MAGNETIC FIELD ASSISTED MICRO EDM - A REVIEW

Aman Kumar[1], P. S. Satsangi[2]
[1]PhD Research Scholar, [2]Professor
Mechanical Engineering Department, PEC University of Technology, Chandigarh
koolamanbansal@gmail.com[1] , pssatsangi@yahoo.com[2]

ABSTRACT

Micro Electrical discharge machining commonly called as Micro EDM (µEDM) is a well known non-traditional technology used for machining of very hard and difficult to machine materials which are extensively used in die-production, machining of complex 3D geometrical structures, aerospace now a days. µEDM as the name suggests produces part at micro level but it is very time consuming process with very low MRR. This paper presents a review and insight on Micro EDM, followed by the ongoing research and development using magnetic field (MF) assistance on Micro EDM (MFMEDM). This paper also includes literature review on improvements in performance measures with the application of magnetic field assistance on µEDM. In last section, a summary of the future research directions are also discussed.

Keywords: EDM, Micro Electrical discharge machining (µEDM), magnetic field assistance, Material Removal Rate, Tool Wear Rate, Surface Roughness

---

INTRODUCTION: Micro EDM (µEDM) is one of the key technologies used for producing micro parts. Micro EDM is a refined form of popular machining method EDM and works on the same principle as conventional EDM works, i.e. Material is removed by a series of rapidly recurring electric spark discharges between the closest point of contact on the tool electrode and the workpiece under the influence of dielectric medium [1, 14]. As the tool and workpiece don't come in direct contact hence there are no forces to affect the tool and workpiece mechanically. As µEDM works on short pulse durations, therefore, the tool electrode is usually charged as cathode [2]. µEDM is capable of producing micro structures, including micro holes, micro slots on materials like stainless steels, hardened steels, tungsten carbide, titanium based alloys which very hard and tough to machine [2, 3, 4]. It is a slow process but still cost effective and capable to produce the required parts and have strong domination for producing micro parts required in industries related to mold manufacturing, defense, aerospace and surgical instruments [4].

- Commonly used micro EDM are classified as
- Die-sinking µEDM: Used to produce mirror image of tool electrode on the workpiece.
- Micro wire EDM: Uses a wire for a through cutting in a workpiece.
- µEDM Drilling: Used for drilling micro holes in workpiece.

- µEDM Milling: Used for produce complex 3D cavities.
- µEDM Grinding: Commonly named as electrode maker process. [5, 6].

µEDM is high precision machining method but it also has some disadvantages or limitations like [6]:

1. Low Metal Removal Rate (MRR)
2. High Tool Wear Ratio (TWR)
3. Very slow machining process
4. Tool electrodes are not easy to produce
5. Cost of process
6. High Surface Roughness (SR)

As the above mentioned limitations also depend upon choice of material of tool electrode and material of workpiece, so suitable electrode material must be chosen as per requirements, [7] provided a table for this purpose

S. No.	Material	Wear Ratio	MRR	Fabrication	Cost	Applications
1.	Cu	Low	High for rough	Easy	High	All metals
2.	Brass	High	High for finish	Easy	Low	All metals
3.	W	Lowest	Low	Difficult	High	Small holes
4.	W-cu Alloy	Low	Low	Difficult	High	Accurate work
5.	CI	Low	Low	Easy	Low	few materials
6.	Steel	High	Low	Easy	Low	finishing work
7.	Zinc alloy	High	High on rough	Easy	High	All metals
8.	Cu-Graphite	Low	High	Difficult	High	All metals

Table 1 commonly used tool materials in µEDM; Reprinted [7]

To improve the performance measures, many researchers have reported various types of assistance on µEDM like

(a) Ultrasonic assisted µEDM [8, 9],
(b) Magnetic field assisted µEDM (MFMEDM) [17 - 21],
(c) Powder mixed µEDM [10, 11], (d) dry µEDM [12].

This paper focuses on magnetic field assisted µEDM (MFMEDM) as limited literature is

ISSN: 2229-6913 (Print), ISSN: 2320-0332 (Online) -, Web Presence: http://ijoes.vidyapublications.com

available on magnetic field assistance.

MAGNETIC FIELD ASSISTED µEDM (MFMEDM): MFMEDM is a new emerging area of research in the field of micro EDM, however only few researchers have contributed in this field. In µEDM, material is removed from both workpiece and tool due to melting and vaporization and flushed by dielectric medium. If this melted material resolidifies, it causes the damage to the workpiece and also affects the machining efficiency [14]. So it is very important to achieve an effective debris removal mechanism for better machining efficiency and surface finish. The main purpose of introducing magnetic field assistance in EDM or Micro EDM is to improve the debris circulation and gap cleaning due to presence of magnetic and centrifugal forces caused by magnetic field assistance.

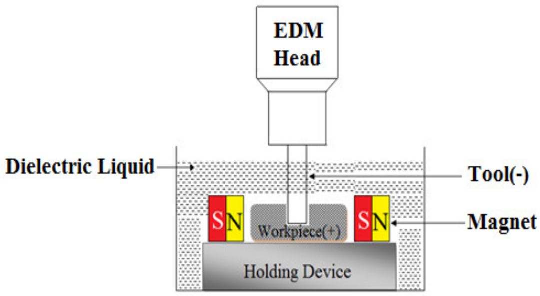

Fig. 1 Schematic Diagram of MFMEDM

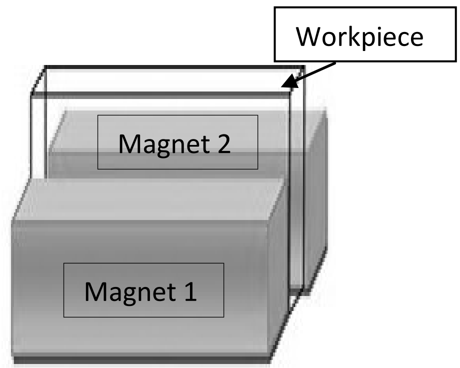

Fig.2 Arrangement of Magnet on workpiece

Fig. 1 and Fig. 2 shows the general working arrangements for MFMEDM in which magnetic field is generated by magnets inside the machining zone of µEDM. The magnetic forces facilitate the debris to be ejected quickly as compared to non magnetic field assistance. The resultant force by which debris are ejected can be calculated as the vector addition of the magnetic force and centrifugal force.

PREVIOUS RESEARCH ON BASIS OF PERFORMANCE MEASURES

µEDM is one of the most popular processes to produce micro holes in products like fuel injection nozzles, biomedical filters, and surgical items etc [15]. In recent years, Most of the published papers on µEDM are about meeting the needs of industrial applications. In this paper, effect of magnetic field on performance measures such as MRR, TWR, SR is studied depending on available literature resources.

(a) RESEARCH ON BASIS OF MATERIAL REMOVAL RATE (MRR) IN MFMEDM

µEDM is known as a very slow process so it amount of material removed is very small. Material removal rate (MRR) may be defined as the amount of material removed per unit machining time [16]. Amount of material removed is calculated as difference between weight of material before machining and weight of material after machining.

MRR = Volume of material removed from workpiece / Time of machining

= (Wt. of material before machining - Wt. of material after machining) / ρ × time

Units of MRR is mm^3/sec.

Many researchers reported the improvement in MRR after the application of magnetic field assistance.

Yeo et. al [17] applied a magnetic field of strength 0.13 Weber m^{-2} and placed it at 90^o to the electrode. Researchers claimed that application of magnetic field during 360 min machining results the better debris circulation as well as 26% higher aspect ratio is also achieved while drilling a micro hole. These results also mean that with effective debris transportation, better tool and workpiece contact existed which may lead to higher MRR.

Heinz et al. [18] investigated the magnetic field assistance on non magnetic materials and found that 50% more volume of material is removed due to magnetic field assistance. They also reported better debris transportation due to Lorentz forces which generated due to magnetic field assistance and higher MRR reported. They used magnetic field strengths 0.33 T, 0.66 T, 0.7 T and 1T for experimentation and found that 0.66 T gave the best MRR.

Jafferson et al. [19] investigated effects of ultrasonic vibration and magnetic field in micro-edm milling of nonmagnetic materials and reported that using 230 Gauss permanent magnets, MRR improved enormously but when ultrasonic vibration and magnetic field applied together, a decrease in MRR is seen.

Chu et al. [20] reported that using 0.3 T magnets on micro EDM, higher MRR is achieved. With increase in voltage, crater diameter shows incremental nature and with magnetic field assistance, it is on higher side which means more material removal for same amount of voltage.

Prasanna et al. [21] used the variable magnetic field intensity (0 - 600 gauss) on materials AISI 304 & AISI 316L stainless steel. They found the incremental nature in MRR with increase in magnetic field intensity (0 - 600 gauss) and maximum increment in MRR reported is 75% of MRR achieved without magnetic field.

(b) RESEARCH ON BASIS OF TOOL WEAR RATIO (TWR) IN MFMEDM

Yeo et. al [17] experimented on μEDM under the influence of magnetic field, due to which higher TWR is seen and shape of tool also seen more distorted.

Heinz et al. [18] conducted detailed experimentation with single-spark discharges to find the tool wear ratio and reported the negligible change in TWR due to application of magnetic field.

Jafferson et al. [19] reported that using permanent magnets, low TWR is seen in comparison of ultrasonic vibration assistance. High TWR is seen when magnetic field ultrasonic vibration applied together.

Prasanna et al. [21] reported a significant reduction in TWR while MEDM drilling on materials AISI 304 & AISI 316L stainless steel. With increase in magnetic field intensity,

ISSN: 2229-6913 (Print), ISSN: 2320-0332 (Online) -, Web Presence: http://ijoes.vidyapublications.com

TWR is seen low.

CONCLUSION:

µEDM is a viable machining method in the area of micro-machining and very much used in production of miniature parts irrespective of complexity of shape. It is slow process of machining and requirements to improve the machining time makes it more considerable for research work. The main purpose of this paper is to discuss the improvements in performance measures due to magnetic field assistance, so a detailed review on MFMEDM is discussed here. Many researchers has contributed in improving commonly measured performance measures, it still requires to be more industry viable as this machining method has a long list of applications like in MEMS, tool and die manufacturing. Otherwise as literature review suggests that magnetic field assistance has a great influence on MRR and TWR. It is learnt that MRR increases on the application of magnetic field on µEDM as it improves the debris extraction from molten area which further leads to better and quick contact between tool and workpiece for next spark. TWR may increase or decrease depending upon type of setup used and process characteristics chosen. Most of researchers reported reduction in TWR only Yeo et al reported otherwise. In future work, more research should be conducted using the electromagnets with variable magnetic field and optimization of process parameters should also be taken in account like what should be optimum magnetic field for a particular set of operation.

REFERENCES

[1] Wong, Y.S., Rahman, M., Lim, H.S., Han, H., Ravi, N., Investigation of micro-EDM material removal characteristics using single RC-pulse discharges, J. Mater. Process. Technol. 140, 2003, 303-307.

[2] Liu, H.S., Yan, B.H., Huang, F.Y., Qiu, K.H., A study on the characterization of high nickel alloy micro-holes using micro-EDM and their applications, J. Mater. Process. Technol. 169, 2005, 418-426.

[3] Kim, Y.T., Park, S.J., Lee, S.J., Micro/Meso-scale Shapes Machining by Micro EDM Process, Int. Journal of Precision Eng. And Manufacturing, 6, 2005, 5-11.

[4] Tansin Tecelliopoz, Manufacturing of micro holes by using micro electric discharge machining, MS thesis, Atilim University, 2008.

[5] Fleischer, J., Masuzawa, T., Schmidt, J., Knoll, M., New applications for micro-EDM, J. Mater. Process. Technol. 149, 2004, 246-249.

[6] Jahan M.P., Wong Y.S., Rahman M., A study on the quality micro-hole machining of

tungsten carbide by micro-EDM process using transistor and RC-type pulse Generator, *J. Mater. Process Technology*, 209, (4), 2009, 1706–1716.
[7] Pandey, P.C., Shan H.S., Modern Machining Process, *Tata McGraw-Hill Publishing Company Ltd*, Page, 1999, 84-113.

[8] Liew P.J., Yan J.W., Kuriyagawa T., Fabrication of deep micro-holes in reaction-bonded SiC by ultrasonic cavitation assisted micro-EDM, Int. J. Machine Tool Manuf., 76, 2014, 13–20.

[9] Gao C., Liu Z., A study of ultrasonically aided micro-electrical discharge machining by the application of work piece vibration, Journal of Materials Processing Technology 139, 2003, 226–228.

[10] Prihandana, G. S., Mahardika, M., Hamdi, M., Mitsui, K., The application of powder suspended dielectric fluid in micro-EDM processes to reduce machining time, Micro and Nano System, 1, (3), 2009, 210–213.

[11] Prihandana, G. S., Mahardika, M., Hamdi, M., Mitsui, K., Wong, Y. S., Accuracy improvement in nanographite powder-suspended dielectric fluid for micro-electrical discharge machining processes, The International Journal of Advanced Manufacturing Technology, 56, 2011, 143–149.

[12] Tanveer, S., Dahmardeh M., Nojeh A., Takahata, K., Dry micro-electro-discharge machining of carbon-nanotube forests using sulphur-hexafluoride, Carbon, 52, 2013, 288-295.

[13] Li, L. Q., Zhu, G. Z., Investigate on Micro-EDM in Air (Dry MEDM) by External Blowing Mode Based on RC Pulse Generator, Advanced Materials Research, 317-319, 2011, 334-340.

[14] Kumar, A., Satsangi, P. S., A Review of Micro Electrical Discharge Machining, Proceedings of National Conference on Advancements and Futuristic Trends in Mechanical Engineering, 60, 2014, 346-353.

[15] Masuzawa, T., State of the art of micromachining, *Ann. CIRP*, 49, 2000, 473-488.

[16] Mahendran, S., Devarajan, R., Nagarajan, T., Majdi, A., A Review of Micro-EDM, proceedings of *IMECS, Hongkong*, 2, 2010, 1-6

[17] Yeo, S.H., Murali, M., Cheah, H.T., Magnetic field assisted micro electro-discharge machining, *J. Micromech. Microengg.*, 14, 2004, 1526-1529.

[18] Heinz, K., Kapoor, S.G., DeVor, R.E., Surla, V., An Investigation of Magnetic-Field-Assisted Material Removal in Micro-EDM for Nonmagnetic Materials, ASME, J. Manuf. Sci. Eng., 133(2), 2011, 021002-021002-9.

[19] Jafferson, J.M., Hariharan, P., Ram Kumar, J., Effects of ultrasonic vibration and magnetic field in micro-EDM milling of nonmagnetic material, Materials and Manufacturing Processes, 29(3), 2014, 357-363.

[20] Chu, X., Zhu, K., Zhang, Y., Wang, C., Study on Erosion Mechanism of Magnetic-field-assisted Micro-EDM, International J. of Sci., 2 (1), 2015, 91-95.

[21] Prasanna, K., Karuppiah, M., Hariharan, K., Hariharan, P., Variable magnetic field intensity assisted micro electric discharge drilling for AISI 304 & AISI 316L stainless steel, 37(167), 2015, 21-27.