REVIEW ARTICLE

SAMRIDDHI Volume 14, Issue 1, 2022 Print ISSN: 2229-7111 Online ISSN: 2454-5767

A Review of Studies on Performance Evaluation of Electro Discharge Machine

Durgesh Verma[1], Bhanu P. Singh[1], Ajay Kumar[2], Syed A. H. Rizvi[3]*

[1]Maharishi University of Information Technology, Lucknow, Uttar Pradesh, India
[2]Inderprasth Engineering College, Sahibabad, Ghaziabad, Uttar Pradesh, India
[3]Khwaja Moinuddin Chishti Language University, Lucknow, Uttar Pradesh, India

Abstract

An electro-discharge machine (EDM) is a majorly used non-traditional machine in modern industry. EDM has been employed to machine complex contours and hard materials for the past five decades. With consistent improvisation in the technique of EDM, its performance is methodically assessed. It found its application in innumerable machining sectors such as aerospace, medical instruments, automotive, and many more. The present study is intended to review the performance evaluation of EDM. The influence of EDM parameters over performance evaluates have been deliberated through past literatures and the trend of research have been discussed in the paper.

Keywords: Cracks, EDM, HAZ, Surface Roughness, Radial Overcut, WLT.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2022); DOI: 10.18090/samriddhi.v14i01.19

Introduction

Electro discharge machine (EDM) is a well-known non-traditional machine that modern industries have incorporated to carve the job into the desired shape without requiring any secondary operation post EDM. It has benefitted from machining complex profiles and impenetrable materials that are strenuous to procure by any other technique. From the past five decades of implementation of commercial EDM, it has been substantially employed in aerospace industries, automobile sector, die making, etc. Conducting a rigorous review of past studies, a relation between EDM parameters and performance evaluations is established. Figure 1 shows the principle of EDM.

The earlier literatures have been reviewed for estimating the ascendancy of EDM parameters on performance evaluates. The elemental performance evaluates which are studied are crack development, heat-affected zone, overcut caused by sparks, deposited recast layer, and roughness of a machined surface. The review of literatures elaborates the inclination of research on performance evaluation of EDM.

Performance Assessment

Cracks

Cracks on the machined surface are considered as flaw resulting on account of uneven cooling rate during machining of a material. Another major reason that lead to crack development is residual stresses that prosper in the machined surface after machining.

In one research, it suggested to keep lower value of peak current and higher level of on duration and duty factor for achieving minimum among of surface cracks.[9] Moreover, Dewangan *et al.*[10] revealed that the crack density is inversely

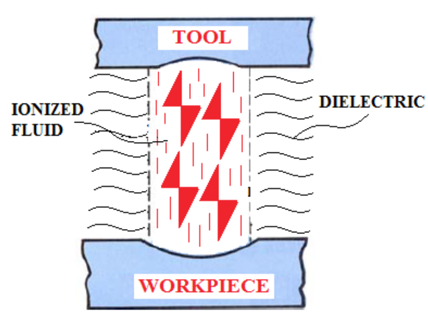

Figure 1: Principle of EDM

Corresponding Author: Syed Asghar Husain Rizvi, Khwaja Moinuddin Chishti Language University, Lucknow, Uttar Pradesh, India, e-mail: sahr.me@gmail.com

How to cite this article: Verma, D., Singh, B.P., Kumar, A., & Rizvi, S.A.H. (2022). A Review of Studies on Performance Evaluation of Electro Discharge Machine. *SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology*, 14(1), 120-124.

Source of support: Nil

Conflict of interest: None

proportional to the peak current. They also elucidated that the surface crack density initially declines and then escalate with increase in tool wear. Ekmekci *et al*[11] in their research on metallurgical properties of EDMed surface inferred that the on duration has major dominance on crack formation and the fractures are radial and concentric about crater. Gill *et al*[14] from their study revealed that while machining with optimum set of EDM factors, cracks will not be developed on the surface.

Hascalık *et al*[18] found the relation between surface crack compactness and recast-layer thickness. They concluded that crack density is lowest when white layer is thick. At curtailed current, the surface cracks are eliminated. Iqbal *et al*[19] it is divulged that rotating electrode reduces the occurrence of micro-cracks over the surface post machining as compared to static electrode. Their research also suggested keeping low level of voltage in order to achieve lesser fractures over the surface. In another investigation, Khan *et al*[20] via research revealed that due to increase in the pulse current, the micro-cracks start to evolve over the surface post machining. Another investigation carried by Mannan *et al*[25] revealed that the openings over EDMed surface results due to thermal stresses that exceed the range of fracture strength of the material. Cracks are also resulted due to sudden cooling post machining.

Mishra *et al*[27] reviled that the cracks occur due to the stresses evolved inside the surface machined because of sudden heating and cooling. Mishra *et al*[28] in another research found that the cracks are dispersed over the machined surface because of high level of peak current and voltage.

Rao *et al*[32] through their research revealed that at higher current, pulse duty factor and pulse on time, crack length and width is increased because of higher temperature development. Furthermore, Sidhom *et al*[35] investigated AISI 316L SS that the cracks formed during machining affects corrosion resistance.

Heat Affected Zone

In a research by Boujelbene[5], it was concluded that thinner HAZ is procured through setting lower value of current and on time. Moreover, Ekmekci *et al*[12] showed the relation between heat affected zone and residual stress and concluded that the value of residual stress is maximum within the HAZ. Gostimirovic *et al*[17] through their research concluded that HAZ arises at every level of discharge energy. Furthermore, Liu *et al*[24] developed a FEA model to simulate the emergence of heat affected zone in the course of phase transition. Shabgard *et al*[34] in their investigation revealed that at higher pulse on duration, extensive heat affected zone is procured. They also concluded that elevated pulse current shall lead to narrow HAZ.

Roughness of machined surface

The necessity of existing time industries is to attain better surface finish. May investigations and studies have been lead to assess the effect of EDM factors over the finish of surface machined by EDM. Several researches have been fetched for optimizing the machining parameters. Almost majority of the investigations have concentrated on producing better quality of machined surface.

Annamalai *et al*[2] found that the peak current must be kept optimum for minimum surface roughness. During increase of the pulse on duration, the roughness average values also increases and thus the pulse on time must be optimum. There is no influence on roughness value when the pulse off time is increased.

Beri and Maheshwari[3] concluded that for minimum surface roughness, copper tungsten electrode must be preferred over copper electrode. Bhattacharya *et al*[4] found that the addition of powders in dielectric improved the surface finish of the machined surface significantly. Powder concentration, current and pulse on time were observed to the major significant factors affecting surface roughness. Chandrasekaran *et al*[6] from their scrutiny revealed that the enhancement of surface quality is anticipated at increased value of tool rotation along with flushing pressure improves surface finish. The surface quality degrades with increase in current and enhances by increasing electrode rotation.

Choudhary *et al*[7] carried study with different electrodes for machining SS 316 and the investigation elucidated that for surface roughness, the electrode material is most influencing factor followed by current and the lastly by pulse-on time. Surface roughness is better with lower value of current whereas higher current values are not preferred. Using brass electrode, better surface quality is acquired while the copper electrode shows the worst surface finish as comparative to graphite and brass.

Dewangan *et al*[9] comes to the conclusion that for minimum SR negative polarity is preferred. Daneshmand *et al*[8] by their research cleared that by raising the current and pulse on time increases the surface roughness consequently. Rotational spark hardly has craters because of recurring motion and surface quality is better as compared to traditional spark.

Gopalakannan *et al*[15] studied the influence of different electrodes on surface roughness and the study deduced that copper-tungsten electrode yields superior surface finish than copper and graphite electrode. A number of studies have been performed over varying materials for determining the ascendancy of EDM factors on surface roughness. Many attempts were made in order to optimize the EDM parameters for better surface finish. Gostimirovic *et al*[16] in their analysis studied the influence of discharge energy and endowed that surface roughness is directly influenced by the discharge energy. The discharge energy and duration cause a uniform increase of surface roughness. Further In 2016 Gostimirovic *et al*[17] through their investigation found that the performance of EDM head on relies over the energy of discharge which is reshaped into thermal energy within the spark region. Discharge energy has a great impact over the surface quality of the material to be machined. Gill and

Kumar[18] revealed that current is the most dominating parameter towards surface roughness whereas percentage of alloying elements in PM tool and duty factor doesn't affect the surface roughness significantly.

Khanra *et al*[21] carried investigation on ZrB2–40wt.% Cu electrode and found that the average surface roughness of tool surfaces are more for ZrB2–40wt.% Cu composite tool than Cu tool. Manoharan *et al*[26] compared brass and Cu tool and concluded that brass electrode gives good surface finish. Payal *et al*[29] suggested that Cu-W offers the lowest SR than graphite and copper. They also deduced that electrode material is a major influencing factor for surface roughness.

Rajesha *et al*[31] revealed that roughness is influenced by off duration of pulse and surface quality initially degrades expeditiously by increasing off time of pulse and later improves steadily by increasing the off duration. Rao *et al*[32] from their investigation found that surface roughness increases with the current and τ while it decreases with increase in pulse-on-time.

Rizvi and Agarwal[33] reported that though the values of SR increase for higher values of pulse current, however, an excessive on duration leads to expansion of the plasma channel, which results in a reduction in the SR.Shabgard *et al*[34] studied the influence of EDM parameters and reaches the conclusion that the pulse current sharply influences and increases the surface roughness. Singh *et al*[36] by their evaluation revealed that the finest surface quality was acquired at minimal setting of current. With an increase of pulse on time, voltage SR increases. Singh *et al*[37] by their researched showed that pessimistic polarity of electrode is desirable for lowering of surface roughness and increasing on duration guide to produce more rough surfaces. Powder mixed dielectric fluid improves surface quality of specimen in EDM process. Higher peak currents produce poor surface quality.

Syed *et al*[40] through their research deduced that for producing low surface roughness values, a low peak current, a moderate pulse on duration, a minimum concentration of abrasive, and positive polarity should be selected. Tang and Du[41] by their research concluded that by increasing the process parameter values, the surface quality degrades.

Vikas *et al*[43] though the investigation found that the spark current lays a larger impact over the surface roughness. The effect of the other parameters was significantly less and can be ignored.

Radial Overcut

Radial overcut is a defect of EDM caused by extra sparks striking the wall of the machined workpiece. In recent years there has been considerable research performed to find the radial overcut of different materials.

Adrian *et al*[1] during their study concluded that the hole overcut increases considerable when the current intensity is kept above 10A. Dewangan *et al*[9] carried a study on AISI P20 and suggested that higher peak current and on duration of pulse have detrimental influence on the dimensional accuracy (OC).

Khanra *et al*[21] in their investigation on influence of tool material on radial overcut found that the diameteral overcut produced on the workpiece are more for ZrB2–40wt.% Cu composite tool than Cu tool. Kuppan[22] studied the radial overcut and revealed that RO is strongly influenced by pulse on-time and rises with enhancing the pulse on-time. Pradhan[30] while machining AISI D2 steel depicted that for radial overcut, the most influencing factor was pulse duty factor followed by peak current.

Singh[38] explored the influence of Cu-Cr and Al tools on EN-31 and deduced that the hole overcut is preferable with brass tool in contrast with Cu-Cr tool and lower overcut is achieved at 12 A. Soni *et al*[39] in their study attempted to optimize EDM employing a hybrid technique of RSM, GRA and PCA found that EDM parameters viz. peak current, pulse on time and duty cycle have considerable influence on the radial overcut.

Verma *et al*[42] carried a study on AISI 4147 and concluded that the hole enlargement is majorly influenced by current while voltage is the minimal effecting factor.

White Layer Thickness

White layer is re-deposited layer produced due to rapid cooling of dielectric medium while machine on electro discharge machine. Various researches have been performed so as to analyze the development of white layer over the machined surface. Review of different literatures on white layer is discussed under this section.

Dewangan *et al*[10] revealed that both Ip and Ton directly influence WLT. Preference of WLT does not have repercussion on the optimal values of EDM factors. Ekmekci *et al*[13] by their research elucidated that the recast layer thickness varies considerably with respect to drilling depth suggesting higher partition of energy and secondary discharges take place at high aspect ratio due to decreased dielectric resistance.

Gostimirovic *et al*[17] carried out experiments to assess the dominance of spark energy over different performance evaluates. The results showed that the rise in spark energy thickens the recast layer. The developed layer is governed by thermal factors, while the discharge duration had a remarkable effect on the recast layer. Iqbal *et al*[19] revealed about dominance of voltage and electrode rotation velocity over white layer thickness. A suppression of white layer using rotating electrode is seen as contrary to static electrode.

Li *et al*[23] revealed that peak current was the major significant factor to affect the WLT. The lower discharge current, lower pulse on time and longer off duration could minimize the WLT. Another investigation conducted by Liu and Guo[24] which developed massive random discharging characteristics using new FEA model to simulate solid white layer formation and heat affected zone (HAZ) formation and the corresponding austenite-martensite phase transformation. It is capable of predicting the macroscale accumulated thermal damage in an EDM process.

Rao *et al*[32] in their research showed when the current increases the thickness of recast layer increased. When the duty factor increases, thicker recast layer is observed. When the pulse-on-time increases, thinner recast layer is achieved. Shabgard *et al*[34] elucidated that the rise in pulse on duration will lead to thicker white layer. A slight decrease was noticed in white layer thickness by an increase in the peak current. By constant level of discharge energy, high current and low pulse on-time guide to thinning of white layer on the surface of work piece. Syed *et al*[40] revealed that lower thickness of white layer is achieved in negative polarity.

Discussion of Review

After surveying various literature on EDM for numerous performance measures, we have drawn the following inferences:

- A significant number of research has been conducted on surface roughness among the chosen performance measures. The other performance measures which have found research interest were radial overcut and white layer thickness.
- Even if a white layer has been explored much by numerous researchers, the scrutiny on the evolution of the white layer is still to be performed.
- Less research has been conducted on crack formation. Early literatures do not properly elaborate the reasons for crack formation.
- Significantly less work has been performed on the machined surface's heat-affected zone post EDM.
- Almost no study has been performed with non-electrical factors to examine ample performance measures.

Summary

The present review is conducted to examine the association between the EDM parameters with performance measures. Research of the past three decades has been reviewed. It was found that every researcher has tried to optimize EDM parameters to achieve the best suitable outcomes of performance evaluates. Optimum values of EDM factors were discovered, and a combination of parameters was concluded in order to obtain the best possible results. Though it was observed that surface roughness, radial overcut, and white layer formation was majorly discussed, it was also seen that crack development and HAZ growth were not discussed in deep.

References

[1] Adrian I., Axinte E., Negoescu F. (2010). A Study about micro-drilling by electrical discharge method of an Al/SiC hybrid composite. *International Journal of Academic Research*, 2, 6-13.

[2] Annamalai N., Sivaramakrishnan V., Kumar B.S., Baskar N. (2014). Investigation and Modeling of Electrical Discharge Machining Process Parameters for AISI 4340 steel. *International Journal of Engineering and Technology*, 5, 4761-4770.

[3] Beri N., Maheshwari S., Sharma C., Kumar A. (2008). Performance Evaluation of Powder Metallurgy Electrode in Electrical Discharge Machining of AISI D2 Steel Using Taguchi Method. *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering*, 2, 225-229.

[4] Bhattacharya A., Batish A., & Kumar N. (2013). Surface characterization and material migration during surface modification of die steels with silicon, graphite and tungsten powder in EDM process. *Journal of Mechanical Science and Technology*, 27, 131-140.

[5] Boujelbene M., Bayraktar E., Tebni W., Salem S. B. (2009). Influence of machining parameters on the surface integrity in electrical discharge machining. *Archives of Materials Science and Engineering*, 37, 110-116.

[6] Chandrasekaran V., Kanagarajan D., Karthikeyan R. (2013). Optimization of EDM Characteristics of WC/5ni Composites Using Response Surface Methodology. *International Journal of Recent Technology and Engineering*, 2, 108-115.

[7] Choudhary S., Kant K., Saini P. (2013). Analysis of MRR and SR with Different Electrode for SS 316 on Die-Sinking EDM using Taguchi Technique. *Global Journal of Researches in Engineering Mechanical and Mechanics Engineering*, 13, 15-21.

[8] Daneshmand S., Kahrizi E.F., Neyestanak A.A.L., Ghahi M.M. (2013). Experimental Investigations into Electro Discharge Machining of NiTi Shape Memory Alloys using Rotational Tool. *Int. J. Electrochem. Sci.*, 8, 7484-7497.

[9] Dewangan S., Biswas C. K., Gangopadhyay S. (2014). Optimization of the quality and productivity characteristics of AISI P20 tool steel in EDM process using PCA-based grey relation analysis. *5th International & 26th All India Manufacturing Technology, Design and Research Conference AIMTDR*, 12-14.

[10] Dewangan S., Gangopadhyay S., Biswas C.K. (2015). Study of surface integrity and dimensional accuracy in EDM using Fuzzy TOPSIS and sensitivity analysis. *Measurement*, 63, 364-376.

[11] Ekmekci B., Tekkaya A.E., Erden A. (2002). Investigation of Residual Stresses on Electrical Discharge Machined Surfaces. *6th Biennial Conference on Engineering Systems Design and Analysis*, 1-6.

[12] Ekmekci B., Elkoca O., Tekkaya A.E., Erden A. (2005). Residual Stress State and Hardness Depth in Electric discharge machining: De-Ionized Water as Dielectric Liquid. *Machine Science and Technology*, 9, 39-61.

[13] Ekmekci B., Sayar A., Öpöz T.T., & Erden A. (2010). Characteristics Of Surface Damage In Micro Electric Discharge Machining Of Micro Holes. *Advanced Materials Research*, 19.

[14] Gill A.S., Kumar S. (2014). Surface Roughness Evaluation for EDM of EN31 with Cu-Cr-Ni Powder Metallurgy Tool. *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering*, 8, 1308-1313.

[15] Gopalakannan S., Senthilvelan T. (2012). Effect of Electrode Materials on Electric Discharge Machining of 316 L and 17-4 PH Stainless Steels. *Journal of Minerals and Materials Characterization and Engineering*, 11, 685-690.

[16] Gostimirovic M., Kovac P., Skoric B., & Sekulic M. (2012). Effect of electrical pulse parameters on the machining performance in EDM. *Indian Journal of Engineering & Materials Sciences,* 18, 411-415.

[17] Gostimirovic M., Kovac P., Sekulic M., & Skoric B. (2012). Influence of discharge energy on machining characteristics in EDM. *Journal of Mechanical Science and Technology*, 26, 173-179.

[18] Hascalık A., Caydas U. (2007). Electrical discharge machining of titanium alloy (Ti–6Al–4V). *Applied Surface Science*, 253, 9007-9016.

[19] Iqbal A.K.M.A., Khan A.A. (2010). Influence of Process Parameters on Electrical Discharge Machined Job Surface Integrity. *American J. of Engineering and Applied Sciences*, 3, 396-402.

[20] Khan A.A., Ndaliman M.B., Zain Z.M., Jamaludin M.F., & Patthi U. (2012). Surface Modification using Electric Discharge Machining (EDM) with Powder Addition. *Applied Mechanics and Materials*, 110, 725-733.

[21] Khanra A.K., Sarkar B.R., Bhattacharya B., Pathak L.C., Godkhindi M.M. (2007). Performance of ZrB2–Cu composite as an EDM electrode. *Journal of Materials Processing Technology*, 183, 122-126.

[22] Kuppan P., Narayanan S. (2015). Effect of EDM parameters on hole quality characteristics in deep hole drilling of Inconel 718 superalloy. *Int. J. Manufacturing Research*, 10, 45-63.

[23] Li J., Shi S., Zhao S. (2013). Modeling and Analysis of Micro-hole in Die-sinking EDM Process through Response Surface Method based on the Central Composite Design. *International Journal of Signal Processing, Image Processing and Pattern Recognition*, 6, 351-364.

[24] Liu J.F., Guo Y.B. (2016). Modeling of White Layer Formation in Electric Discharge Machining (EDM) by Incorporating Massive Random Discharge Characteristics. *Procedia CIRP,* 42, 607-702.

[25] Mannan K.T., Krishnaiah A., Arikatla S.P. (2013). Surface Characterization of Electric Discharge Machined Surface of High Speed Steel. *Advanced Materials Manufacturing & Characterization*, 3, 161-167.

[26] Manoharan M.,Valera A.P., Trivedi S.M., Banker K.S. (2013). Material Removal Rate, Tool Wear Rate and Surface Roughness Analysis of EDM Process. *International Journal for Scientific Research & Development*, 1, 407-409.

[27] Mishra D., Rizvi S.A.H., Ziaulhaq M. (2017). Experimental Investigation of EDM of AISI 4340 for Surface Integrity. *International Journal of Innovative Research in Science, Engineering and Technology*, 6, 133-136.

[28] Mishra D., Rizvi S.A.H. (2017). Influence of EDM Parameters on MRR, TWR and Surface Integrity of AISI 4340, *International Journal of Technical Research and Applications*, 42, 95-98.

[29] Payal H., Maheshwari S., Bharti P.S. (2016). Effect of Tool Material on Surface Roughness in Electrical Discharge Machining. *Journal of Production Engineering*, 9, 27-30.

[30] Pradhan M. K. (2013). Estimating the effect of process parameters on MRR, TWR and radial overcut of EDMed AISI D2 tool steel by RSM and GRA coupled with PCA. *The International Journal of Advanced Manufacturing Technology*, 68, 591–605.

[31] Rajesha S., Jawalkar C.S., Mishra R.R., Sharma A.K., Kumar P. (2014). Study of Recast Layers and Surface Roughness on Al-7075 Metal Matrix Composite During EDM Machining. *International Journal of Recent advances in Mechanical Engineering*, 3, 53-62.

[32] Rao G.K.M., Satyanarayana S., Praveen M. (2008). Influence of Machining Parameters on Electric Discharge Machining of Maraging Steels – An Experimental Investigation. *Proceedings of the World Congress on Engineering*, 2, 1-6.

[33] Rizvi S.A.H., Agarwal S. (2016). An investigation on surface integrity in EDM process with a copper tungsten electrode. *Procedia CIRP*, 42, 612-617.

[34] Shabgard M., Seyedzavvar M., Oliaei S.N.B. (2011). Influence of Input Parameters on the Characteristics of the EDM Process. *Journal of Mechanical Engineering*, 5, 689-696.

[35] Sidhom H., Ghanem F., Amadou T., Gonzalez G., Braham C. (2013). Effect of electro discharge machining (EDM) on the AISI316L SS white layer microstructure and corrosion resistance. *International Journal of Advanced Manufacturing Technology*, 65,141–153.

[36] Singh B., Kumar J., & Kumar S. (2013). Investigating the Influence of Process Parameters of ZNC EDM on Machinability of A6061/10% SiC Composite. *Advances in Materials Science and Engineering*, 2013, 1-8.

[37] Singh G., Singh P., Tejpal G., Singh B. (2012). Effect of Machining Parameters on Surface Roughness of H13 Steel in EDM Process using Powder Mixed fluid. *International Journal of Advanced Engineering Research and Studies*, 2, 148-150.

[38] Singh H. (2012). Investigating the Effect of Copper Chromium and Aluminum Electrodes on EN-31 Die Steel on Electric Discharge Machine Using Positive Polarity. *Proceedings of the World Congress on Engineering*, 3, 1-5.

[39] Soni H., Mishra T. K., Pradhan M.K. (2013). Multi-Response Optimization of EDM Parameters by Grey-PCA Method. *International Journal of Current Engineering and Technology*, 3, 1941-1945.

[40] Syed K.H., Palaniyandi K. (2012). Performance of electrical discharge machining using aluminium powder suspended distilled water. *Turkish J. Eng. Env. Sci.*, 36, 195-207.

[41] Tang L., & Du Y.T. (2014). Experimental study on green electrical discharge machining in tap water of Ti–6Al–4Vand parameters optimization. *Int J Adv Manufacturing Technology*, 70, 469-475.

[42] Verma D., Hasan M.F., Rizvi S.A.H. (2016). Parametric Optimization of Performance of EDM on Alloy Steel AISI 4147 using Taguchi Approach, *Journal of Recent Activities in Production*, 1, 1-9.

[43] Vikas, Roy A.K., Kumar K. (2014) . Effect and Optimization of various Machine Process Parameters on the Surface Roughness in EDM for an EN41 Material using Grey-Taguchi. *Procedia Materials Science*, 6, 383–390.