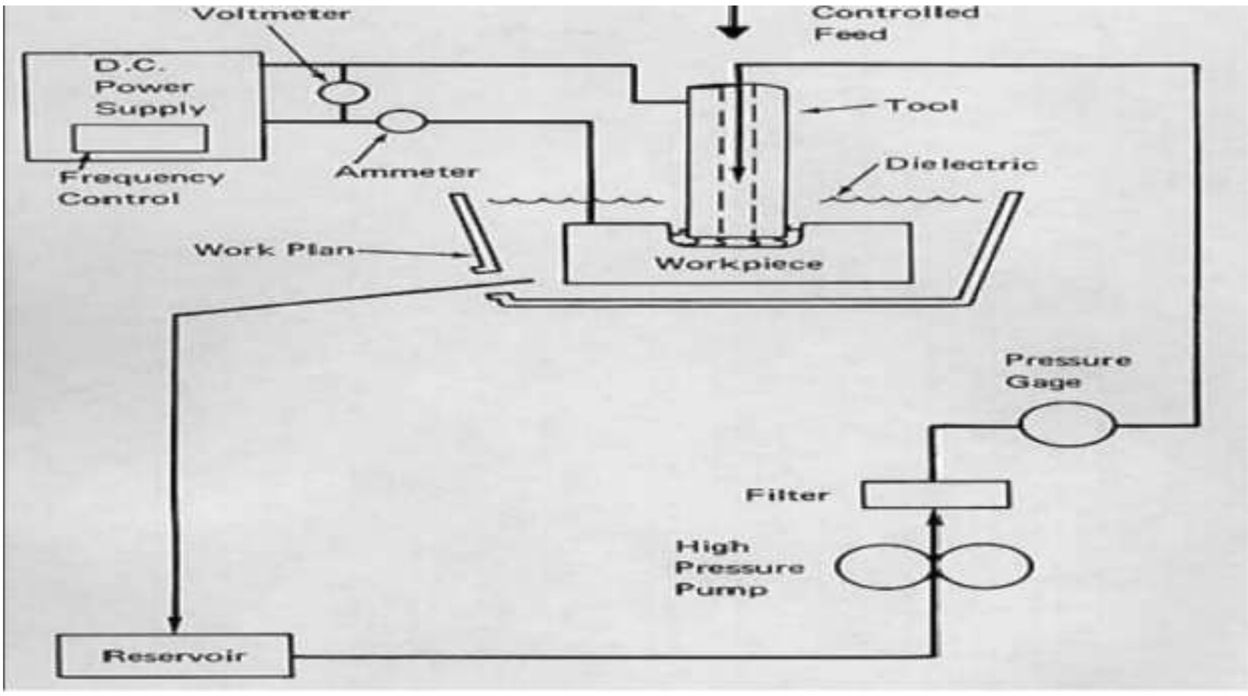

Fig-2: working principle of EDM process [19]

3. Characteristics of EDM: -

a) By this process machining of materials is limited to only electrically conductive or partially electrically conductive materials. Hence value of conductivity of same materials is specified in Table 1.
b) During the processing of material removal depends on conductivity of material and its thermal properties
c) Also instead of its hardness and toughness. Thermal conductivity of some specified materials is given in table 2.
d) Electrically conductive tool is used and tool wear depends upon the thermal properties of tool material.
e) However, there may be a chance of taper and overcut in EDM process but it can be further compensated.

Table-1: Value of electrical conductivity of some selected materials [21]

Non conductive materials	Partly conductive materials	Conductive materials	Electrical conductivity
Diamond	_	-	10^{-16}
Al_2O_3	_	-	10^{-14}
Zro_2	_	-	10^{+13}
_	Si	-	10^{-10}
_	SiC	-	10^{-4}
_	B_4C	-	10^{-4}-10^{0}
_	-	SiSiC	10^{-1}-10^{+1}
_	-	SiN_4-TiCN	10^{+1}-10^{+2}
_	-	TiB_2	10^{2}
_	-	Al_2O_3- TiCN	10^{3}
_	-	Zro_2-TiN	10^{3}
_	-	Steel	10_4
_	-	Copper	10^{5}
_	-	Silver	10^{6}
_	-	WC-Co	10^{6}
_	-		

Table 2 Thermal conductivity of materials and liquids [22]

Liquid/material	Thermal conductivity
Engine oil 0.145	0.145
Ethylene glycol 0.253	0.253
Water 0.613	0.613
Cuo_2	19.6
Al_20_3	40
Si 148	148
Aluminum	236
Copper	401
Diamond 2300	2300
Carbon nanotube 3000	3000

4. PMEDM process

Powder mixed electric discharge machining process (PMEDM) is an advance technology which is introduced to enhance the capabilities of EDM. For this purpose solid particle are used along with dielectric which are electrically conductive in nature. PMEDM process is applicable to any conductive material irrespective of its hardness, toughness, strength and microstructure. Metallic powder in dielectric decrease its insulating strength and increases the inter-electrode gap, therefore this improves the EDM performance and provides better surface finish as compared to conventional EDM. Working Principle of the PMEDM states that with the help of appropriate voltage applications an electric field gets generated due to which there is rise in positive and negative charges on the powdered particles. Hence the powered particles get accelerated and move in a zigzag manner which leads to improve spark gap between electrodes. Due to bridging the discharge gap between electrodes the insulating strength of dielectric decreases and spark gap increases.

5. Mechanism of PMEDM process

Fine powder gets mixed with dielectric solution and a circulation pump may be installed for the reuse of powder. Gap between tool and work piece is kept a 25μm to 50μm. by the application of voltage of 80-320 volts and electric fields of intensity 105-107 v/m is produced [23]. As a result, positive and negative charges get accumulated at the top and bottom of powder particles respectively. Discharges Breakdown may be occur between powder particles or between powder particles and tools or work piece electrode. Due to interlocking between different powder particles chain formation occurs that causes short-circuiting in the gap [24]. The combined effect may be called as bridging effect. Due to bridging effect gap voltage and insulating strength of dielectric fluid decreases hence short circuit and early explosion occurs between the gaps.

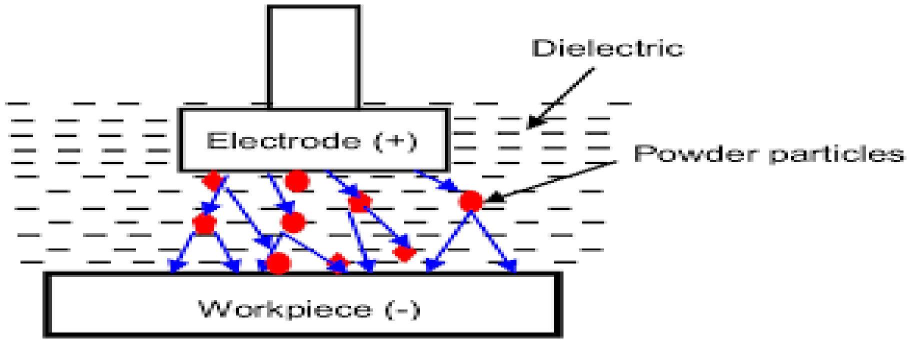

Fig. 3 mechanism of PMEDM process

6. Effect of addition of various powder additives: -

Inconel 718 like super alloys comes under the category of materials which are difficult to machine by traditional methods hence PMEDM process can be adopted for the material removal process because EDM process results in low material removal efficiency and inferior surface finish as compared to PMEDM process. And for this purpose cu powder can be added with EDM oil. The physical properties of Cu powder have been given below [25]

Density: 8.96 g/cc

Thermal conductivity: 4.16 W/cm-K

Electrical resistivity: 1.59 µΩ-cm

Melting Point: 1356K

Specific heat: 0.092cal/g-0C

When Inconel 718 is used as a work material chemical composition and mechanical properties of inconel could be found in [26]. PMEDM process is utilized in which kerosene is used as a dielectric. the process gets executed by addition of sic with EDM oil.

7. Applications of PMEDM

a) PMEDM can be used in high precision instruments where large area with fine surface finish are required to be machined
b) Complex 3-D shapes, complex profiles and fragile components can also be machined successfully using the PMEDM process regardless of their strength and hardness.
c) PMEDM is applicable in machining of advance materials like metal matrix composite materials are perceived promising.

d) It can be used where rough machining is required

8. CONCLUSIONS

EDM is one of the most preferable un-conventional manufacturing processes used to machine a conductive material with high strength and high hardness. To enhance the performance and effectiveness of existing EDM process, PMEDM gets innovated. Many researchers have different experimental results with different powder materials and various dielectric combinations.

This paper presents a brief summary of published research work based on the experimental investigation on PMEDM. Few conclusions can be described from the present review are:-

a) Dielectric used in PMEDM process along with additive powders plays a significant role in increasing material removal rate and reducing tool wear rate as compared to traditional EDM process.
b) The application of powder mixed dielectric fluids results in better surface finish; it also helps to modify surface characteristics.

REFERENCES

[1] Abbas, M. N., Solomon, D. G., & Fuad Bahari, M. (2007). A review on current research trends in electrical discharge machining (EDM). Internatioal Journal of Machine Tools and Manufacture,47(7), 1214-1228.

[2] Liao, Y. S., Chen, S. T., & Lin, C. S. (2005). Development of a high precision tabletop versatile CNC wire-EDM for making intricate micro parts. Journal of Micromechanics and Micro engineering, 15, 245-253.

[3] Yoo, H. K., Kwon, W. T., & Kang, S. (2014). Development of a new electrode for micro-electrical discharge machining (EDM) using Ti(C,N)-based cermet. International Journal of Precion Engineering and Manufacturing, 15 (4), 609-616.

[4] Hoang, K. T. & Yang, S. H. (2013). A study on the effect of different vibration-assisted methods in micro-WEDM. Journal of Materials Processing Technology, 213, 1616-1622.

[5] Hoang, K. T. & Yang, S. H. (2015). A new approach for micro-WEDM control based on real-time estimation of material removal rate. International Journal of Precision Engineering and Manufacturing, 16 (2), 241-246.

[6] Debroy, A. & Chakraborty, S. (2013). Non-conventional optimization techniques in optimizing non-traditional machining processes: a review. Management Science Letters, 3(1), 23-38.

[7] Yan, M. T. (2010). An adaptive control system with self-organizing fuzzy sliding mode control strategy for micro wire-EDM machines. International Journal of Advanced Manufacturing Technology, 50, 315-328.

[8] Ho, K. H. & Newman, S. T. (2003). State of the art electrical discharge machining (EDM). International Journal of Machine Tools and Manufacture, 43, 1287-1300. DOI: 10.1016/S0890-6955(03)00162-7.

[9] Jahan, M. P., Wong, Y. S., & Rahman, M. (2009). A study on the quality micro-hole machining of tungsten carbide by micro-EDM process using transistor and RC-type pulse generator. Journal of Materials Processing Technology, 209, 1706-1716. DOI:10.1016/j.jmatprotec.2008.04.029.

[10] Masuzawa, T. (2000). State of the art of micromachining. CIRP Annals – Manufacturing Technology, 49 (2), 473-488. DOI:10.1016/S0007-8506(07)63451-9.

[11] Schubert, A., Zeidler, H., Hackert, M., Schneider, J., & Hahn, M. (2013). Enhancing micro-EDM using ultrasonic vibration and approaches for machining of nonconducting ceramics. Journal of Mechanical Engineering, 59 (3), 156-164. DOI:10.5545/sv-jme.2012.442.

[12] Pour, G. T., Pour, Y. T., & Ghoreishi, M. (2014). Electro-spark nanomachining process simulation. International Journal of Materials, Mechanics and Manufacturing, 2 (1).

[13] Pour, G. T., Pour, Y. T., & Ghoreishi, M. (2014a). Thermal model of the electro-spark nanomachining process. International Journal of Materials, Mechanics and Manufacturing, 2 (1), 56-59.

[14] Chow, H. M., Yang, L. D., Lin, C. T., & Chen,Y. F. (2008). The use of SiC powder in water as dielectric for micro-slit EDM machining. Journal of Materials Processing Technology, 195 (1-3), 160–170.

[15] Chen, Y. F., Lin, Y. C., Chen, S. L., & Hsu, L. R. (2009). Optimization of electro discharge machining parameters on ZrO2 ceramic using the Taguchi method. Proceeding of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 224, 195-205.

[16] N.K. Singh, P.M. Pandey, K.K. Singh, EDM with an Air-Assisted Multi-Hole Rotating Tool, Mater. Manuf. Processes 31 (2016) 1872–1878, 2016/10/252016.

[17] S. Abdulkareem, A.A. Khan, M. Konneh, Reducing electrode wear ratio using cryogenic cooling during electrical discharge machining, Int. J. Adv. Manuf.Technol. 45 (2009) 1146–1151.

[18] T.C. Jegan, M.D. Anand, D. Ravindran, Determination of electro discharge machining parameters in AISI202 stainless steel using grey relational analysis,Procedia Eng. 38 (2012) 4005–4012.

[19] E. Aliakbari, H. Baseri, Optimization of machining parameters in rotary EDMprocess by using the Taguchi method, Int. J. Adv. Manuf. Technol. 62 (2012)1041–1053.

[20] K. Ho, S. Newman, State of the art electrical discharge machining (EDM), Int. J.Mach. Tools Manuf 43 (2003) 1287–1300.

[21] Banu, M.Y. Ali, M.A. Rahman, Micro-electro discharge machining of nonconductivezirconia ceramic: investigation of MRR and recast layer hardness,Int. J. Adv. Manuf. Technol. 75 (2014) 257–267.

[22] C. Li, J. Li, S. Wang, Q. Zhang, Modeling and numerical simulation of the grinding temperature field with nanoparticle jet of MQL, Adv. Mech. Eng. 5(2013) 986984.

[23] H.K. Kansal, S. Singh, P. Kumar, Technology and research developments in powder mixed electric discharge machining (PMEDM), J. Mater. Process. Technol.184 (2007) 32–41.

[24] G.S. Prihandana, M. Mahardika, M. Hamdi, Y.S. Wong, K. Mitsui, Accuracyimprovement in nano graphite powder-suspended dielectric fluid for microelectricaldischarge machining processes, Int. J. Adv.Manuf. Technol. 56 (1–4)(2011) 143–149.

[25] Y.-F. Tzeng, C.-Y. Lee, Int. J. Adv. Manuf. Technol. 17(8) (2001) 586–592.

[26] T.R. Newton, S.N. Melkote, T.R. Watkins, R.M. Trejo, L. Reister, Mater. Sci. & Engg: A, 513–514 (2009) 208–215.