A REVIEW ON ROTARY ELECTRICAL DISCHARGE MACHINING

Abhinav Panwar[1], C.S. Jawalkar[2], N.M. Suri[3], Manjot Singh Cheema[4]

[1,2,3,4]*Department of Production and Industrial Engineering, PEC University Of Technology (India)*

ABSTRACT

Electrical Discharge Machining (EDM) is a non-conventional machining process in which the machining takes place through spark erosion between tool electrode and workpiece. EDM is used for hard materials which are generally difficult to machine using conventional machining method. Complex 3-D cavities which are not easy to produce through traditional machining method can be easily produced using EDM.

A lot of research has been done on EDM to improve its performance measures like Material removal rate (MRR), tool wear rate (TWR), surface roughness (SR) and dimensional accuracy. Researchers have performed the work on various types of EDMs like Die Sinking EDM, Dry EDM, Powder Mixed EDM (PMEDM) and Wire EDM (WEDM) etc. However many a times these EDMs have been used as hybrid EDMs providing vibratory, rotary and orbital motion either to the tool or to the workpiece.

This paper objective is to review the research done on EDM assisted with rotary and orbital motion either to the toolor the workpiece. In this paper there is also a description about the machining and non-machining parameters used during the particular research work. Present paper reviews the research work done on rotary and orbital EDM to improve its performance measures like MRR, TWR and SR.

Keywords: Electrical Discharge Machine, Material Removal Rate, Rotary EDM

I. INTRODUCTION

EDM is the spark erosion machining where material is removed due to repeated sparks erosion. In EDM only conducting materials can be machined. There is always a gap of approax0.025 to 0.05 mm between tool and workpiece. Due to gap maintained between tool and workpiece there is no force acting on tool and workpiece and it also avoids chatter and vibrations during machining. In EDM process this gap is filled with a dielectric medium which behaves as an insulator up to a threshold voltage and when the voltage exceeds the threshold value it behaves as a conducting medium. During a major portion of the voltage cycle a bank of capacitor charges and once voltage reaches a threshold value,all the capacitors will discharge causing a spark at the tool tip. However these sparks occur in a period of microseconds and hence causes a local rise in temperature up to 8000℃ to 12000℃ [1]. Such a high temperature causes melting of workpiece and tool and machining takes place and so EDM is also called as thermoelectric erosion process.

In EDM the counter shape of the tool is replicated in the workpiece [2] and it also results in good dimensional accuracy. As there is no contact between tool and workpiece so this process can be used to machine complex shapes in the materials irrespective of their hardness. EDM is widely used in industries to produce moulds and dies and also finds its wide application in aerospace and automotive industry to produce finished parts [3].

The concept of erosion by electrical discharges or sparks was very first observed by Joseph Priestly in 1770s. Further in 1943 Dr. N.I. Lazarenko and Dr. B.R. Lazarenko discovered resistance – capacitance circuit which has been used as power supply in EDMs over a long period of time. During 1960s and 1970s various modifications in EDM took place and a Computer Numerical Controlled (CNC) EDM was developed finally in 1980s. However over the period of time various types of EDMs have been used such as Die Sinking EDM, Wire EDM (WEDM), Dry EDM, Powder Mixed EDM (PMEDM). EDM has also been used to produce micro cavities in the workpiece and hence called Micro EDM. This paper reviews the research work done on EDM assisted with rotary and orbital motion of the tool.

II. LITERATURE REVIEW

Sato T., Mizutani T. et al. (1986) described the development of a rotary EDM for microhole boring. The microholes were having diameter from 15µm to 300µm. These microholes were obtained at least with the roundness accuracy of 0.5µm and less than 0.1µm surface roughness. The rotation of the electrode eliminates the welding between the workpiece and tool during the short circuit and also helps to extract the waste workpiece material from the machining region [4].

Kagaya K., Oishi Y., Yada K. (1986) used rotary tool in Micro EDM for deep microhole drilling. The author investigated that the use of purified water as a working medium when compared to the use of kerosene oil as a working medium gives higher material removal rate , lesser electrode wear and higher working efficiency [5].

Soni J.S., Chakraverti G. (1993) performed machining of titanium using rotary copper-tungsten electrode on die sinker EDM. Surface roughness, out of roundness and overcut are the measured responses to determine the effect of rotation of tool during machining and further the results have been compared to stationary electrode machining.It is observed that rotary EDM improves surface finish, overcut and out of roundness. The results show that rotary EDM should be preferred to blind hole machining for through hole machining [6].

Soni J.S. (1994) performed rotary electro discharge machining of titanium alloy and high chromium die steel. In the scanning electron microscopy of the debris formed it is observed that the material migrates from the rotating tool electrode and the dielectric fluid and so changes the chemical composition of debris particles from parent metal.It is observed that the chemical composition of debris is independent of pulse current and electrode rotation. However the debris particle size is dependent on electrode rotation speed and a little on pulse current too [7].

Soni J.S., Chakraverti G. (1994) investigated material removal rate, electrode wear and surface roughness by varying electrode rotation speed and current during EDM of titanium alloy with copper tungsten electrode.It is observed that due to the rotation of electrode MRR improves but surface roughness increases. Electrode wear rate increases with the increase in rotation speed but there is no significant change in wear ratio [8].

Yan B.H., Wang C.C. et al. (2000)investigated the feasibility and optimization of Ball Burnishing EDM (B-EDM) assisted with rotary tool. Three ZrO_2balls were attached to the tool for burnishing effect.It is observed that improvement of surface roughness increases from 55% to 92% with different values of parameters. B-EDM provides higher material removal rate and finer surface roughness [9].

Yan B.H. and Wang C.C. (2000)compared blind hole drilling of Al_2O_3/6061 Al composite performed on EDM. The different electrodes used are stationary copper electrode, rotary electrode and a rotary electrode having an eccentric hole through it.It is observed increase in rotational speed may cause higher material removal rate. Machining with rotary electrode having an eccentric hole through it results in higher MRR as compared to other electrodes but with a higher electrode wear rate (EWR). Peak current mainly affects the EWR while the polarity largely affects either the MRR or surface roughness (SR) [10].

Guu Y.H., Hocheng H. (2001)investigated the effect of workpiece rotation during EDM and compared the results with conventional EDM without workpiece rotation.They concluded that conventional EDM with rotating workpiece causes two times increase in MRR as compared to without workpiece rotation. Increase in workpiece rotation speed causes decrease in surface roughness. Rotation of workpiece can reduce the micro voids and defects formation on the machined surface [11].

Mohan B., Rajadurai A. et al. (2002) investigated the effect of SiC% in Al alloy (LM25) and also the effect of electrode rotation on MRR, tool wear rate(TWR) and surface roughness (SR) while machining on EDM.It is observed that with increase in current MRR increases and it is more with positive polarity. Increase in rotational speed causes increase in MRR, and increase in volume percentage of SiC particle causes less MRR and increase in surface roughness(SR) [12].

Ghoreishi M. and Atkinson J. (2002) presented a comparative study of the effect of rotary tool, vibratory tool and vibro-rotary tool die sinking EDM process on MRR, TWR and SR of AISI 01 tool and die steel using copper tool electrode.It is observed that vibro-rotary EDM process using high frequency vibration shows best result in terms of MRR and SR as compared to conventional EDM, vibratory EDM and rotary EDM processes [13].

Mohan B.,Rajadurai A. et al. (2004) described the machining characteristics of SiC/6025 Al composite using rotary EDM with a tube electrode. They used brass electrode with eccentric holes of diameter 1.5, 2.5 and 3.5 mm.They concluded that hollow rotating tube electrode causes higher MRR than rotating solid electrode. Increasing the rotational speed of the tube electrode and decreasing the eccentric hole diameter results in higher MRR and better SR but with higher EWR [14].

Kuppan P., Rajadurai A. et al. (2008) performed small deep hole drilling on Inconel 718 using EDM process. It is observed that MRR increases irrespective of current values as the speed of rotation increases. The electrode rotation causes effective removal of debris from electrode gap and so better flushing conditions which further results in improvement of MRR.It is observed that speed has insignificant effect on Depth averaged surface roughness (DASR) [15].

Chattopadhyay K.D., Satsangi P.S., Verma S. and Sharma P.C. (2008) investigated the effect of periodically reversed induced magnetic field applied to workpiece during rotary EDM. They used EN-8 Steel as the workpiece material and disc type copper tool electrode. They observed that compared to machining in non-magnetic field, there is increase in MRR and decrease in EWR while machining with rotary EDM in induced magnetic field [16].

Chattopadhyay K.D., Satsangi P.S. et al. (2009)machined EN-8 Steel using copper tool electrode with rotary EDM process. They investigated the effect of peak current, pulse on time and rotational speed on MRR, EWR and SR.It is observed that decrease in electrode rotation speed and peak current and increase in pulse on time improves SR. Decrease in pulse on time and electrode rotation speed and increase in peak current results increase in MRR and EWR [17].

K. SahaSourabh and Choudhury S.K. (2009) presented parametric study of dry EDM of EN-32 mild steel using copper tube electrode. Gap voltage, discharge current, pulse time on, duty factor, air inlet pressure and tool rotational speed were used as variable parameters while MRR, TWR and SR were measured responses.It is concluded that with the increase in rotational speed MRR increases and SR decreases up to a level and then becomes saturate. Spark frequency increases with increase in rotational speed of the tool and crater depth becomes lower due to rotation of tool and so less SR is obtained [18].

Govindan P., Joshi S.S. (2010) investigated the effect of various process parameters such as current, voltage, pulse time off, gap pressure and electrode rotation speed on MRR, dimensional accuracy and TWR during dry electro discharge drilling of SS304 using copper tool. They observed that rotation speed of electrode is the third most significant factor after gap voltage and current in normal EDM process [19].

Dongjue H.E. et al. (2011) compared machining of a 5-DOF controlled magnetically levitated local actuator assisted conventional EDM with rotary tool to that of a conventional EDM without tool rotation.It is observed that due to tool rotation, machining speed increases up to 343% while machining Φ0.5mm x 4mm through holes at 800 rpm and up to 433% while machining Φ1mm x 4mm through holes at 600 rpm [20].

Reza Teimouri and Hamid Baseri(2012) investigated the effect of intensity of magnetic field and tool rotation on EDM performance. They have used 1.2080X210Cr12 cold worked steel as workpiece material and copper as tool electrode.It is observed that rotary tool electrode causes better flushing conditions and improves machining performance. As the rotation speed of tool increases, MRR increases up to a maximum value and then starts decreasing. SR decreases with increase in the rotational speed of electrode [21].

Abhishek Singh, Pradeep Kumar et al. (2013) designed and developed the setup of Electro Discharge Drilling (EDD) and compared the results with the conventional EDM. They selected peak current (9A), pulse on time (90 µs), gap voltage (50 V) and tool speed (500 rpm) as the input parameters. They have worked on Metal Matrix Composites (MMC) using copper as tool material. They measured MRR and TWR as the outcome parameters.They observed that there is increase in MRR in EDD process as compared to EDM process but TWR also increases in EDD process as compared to EDM process [22].

Singh S., Pandey A. (2013) presented the effect of aspect ratio of copper disc electrode on disc EWR, MRR and SR during machining of Nimonic 75 super alloy using rotary tool. It is observed that rotation of disc electrode results in better surface finish and increase in MRR.However aspect ratio and peak current are found to be main factors causing improvement in MRR, EWR and SR [23].

Vishwakarma U.K., Dwivedi A. and Kumar P.(2014) presented a comparative study of the effect of various process variables on machining characteristics of Al-SiC MMC using Powder Mixed EDM (PMEDM) and Rotary EDM (REDM) process. They measured MRR and TWR as the outcome parameters. They concluded that MRR in PMEDM is higher than that of conventional die sinker EDM while MRR in REDM is 2.5 times that of PMEDM [24].

Dwivedi A.P., Choudhury S.K. (2016) investigated the effect of tool rotation speed on MRR, TWR and surface integrity of AISI-D3 tool steel machined with copper tool electrode.They observed that there is on an average 49% and 9-10% increase in MRR and surface finish respectively using rotary tool EDM as compared to stationary tool EDM. They also found on an average 13.5% increase in TWR using rotary EDM as compared to stationary tool EDM [25]. They also observed that there is on an average about 50% decrease in average recast layer thickness while machining using rotary tool as compared to stationary tool.Rotary tool EDM results in finer machined surface and fewer micro cracks as compared to stationary tool EDM process [26].

III. CONCLUSION

From the literature review of research work published on EDM, the authors have concluded that for the machining of hard materials traditional machining methods are not successful because of high tool wear and more machining time and so EDM is highly recommended. It is found that a lot of research has been performed to optimize the input process parameters of rotary tool EDM to obtain better performance parameters such as MRR, TWR, SR and dimensional accuracy. The authors suggest that research can be performed by considering a wide range of input parameters and further the rotary EDM can be compared to orbital EDM process.

REFERENCES

Journal Papers:

[1] G. Boothroyd, A.K. Winston, *Non-conventional machining processes, in: Fundamentals of Machining and Machine Tools, Marcel Dekker, Inc, New York, 1989, p. 491.*

[2] W. Konig, D.F. Dauw, G. Levy, U. Panten, *EDM—future steps towards the machining of ceramics, Ann. CIRP 37 (2) (1988) 623–631.*

[3] Ho KH, Newman ST State of the art electrical discharge machining (EDM).Int J Mach Tools Manuf 43(2003): 1287–1300

[4] *Sato, T., et al. "The development of an electro discharge machine for micro-hole boring." Precision engineering 8.3 (1986): 163-168.*

[5] Kagaya, K., Y. Ōishi, and K. Yada. *"Micro-electro discharge machining using water as a working fluid—I: micro-hole drilling." Precision Engineering 8.3 (1986): 157-162.*

[6] Soni, J. S., and G. Chakraverti. *"Surface characteristics of titanium with rotary EDM." Bulletin of Materials Science 16.3 (1993): 213-227.*

[7] Soni, J. S. *"Microanalysis of debris formed during rotary EDM of titanium alloy (Ti 6A1 4V) and die steel (T 215 Cr12)." Wear 177.1 (1994): 71-79.*

[8] Soni, J. S. *"Microanalysis of debris formed during rotary EDM of titanium alloy (Ti 6A1 4V) and die steel (T 215 Cr12)." Wear 177.1 (1994): 71-79.*

[9] Yan, Biing Hwa, et al. *"Feasibility study of rotary electrical discharge machining with ball burnishing for Al 2 O 3/6061Al composite." International Journal of Machine Tools and Manufacture 40.10 (2000): 1403-1421.*

[10] Wang, Che Chung, and Biing Hwa Yan. *"Blind-hole drilling of Al 2 O 3/6061Al composite using rotary electro-discharge machining." Journal of materials processing technology 102.1 (2000): 90-102.*

[11] Guu, Y. H., and H. Hocheng. *"Effects of workpiece rotation on machinability during electrical-discharge machining." Materials and Manufacturing Processes 16.1 (2001): 91-101.*

[12] Mohan, B., A. Rajadurai, and K. G. Satyanarayana. *"Effect of SiC and rotation of electrode on electric discharge machining of Al–SiC composite." Journal of Materials Processing Technology 124.3 (2002): 297-304.*

[13] Ghoreishi, M., and J. Atkinson. *"A comparative experimental study of machining characteristics in vibratory, rotary and vibro-rotary electro-discharge machining." Journal of Materials Processing Technology 120.1 (2002): 374-384.*

[14] Mohan, B., A. Rajadurai, and K. G. Satyanarayana. *"Electric discharge machining of Al–SiC metal matrix composites using rotary tube electrode." Journal of materials processing technology 153 (2004): 978-985.*

[15] Kuppan, P., A. Rajadurai, and S. Narayanan. *"Influence of EDM process parameters in deep hole drilling of Inconel 718." The International Journal of Advanced Manufacturing Technology 38.1-2 (2008): 74-84.*

[16] Chattopadhyay, K. D., et al. *"Analysis of rotary electrical discharge machining characteristics in reversal magnetic field for copper-en8 steel system." The International Journal of Advanced Manufacturing Technology 38.9 (2008): 925-937.*

[17] Chattopadhyay, K. D., et al. *"Development of empirical model for different process parameters during rotary electrical discharge machining of copper–steel (EN-8) system." Journal of materials processing technology 209.3 (2009): 1454-1465.*

[18] Saha, Sourabh K., and S. K. Choudhury. *"Experimental investigation and empirical modeling of the dry electric discharge machining process." International Journal of Machine Tools and Manufacture 49.3 (2009): 297-308.*

[19] Govindan, P., and Suhas S. Joshi. *"Experimental characterization of material removal in dry electrical discharge drilling." International Journal of Machine Tools and Manufacture 50.5 (2010): 431-443.*

[20] Dongjue, H. E., et al. *"Improving the Speed of Small Deep Hole Electrical Discharge Machining by Combining Rotation of the Electrode with a Rapid-Response." Journal of Advanced Mechanical Design, Systems, and Manufacturing 5.4 (2011): 284-294.*

[21] Teimouri, Reza, and Hamid Baseri. *"Effects of magnetic field and rotary tool on EDM performance." Journal of Manufacturing Processes 14.3 (2012): 316-322.*

[22] Singh, Abhishek, Pradeep Kumar, and Inderdeep Singh. *"Design and development of electro-discharge drilling process."Advanced Materials Research.Vol. 651.Trans Tech Publications, 2013.*

[23] Singh, S., and A. Pandey. *"Some Studies into Electrical Discharge Machining of Nimonic75 Super Alloy Using Rotary Copper Disk Electrode." Journal of materials engineering and performance 22.5 (2013): 1290-1303.*

[24] Vishwakarma, Umesh Kumar, AkshayDvivedi, and Pradeep Kumar. *"Comparative study of powder mixed EDM and rotary tool EDM performance during machining of Al-SiC metal matrix composites." International Journal of Machining and Machinability of Materials 16.2 (2014): 113-128.*

[25] Dwivedi, Anand Prakash, and Sounak Kumar Choudhury. *"Effect of Tool Rotation on MRR, TWR, and Surface Integrity of AISI-D3 Steel using the Rotary EDM Process." Materials and Manufacturing Processes 31.14 (2016): 1844-1852.*

[26] Dwivedi, Anand Prakash, and Sounak Kumar Choudhury. *"Improvement in the Surface Integrity of AISI D3 Tool Steel Using Rotary Tool Electric Discharge Machining Process." Procedia Technology 23 (2016): 280-287.*