# Electrical Discharge Machining of Advanced Materials: Effect of Input Parameters on Electrically Conductive Tool Wear Rate

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## Abstract

Tool wear rate (TWR) is a measurement response measured during machining of aerospace and advanced materials during electrical discharge machining (EDM). This is a type of erosion wear, where electrically conductive tool-electrode has no physical contact with the work-piece surface. The paper describes the state of art research works done by researchers, scientist and academicians on the effect of machining process parameters on machining response viz. tool wear rate.

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***Key words:*** *EDM, Tool Wear, TWR*

## 1. INTRODUCTION

Machining equates to more than 15% of the total cost of all products of the manufacturing industry [1] and plays a central role in modern manufacturing [2]. Electrical discharge machining (EDM) is a non-traditional and modern machining method to give high aspect ratio features such as slots and cavities in hard and electrically conductive materials [3]. Tool shape tends to play a considerable role as it affects tool wear rate and therefore, the machining accuracy. When the tool reaches the tool wear criterion, the cutting edge fails and cannot be used further [4]. Tool and work materials, geometry, machining current, pulse time, pause time, dielectric flushing conditions, pulse waveforms and machining voltage polarity are the effective parameters on wear ratio [5].

1.1. Tool shape and size

Maximum tool wear has been observed in diamond shaped tools followed by triangular, square and round shaped electrodes. It is experimentally observed that tool wear rate (TWR) increases with the increase of tool electrode diameter.

1.2. Tool Materials

The focus of Ibrahem Maher et al [6] was on the evolving technologies of EDM wire electrodes from using copper to brass wire electrodes and from brass to coated wire electrodes. Copper Electrode gives high MRR in compare of Brass Electrode while machining Al 7075 whereas brass electrode gives high TWR in compare of Copper Electrode while machining Al 7075 [7].

## 2. TOOL WEAR- A REVIEW

EDM is a well-established machining choice for manufacturing geometrically complex or hard material parts that are difficult-to-machine by conventional machining processes [2]. It uses a thermo-electrical material removal process, in which the tool electrode shape is reproduced mirror wise into a work material, with the shape of the electrode defining the area in which the spark erosion will occur [8]. Tool wear is affected by the precipitation of carbon from the hydrocarbon dielectric onto electrode surface during sparking [7].

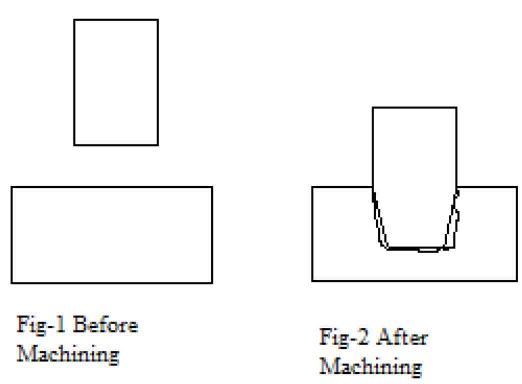


Fig 1&2- Electrode Wear in EDM [9]

## 2.1. Discharge energy

Authors derived the measurement of tool wear from the study of pulse characteristics based on discharge voltage fall time. They reduced tool wear ratio by performing MEDM (Micro-EDM) using high velocity gas as the dielectric medium [10]. Discharge energy determines the electrode wear per discharge. Discharge energy reduction is consequently one of the key elements for further miniaturization of the tool wear [11].

## 2.2 TWR indicator for various workpieces

According to researchers G. D'Urso and C. Merla, regarding stainless steel workpiece material, TWR is higher for tubular electrode. For titanium workpiece TWR is always higher for the cylindrical electrode. Electrode geometry is the only factor having an influence on TWR in Magnesium workpiece. In the brass workpiece, higher values of the TWR indicators are for the tubular electrode [12]. Traditional EDM is disadvantaged by low efficiency and high electrode wear in machining titanium alloy (Ti–6Al–4V) [13, 14, 15].

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## 2.3. Peak current and pulse time influence

Chattopadhyay et al. [16] investigate the machining characteristics of EN-8 steel with copper as a tool electrode during rotary electrical discharge machining process. In case of MRR and EWR, it has been seen that the decrease in pulse on time, decrease in electrode rotation and increase in peak current, increases both the machining output. The similar observation is carried out by Lee and Li [17]; Habib [18]; Chiang [19] and Shabgard and Shotorbani [20]. In this research the lowest value of TWR is found at maximum pulse on time.

## 2.4. Experiments on tool and dielectric to decrease TWR

Singh P. et al. [21] experimented on concentration of Al powder in dielectric fluid with copper electrode. Their findings stated that the addition of Al powder in dielectric fluid increases MRR, and decreases TWR. In [11], performance measurement improvement was suggested by the use of CNC to EDM for facilitating the MRR and improving the tool wear compensation techniques.

## 2.5. Modification in parameters

The best parameter combination obtained for experiments done on copper work-piece with copper tool are Voltage of 50 V, 6 KHz Frequency and 70% Duty factor. Test results provide MRR =

0.797mg/min and TWR =0.278 mg/min [22]. Tool wear increases with the deeper penetration of melting and evaporation isothermals inside the tool electrode [23] [24].

A. Senthil Kumar et al [4] mentioned that the tool rejection criteria for rough machining operation are employed and the following values are considered from ISO Standard 3685 for tool life testing:-

| S.No | Criteria | Value |
|---|---|---|
| 1 | Average flank wear | >0.4mm |
| 2 | Maximum flank wear | >0.7mm |
| 3 | Maximum crater wear | >0.14mm |
| 4 | Notch wear | >1.0mm |
| 5 | Surface roughness | >6.0mm |
| 6 | Excessive chipping (flaking) or catastrophic fracture of the cutting edge. | na |

Table 1. Criteria for tool rejection [4]

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As many authors have reported, higher values of current discharge and open voltage clearly increase material removal rate (MRR), electrode wear ration (EWR) and surface roughness (Salman and Kayacan 2008; Ferreira 2007; Liu et al. 2008) [25], also at micro-machining scale.

**2.6. Mathematical model to optimize parameters**

In past [26], academicians have developed mathematical models using multiple regression analysis in order to enhance EDM machining characteristics, such as metal removal rate, tool wear rate and surface finish and the significance of the models are checked by analysis of variance. [27, 28].

**2.7. Micro-hole and electrode wear**

As the development of aviation, aerospace, automobile and biomedical engineering fields, a lot of components are developed with complex spatial location micro-hole structure [29]. Due to the advantages of micro-EDM machining such as high machining precision without macro cutting force during machining, it plays the irreplaceable and key role for machining such kind of components that have small micro-hole aperture, low structure rigidity and special material [30, 31]. A fast removal rate can be obtained when negative polarity EDM machining is used with an

EDM process, as there is a tungsten carbide electrode. [32]. P. Kuppan et al [33] state that as depth-to diameter ratio increases, it becomes tough to produce these holes, especially, in super alloys like Inconel 718. Very less published information is available on drilling studies of Inconel 718 [34-37].

## 3. CONCLUSION

In this review study of past work done by several researchers, it has been seen that various factors account to tool wear rate in the EDM operation, such as tool or work-piece material, geometry, discharge current, etc. We also saw that since machining accounts to such high costs in the industry, tool wear heavily affects both cost factors and finishing of work-piece, along with other factors. Hence, research is needed in this field.

## 4. REFERENCES

[1] M.E. Merchant: Machin. Sci. Technol. Vol.2, No. 2, pp. 157–163, 1998

[2] M. M. Rahman, Md. Ashikur Rahman Khan, K. Kadirgama, M.M. Noor and Rosli A. Bakar, "Optimization of Machining Parameters on Tool Wear Rate of Ti- 6Al-4V through EDM using Copper Tungsten Electrode: A Statistical Approach", Advanced Materials Research Vols 152-153, pp 1595-1602, 2011

[3] Yin Qingfeng, Wang Baorui, Zhang Yongbin, Ji Fang, Liu Guangmin, "Research of lower tool electrode wear in simultaneous EDM and ECM", Journal of Materials Processing Technology 214, 1759–1768, 2014

[4] A. Senthil Kumar, A. Raja Durai, T. Sornakumar, "The effect of tool wear on tool life of alumina-based ceramic cutting tools while machining hardened martensitic stainless steel", Journal of Materials Processing Technology 173, 151–156, 2006

[5] Can OGUN, S. Akaslan, "The Effect of Machining Parameters on Tool Electrode Edge Wear and Machining Performance In Electric Discharge Machining (EDM)", KSME International Journal Vol 16, No. I, pp. 46-59. 2002

[6] Ibrahem Maher, Ahmed A. D. Sarhan & M. Hamdi, "Review of improvements in wire electrode properties for longer working time and utilization in wire EDM machining", Int J Adv Manuf Technol, 76:329–351, 2015

[7] Pretesh John and Rahul Davis, "Performance study of electrical discharge machining process in burr removal of drilled holes in Al 7075", Cogent Engineering, 3: 1270702, 2016.

[8] Dauw, D.F. et al, “Surface topography investigations by fractal analysis of spark eroded electrically conductive ceramics”, Annals of CIRP, 39 (1), pp. 161–165, 1990

[9] Can Çoğun , Tayfun Çağlar Deniz & Gökhan Küçüktürk, A Geometrical approach for reduction of tool shape degeneration in Electric discharge machining (EDM), Machining Science and Technology, 16:3, 445-458, 2012

[10] K.H. Ho, S.T. Newman, "State of the art electrical discharge machining (EDM)" Inter. J. Machine Tools Manuf. Vol. 43, pp. 1287–1300, 2003

[11] Giuliano Bissacco, Joško Valentinčič, H. N. Hansen, “Towards the effective tool wear control in micro-EDM milling”, International Journal of Advanced Manufacturing Technology 47(1):3-9

[12] G. D’Urso, C. Merla, “Workpiece and electrode influence on micro-EDM drilling performance”, Precision Engineering 38, 903–914, 2014

[13] Lian, F.; Zhang, H.C. The latest research on processing technology of titanium alloy by EDM. Modern Manufacturing Engineering (02), 18–23, 2012

[14] Chen, W.A.; Liu, Z.D.; Wang, X.Z.; Wang, H.Z. Research on electrode wear of processing titanium alloy by EDM. Machine Building & Automation, (04), 163–166, 2012

[15] Zhiguang Hui, Zhidong Liu, Zhongli Cao & Mingbo Qiu, “Effect of Cryogenic Cooling of Tool Electrode on Machining Titanium Alloy (Ti–6Al–4V) during EDM”, Materials and Manufacturing Processes, 0: 1–8, 2015

[16] Sushil Kumar Choudhary, R S Jadoun, “Current Advanced Research Development of Electric Discharge Machining (EDM): A Review”, International Journal of Research in Advent Technology, Vol.2, No.3, March 2014

[17] S.H. Lee, X.P. Li, X.P. 2001. J. Mater. Process. Technol. Vol. 115, pp. 344-358, 2001

[18] S.S. Habib: Appl. Math. Modelling. Vol. 33, pp. 4397–4407, 2009

[19] K.T. Chiang: Inter. J. Adv. Manuf. Technol. Vol. 37, pp. 523–533, 2008

[20] M.R habgard, R.M. Shotorbani: WASET. Vol. 52, pp. 403-409, 2009

[21] Singh P. et al., “Concentrations of aluminum powder and grain size of powder”

[22] Lijo Paul and Ivin Jose, Comparative study of effect of tool materials in EDM process, IOP Conf. Ser.: Mater. Sci. Eng. 396 012071, 2018

[23] G. Spur, J. Schnbeck, Anode erosion in wire-EDM---A theoretical model, Annals CIRP 42 (1) 253, 1993

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[24] J. Prohaszka A.G. Mamalis, N.M. Vaxevanidis, “The effect of electrode material on machinability in wire electro-discharge machining”, Journal of Materials Processing Technology 69, 233-237, 1997

[35] Salman Ö, & Kayacan, M. C. Evolutionary programming method for modeling the EDM parameters for roughness. Journal of Materials Processing Technology, 200(1–3), 347–355, 2008

[26] R. Karthikeyan, P.R. Lakshmi Narayanan, R.S. Naagarazan, Mathematical modelling for electric discharge machining of aluminium–silicon carbide particulate composites, J. Mater. Process. Technol. 87, 59–63, 1999

[27] J. Paulo Davim, Study of drilling metal–matrix composites based on the Taguchi techniques, J. Mater. Process. Technol. 132, 250–254, 2003

[28] A. Senthil Kumar, A. Raja Durai, T. Sornakumar, The effect of tool wear on tool life of alumina-based ceramic cutting tools while machining hardened martensitic stainless steel, Journal of Materials Processing Technology 173, 151–156, 2006

[29] Zhai L J, Fu J J, Liu J Y et al, Metal Machining (Cold Machining), 21:1, 2016

[30] Jahan M P, Wong Y S, Rahman M, Journal of Materials Machining Technology, 209(4):1706, 2009

[31] Jiang Y, Zhao W, Xi X., Journal of Materials Machining Technology. 212(7):1463, 2012

[32] Y Liu, J M Guo, D J Sun, Y H Cai, L T Ding, H Jiang, “Research on the EDM Technology for Micro-holes at Complex Spatial Locations”, IOP Conf. Ser.: Mater. Sci. Eng. 281 012045, 2017

[33] F.-T. Weng, M.-G. Her, “Study of the Batch Production of Micro Parts Using the EDM Process”

[34] P. Kuppan, A. Rajadurai, S. Narayanan, Influence of EDM process parameters in deep hole drilling of Inconel 718, Int J Adv Manuf Technol, 38:74–84, 2008

[35] 3. Chen JC, Liao YS, Study on wear mechanisms in drilling of Inconel 718 super alloy. J Mater Process Technol 140:269–273 4. 5, 2003

[36] WeiYX, "Experimental study on the machining of a shaped hole in Ni-based super-heat-resistant alloy". J Mater Process Technol 129:143–147, 2003

[37] Tam SC, Yeo CY, Jana S, Lau MWS, Lim LEN, Yang LJ, Noor YM, Optimization of laser deep-hole drilling of Inconel 718 using the Taguchi method. J Mater Process Technol 37:741–757, 1993