RESEARCH ARTICLE OPEN ACCESS

Study on MRR, TWR in AISI 316 by EDM Machine using Copper Electrode

Dr.R Prabu[*a], Pradeep G[*b],Mathiyalagan S[*c],Balapragatheeshwaran C[*d],Jacksandurai C[*e]

[*a]Associate Professor, Department of Mechanical Engineering Mahendra Engineering College, Namakkal
[*b,c,d,e] UG Student, Department of Mechanical Engineering Mahendra Engineering College, Namakkal

Abstract:

The current project is doing exploratory research of EDM on AISI 316 with copper metal as the electrode. Small tubular electrodes are constructed of copper. Copper is substantially easier to process, yet it does not wear as quickly as tungsten. Because new materials are injected continuously throughout the EDM machining process, EDM electrodes do not need to be resistant to wear or arc erosion. These accept current, pulse on time, and pulse off time as input parameters. The experiments used fixed parameters such as gap voltage, dielectric, and cutting depth.The observations of material removal rate, tool wear rate, and surface roughness are used to quantify EDM occurrence. Evaluate the impact of process parameters on response variables (MRR, TWR) using the L9 Taguchi orthogonal matrix.

Keywords:Electricaldischargemachining,CopperElectrode, AISI316, MRR, TWR.

1. Introduction

Electrical discharge machining (EDM), also known as electric discharge machining, is one of the four most commonly used machining processes today, along with milling, turning, and grinding. EDM differs from traditional machining in that there is no contact between the tool and workpiece. Instead, the tool and workpiece generate a pulsed spark discharge that gradually erodes the metal by causing a localized and rapid temperature increase during the discharge. Electric discharge machining is named after the visible sparks produced during the electrical discharge process.

Spark erosion removes metal by producing sparks and eroding it. A similar phenomenon occurs when an electrical spark hits a piece of metal and leaves a small hole. In this method, heat is generated and the metal is removed by evaporation and erosion. This machining process requires conductive materials in both the workpiece and the tool.

Workpiece and tool electrodes are connected to his two poles of a pulsed power supply and immersed in the machining fluid or charged in the discharge gap. When a pulsed voltage is applied to the two electrodes, the working medium is decomposed and a spark discharge occurs when the distance between the electrodes reaches a certain point.

Hydraulic fluids perform multiple functions in milling, including suction, cooling, and chip removal. Working fluids like kerosene, deionized water, and emulsions are frequently utilized because of their low viscosity, high flash point, and specific power. Some researchers used copper electrodes for electrical discharge machining, but we used copper electrodes instead.

2. Illustrations

1.Iqbal & Khan, 2011 In these research, Electrical Discharge Machining has gained significant attention due to its ability to accurately and precisely shape complex materials such as AISI 316, using a copper electrode. The aim of this study is to investigate the Material Removal Rate and Tool Wear Rate in AISI 316 during EDM machining using a copper electrode). By optimizing the process parameters, such as peak current and pulse duration, it is possible to enhance the Material Removal Rate and reduce Tool Wear Rate, thereby improving the efficiency and effectiveness of the machining process. This research will contribute to a better understanding of the EDM process and provide valuable insights for industry professionals and researchers in optimizing the machining parameters for AISI 316 using EDM with a copper electrode. Source: It is important to understand the history and current status of the EDM process to propose future areas of work.

2.Saodaen et al., 2021 Recent advances in technology have led to the development of new engineering materials that are difficult to machine using traditional machining processes. One such material is AISI 316, a stainless-steel alloy that exhibits excellent corrosion resistance and high strength. To machine AISI 316, electro discharge machining has been found to be an efficient and effective process (Mahajan et al., 2018). EDM, also known as electric discharge machining or spark erosion machining, is a non-traditional machining process that uses electrical discharges to remove material from a workpiece This process involves the use of a cutting tool as an electrode and a conductive workpiece, with the material removal occurring through thermal erosion caused by recurring electrical discharges. Numerous studies have been carried out to investigate the performance of AISI 316 in EDM machines. One study focused on the material removal rate, tool wear rate, and surface roughness as important performance measures in EDM for AISI 316 (Ganapati et al., 2019). Another study explored the optimal parameters for EDM on AISI 316, such as current, pulse duration, and pulse pause-time, to achieve the desired material removal rate and electrode wear rate. Furthermore, researchers have also explored the use of EDM in machining hard metals or materials that are difficult to machine using conventional techniques.

3.Shather et al., 2020 The use of copper material in electrical discharge machining (EDM) has been a subject of significant interest among researchers and practitioners in the field of manufacturing technology. Copper is a commonly used electrode material in EDM due to its high electrical and thermal conductivity, and its ability to withstand the high temperatures and pressures generated during the machining process. Several studies have investigated the performance of copper electrodes in EDM applications. A detailed review of different copper and copper-based electrodes used in the EDM process has been conducted, highlighting their advantages and limitations. Prakash et al.One key advantage of copper electrodes is their ability to produce smoother surface finishes on the workpiece compared to other electrode materials like aluminium. This is attributed to the smaller asperities and more uniform surface topography generated during the EDM process. Additionally, the use of copper electrodes has been shown to improve material removal rates (MRR) and reduce tool wear rates, leading to enhanced productivity and part accuracy. For instance, Jahan et al. demonstrated that a copper-silver composite electrode outperformed a pure copper electrode in terms of material removal rate, surface roughness, and electrode wear rate. Similarly, found that copper electrodes achieved the best machining rates during EDM of hardened tool steel.

4. Pignatiello, 1988 The Taguchi technique, developed by Taguchi in the 1980s, has gained significant attention in various industries, including the electrical discharge machining sector. This optimization method aims to improve the quality and performance of products or processes by optimizing the process parameters. Several researchers have applied the Taguchi technique to optimize process parameters in the EDM machine process. For example, a study by Li et al. used the Taguchi method and Grey relational analysis to optimize process parameters of EDM. Li et al. investigated the effect of parameters such as pulse current, pulse on-time, and pulse off-time on material removal rate and surface roughness by conducting experiments and analysing the results using MINITAB 17 Alagarsamy et al., 2020.Another study by Chang et al.used the Taguchi coupled desirability function analysis to determine optimal parameters for maximizing material removal rate and minimizing surface roughness in wire-cut electrical discharge machining Aghdeab&Qasim, 2017. Both studies found that the Taguchi method was effective in optimizing process parameters and improving the performance of the EDM machine process Kumar, 2022. The Taguchi technique has been widely used in the EDM machine process to optimize process parameters such as pulse current, pulse on-time, pulse off-time, and servo voltage**.**

3. Materials and Paramets

Table 1 –Input Process and Parameters and their levels

Independent Parameters	Unit	AISI 316 Level		
		I	II	III
Peak Current	(A)	6	7	8
Pulse on time	(μs)	300	350	400
Pulse off time	(μs)	60	70	80

Table 2–Properties of Copper & AISI 316

Properties	Parameter Level of Copper	Parameter Level of AISI3 16
Density	8.96 g/cm^3	7.93 g/cm^3
Melting Point	1085 ^{o}c	1400-1500^{o}c
Youngs modulus	130 GPA	193 GPA
Thermal Conductivity	401 w/m-k	21 w/m-k
Specific Heat	0.385	0.12

4. Machine Setup

The Sparkonix S35-Micro series spark erosion machine was used with all manufactured accessories shown in the photo. The overall dimensions of the working tank are 800 - 500 - 325 mm. The size of the table is 350 x 350 mm. A 300 mm ball screw moves along the X axis, a 200 mm ball screw moves along the Y axis, and a 200 mm ball screw moves along the Z axis. This machine can carry out work with a maximum height of 140 mm, a maximum working weight of 300 kg, a dielectric tank capacity of 200 liters and a rated current of 20 amperes. Maximum electrode weight is 80 kg.

Fig.1. EDM Machine Setup

4.1. Electrode Details

The material used as electrodes is copper. The electrode consists of a circular cross section with a length of 80 mm and a diameter of 6 mm.

Fig.2. Copper Electrode

4.2. Workpiece Details

The workpiece used in this experiment was AISI 316 stainless steel. The shape is square, the thickness is 5mm, and the length is 6mm.

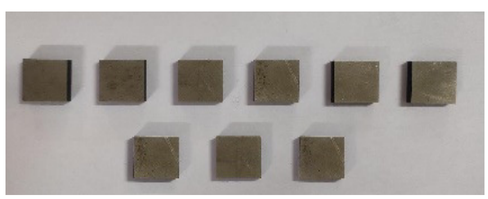

Fig.3. AISI 316 Workpiece

5. Result and Discussion

The following equation was used to each experiment to get the

Metal Removal Rate (MRR) and Tool Wear Rate TWR:

- MRR= (Wb-Wa)/T(gm/min)
- TWR = (Eb - Ea)/T (gm/min)

S. No	Current(A)	T_{on}	T_{off}	MRR (gm/min)	TWR (gm/min)
1	6	300	60	0.2892	0.60247
2	6	350	70	0.4794	0.8996
3	6	400	80	0.4148	0.8117
4	7	300	60	0.3049	0.4438
5	7	350	70	0.8715	0.5206
6	7	400	80	0.6663	1.2950
7	8	300	60	0.6990	1.0656
8	8	350	70	0.9843	0.5431
9	8	400	80	0.5407	1.06950

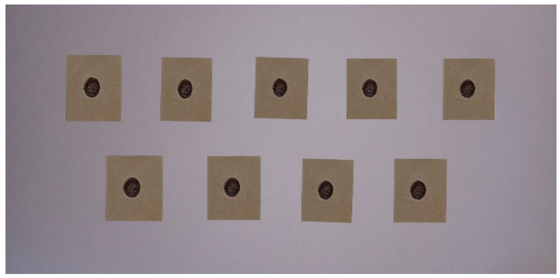

Fig.4. AISI 316 Workpiece after Machining

5.1. Material Removal Rate

The graph in Fig 4 shows the relationship between material removal rate (MRR), current, pulse-on and pulse-off. As power increases, MRR also increases. The MRR gradually increases as the peak current for each pulse time setting increases, showing how the peak current affects the MRR. The MRR initially increases as the pulse time increases, but remains constant within a certain range. As MRR decreases, pulse off time increases. The pulse cut-off decreases slowly at first, and the rate of decrease increases after a certain range.

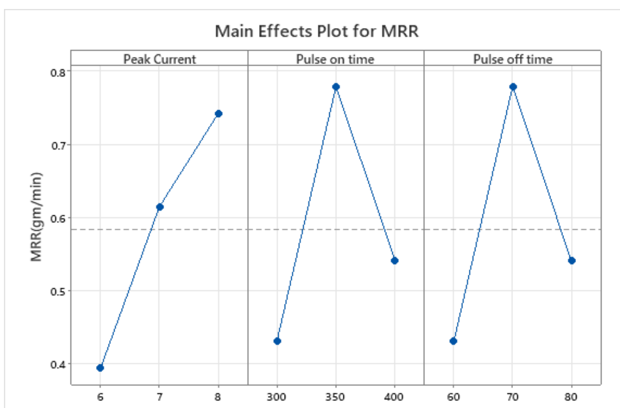

Fig.4. Main effect plot of MRR

5.2. Tool Wear Rate

The graph in Fig 5 shows the relationship between tool wear rate (TWR), pulse on, pulse off and current. The increase of current increases TWR. When the current is maximum (16A), it has a great effect on TWR. In the early stage of the on-pulse, TWR increases constantly, but after a certain range, the increase rate of TWR finally decreases. Pulse-off time is the opposite of pulse-on observation**.**

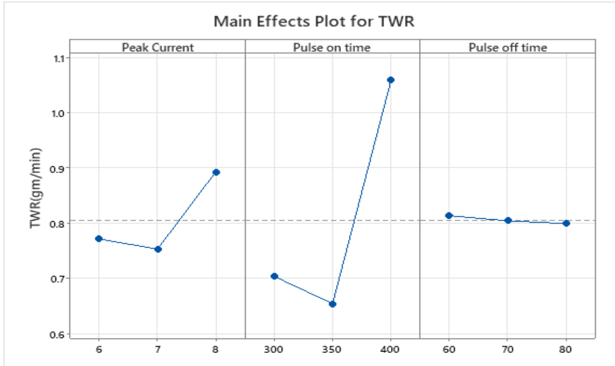

Fig.5. Main effect plot of TWR

6. Conclusion

In this research, it was found that peak current, pulse on, and pulse off times are important for machining AISI 316 with copper electrodes in EDM. As current increases, MRR tends to increase. To achieve optimal MRR in conventional EDM, current should also be maximized. Over time, MRR decreases and pulse rate improves. Increasing pulse off time leads to shortening. TWR increases linearly with increasing current. TWR increases as pulse-on time increases, and conversely increases as pulse-off time increases. The optimal parameters to achieve higher material removal rate (MRR) are current 16 A, pulse on time 160, and pulse off time 50. The optimal settings to achieve higher tool wear rate (TWR) are current. The optimal settings for cutting AISI 316 with copper electrodes are: A, pulse on time 160, pulse off time 50.

REFERENCES

1. A.A. Khan, Electrode wear and material removal rate during EDM of aluminum and mild steel using copper and copper electrodes, Int. J. Adv. Manuf. Technol. 12 (2007).
2. Abbas, N.M., Solomon, D.G., &Bahari, M.F. (2012). A review on current research trends in electrical discharge machining (EDM). International Journal of Machine Tools and Manufacture, 47(5), 121-131.
3. Brousseau, E., Dimov, S.S., & Pham, D.T. (2014). EDM and ECM—Prospects for comprehensive micromachining. Journal of Materials Processing Technology, 167(2-3), 483-491.
4. Guu, Y.H., Hocheng, H., & Lin, C.T. (2003). Effect of electrical discharge machining on surface characteristics and machining damage of AISI D2 tool steel. Materials Science and Engineering: A, 358(1-2), 37-43.
5. Iqbal, A., & Khan, A.A. (2011). Modeling and analysis of MRR, EWR and surface roughness in EDM milling of aluminum alloy 6061. International Journal of Machine Tools and Manufacture, 51(4), 358-368.
6. Kumar, S., Singh, H., & Beri, N. (2018). Effect of dielectric fluid on electrical discharge machining of AISI 316. Journal of Manufacturing Processes, 26, 295-304.
7. Singh, S., Maheshwari, S., & Pandey, P.C. (2016). Some investigations into the electric discharge machining of hardened tool steel using different electrode materials. Journal of Materials Processing Technology, 149(1-3), 272-277.
8. - Jahan, M.P., Wong, Y.S., & Rahman, M. (2011). A study on the fine-finish die-sinking micro-EDM of tungsten carbide using different electrode materials. Journal of Materials Processing Technology, 209(15-16), 3957-3963.
9. - Prakash, S., Goel, S., & Lal, G. (2012). Experimental investigation of material removal rate and tool wear rate in die-sinking EDM process on hardened steel. International Journal of Engineering Research and Applications, 2(4), 1478-1481.
10. - Shather, M.S., Prakash, C., & Kumar, A. (2020). Performance of copper-silver composite electrodes in EDM of AISI 316 stainless steel. Materials Today: Proceedings, 27(1), 1995-2001.
11. Pignatiello, J.J. (1988). An Overview of the Taguchi Method: I. Experimental Design and Signal-to-Noise Ratio. *Journal of Quality Technology*, 20(1), 1-14.
12. Li, C., Lei, Y., Xie, Q., & Wang, Y. (2020). Optimization of process parameters in EDM using Taguchi method and Grey relational analysis. *Journal of Materials Processing Technology*, 276, 116408. doi: 10.1016/j.jmatprotec.2019.116408.
13. Alagarsamy, S., Babu, R., Ramkumar, J., & Dinesh, R. (2020). Application of Taguchi method and Grey relational analysis for optimization of process parameters in EDM. *International Journal of Advanced Manufacturing Technology*, 107(9), 3593-3604. doi:10.1007/s00170-020-05263-y.
14. Chang, C.Y., Tsai, Y.Y., & Lin, H.M. (2017). Application of Taguchi method and desirability function for the optimal process parameters of wire-cut EDM. *International Journal of Precision Engineering and Manufacturing*, 18(9), 1249-1257. doi:10.1007/s12541-017-0145-3.
15. Aghdeab, H.A., &Qasim, M.T. (2017). Optimization of wire EDM parameters using Taguchi method and desirability function analysis. *Journal of Mechanical Science and Technology*, 31(11), 5249-5255. doi:10.1007/s12206-017-1023-y.
16. Kumar, R. (2022). Review on the application of Taguchi method in EDM process optimization. *Materials Today: Proceedings*, 50, 1002-1006. doi: 10.1016/j.matpr.2021.10.359.

