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Comparison Study between Experimental and ANFIS Results for Material Removal Rate in EDM Process

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***Abstract**:*

This work is a comparison study between experimental and ANFIS results focuses on studying the material removal rate (MRR) for five shapes under different conditions of pulse on time (T-on), current (I) and the shape of work piece (Sh_w). The major purpose of this study is to obtain the best MRR, by using a flat electrode of copper when machining five shapes (A,B,C,D,E). Experiment is carried out by using AISI 304 stainless steel specimens of thickness (2 mm). Different values of (T-on) (100,150 and 200) µs, and different currents of (10, 20 and 30) A were used. The experimental results reveal that the MRR enhances by an increase in the current values. Also the results show that the MRR improves with an increase in the (T-on). From the comparison between experimental and ANFIS results, the min. error is (0.0006) was obtained in shape (B), the max. error is (-0.0252) was obtained in shape (C).

Keywords

Material Removal Rate, Electrode Wear Rate, EDM, ANFIS.

1. Introduction

Electrical Discharge Machining (EDM) is an important manufacturing process for machining alloys and hard metals irrespective of the hardness, such as, graphite, metallic alloys, or even some conductive ceramic materials. This process is widely used for producing molds, dies, and finishing parts for automotive, surgical components, and aerospace. The process is capable of getting surface finish and required accuracy by controlling the process parameters. EDM performance is generally evaluated on the basis of MRR, OC, SR and EWR. The important EDM parameters affecting to the performance measures of the process are (I), (T-on), (T-off), gap between the electrod and the w.p, and (τ) [1]. EDM has been replacing the almost all machining operations, and is capable of machining complex shapes or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold, aerospace, medical and surgical, optical, automotive and nuclear industries [2,3].

2. Principle of EDM Process

Removal of metals by spark was first introduced by Joseph Priestily in 1878. EDM has no direct contact between the electrod and the w.p, and that eliminated the chance of mechanical stress, vibration and chatter problems [4]. EDM process is based on thermo-electric energy between the electrod and the w.p. A pulse discharge occurs in a small gap between the electrod and the w.p and removes the unwanted material from the material during melting and vaporizing processes [5]. electrod and w.p are separated by a spark gap (0.005 - 0.05mm) and both were immerged in a suitable dielectric (non-conductor of electricity), is forced through this gap at a certain pressure. When a proper voltage is applied the dielectric breaks down and electrons are emitted from cathod and the gap became ionized, as in Figure (1) [6]. Then many electrons collection in the gap, consequently the resistance drops causing electric spark to jump between the electrod and w.p. Sparking occurs in a frequency rang from (2.000 - 500.000 sparks per sec.). Each electric discharge causes a focused stream of electrons to move with a very high velocity, and that lead to raise the temp. more than (10.000 C°). Each spark produces a tiny crater by erosion of material. The spark removes material from both the electrod and w.p, which increases the distance between the electrod and w.p at that point. This causes the next spark to occur at the next-closest points between the electrod and w.p. The MRR is usually between (2-400 mm^3/min) [2,3].

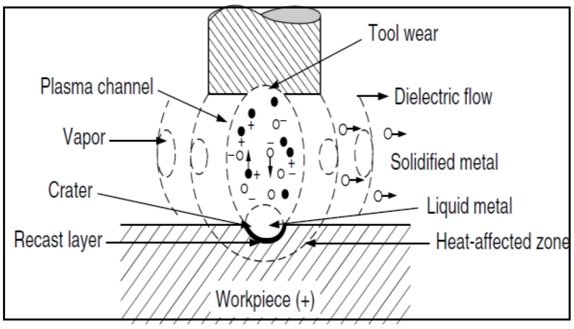

Figure (1): EDM spark description [6].

This study aims to achieve the best MRR by make a comparison study between experimental and ANFIS results, by using a flat copper electrode with dimensions (6×5 mm) when machining five shapes of AISI 304 SS specimens of thickness (2 mm) by using an EDM process.

3. Experimental Work

The experiments were done on the EDM machine as in Figure (2), called CHMER of model (CM 323C) at the University of Technology-Training and Workshops Center. Copper electrode used to machine a w.p of AISI 304 SS, and transformer oil was used as a dielectric.

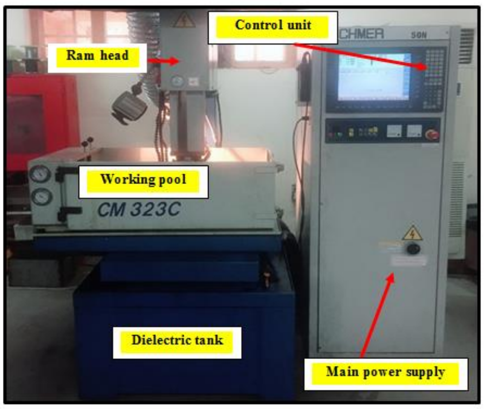

Figure (2): CHMER EDM machine.

The electrode material selected in this study is copper. The shape of electrode is rectangular with dimensions (6×5 mm) as shown in Figure (3).

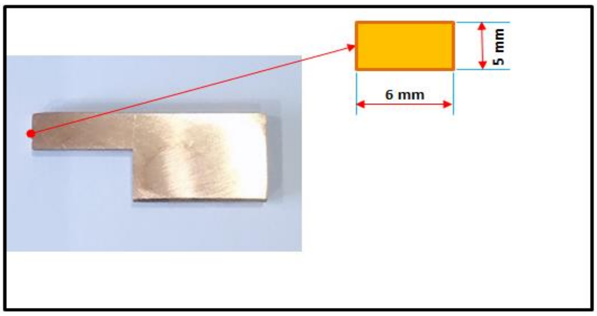

Figure (3): The dimensions of electrode after cutting by WEDM.

4. Design of experiments

The process parameters, selected for this study were the Sh_w, (I) and (T-on) as shown in Table (1).

Table (1) shows the factors and their levels with coded and actual values.

Coded/ Actual levels							
Machining Parameters	**Symbol**	**Unit**	1	2	3	4	5
Workpiece shape	Sh_w	-	A	B	C	D	E
Discharge current	I	A	10	20	30		
Pulse on time	T-on	µs	100	150	200		

5. Material Removal Rate (MRR)

MRR is the rate at which the material is removed the w.p. The MRR is defined also, as the ratio of the difference in weight of the w.p before and after machining to the density of the material and the machining time [7].

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MRR is calculated by using formula (1) [8]

$$\mathbf{MRR} = \frac{W_{iw} - W_{fw}}{\rho_{w} \times t} \qquad (\mathbf{mm^3.min^{-1}})$$

Where:

W_{iw} = Initial w.p weight (gm).
W_{fw}= Final w.p weight (gm).
ρ_w = W.p density (gm.mm^{-3}).
t = Period machining time (min).

6. Results and Discussion

The effects of main process variables like the (Sh_w), (I) and (T-on), have been analyzed to obtain the optimal machining performance. Five shapes (A, B, C, D and E) of AISI 304 SS w.p after machining by EDM are shown in Figure (4).

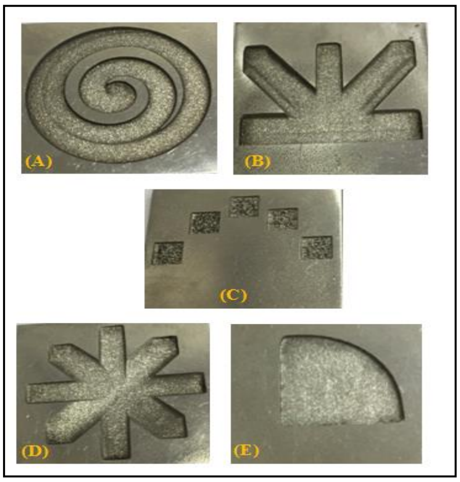

Figure (4): Five shapes of 304 SS workpiece: A-Spiral cone shape, B- Plane radial square 3D shape, C- Arc shape, D- Plane radial circle 3D shape, and E-Quadrant shape.

6.1 Comparison MRR for A Shape

Figure (5) shows the comparison between the experimental and predicted values obtained by ANFIS model. The ANFIS predicted MRR values show a good agreement with those obtained experimentally. The prediction error (- 0.0077), it is evident that the ANFIS technique can help to get better prediction of the experimental data. The max. value of MRR was (25.804 mm^3.min^{-1}) getting with a higher (I) of (30A) and high (T-on) of (200 µs). While the min. MRR was (9.995 mm^3.min^{-1}) get with a low (I) of (10A), and low (T-on) of (100 µs).

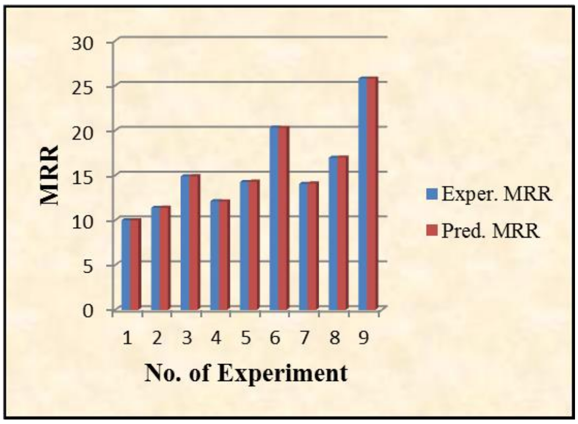

Figure (5): Comparison MRR between experimental and ANFIS for A shape.

6.2 Comparison MRR for B Shape

Figure (6) shows the compared and predicted values obtained by ANFIS model with those obtained and estimated from the experiment. The ANFIS predicted MRR values show a good agreement with those obtained experimentally. The prediction error is (0.0006). The max. value of MRR was (21.9803 mm^3.min^{-1}) getting with a higher (I) of (30A) and high (T-on) value of (200 µs). While the min. MRR was (5.7951 mm^3.min^{-1}) got with a low (I) of (10A), and low (T-on) of (100 µs).

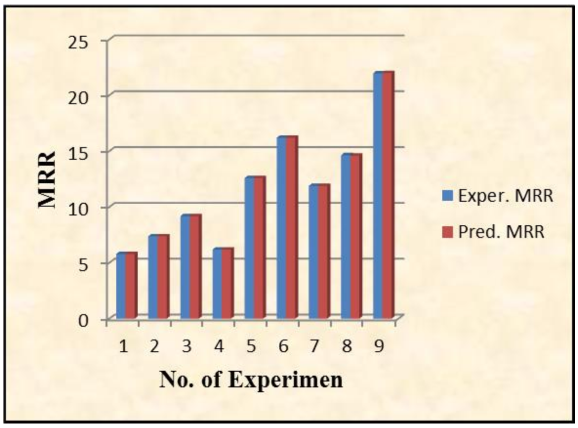

Figure (6): Comparison MRR between experimental and ANFIS for B shape.

6.3 Comparison MRR for C Shape

Figure (7) shows the compared and predicted values obtained by ANFIS model with those obtained and estimated from the experiment. The prediction error (- 0.0252). The max. MRR was (31.5648 mm^3.min^{-1}) getting with a higher current value of (30A) and high (T-on) value of (200 µs). While the min. MRR was (17.182 $mm^3.min^{-1}$) got with a low (I) of (10A), and low (T-on) of (100 µs).

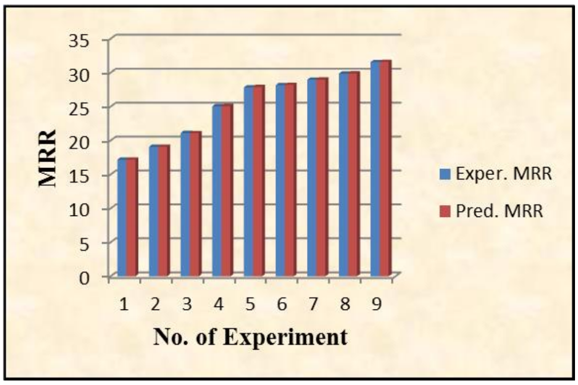

Figure (7): Comparison MRR between experimental and ANFIS for C shape.

6.4 Comparison MRR for D Shape

Figure (8) shows the compared and predicted values obtained by ANFIS model with those obtained and estimated from the experiment. The prediction error (0.0022). The maximum value of MRR was (12.1049 $mm^3.min^{-1}$) getting with a higher (I) of (30A) and high (T-on) of (200 µs). While the min. MRR was (3.6624 $mm^3.min^{-1}$) got with a low (I) of (10A), and low (T-on) of (100 µs).

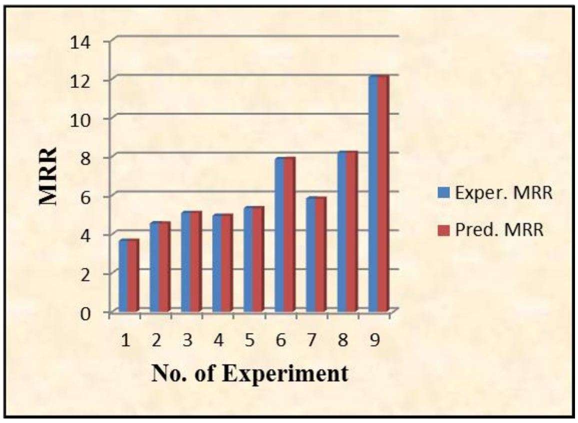

Figure (8): Comparison MRR between experimental and ANFIS for D shape.

6.5 Comparison MRR for E Shape

Figure (9) shows the compared and predicted values obtained by ANFIS model with those obtained and estimated from the experiment. The prediction error (0.0085). The max. of MRR was (18.797 $mm^3.min^{-1}$) getting with a higher (I) of (30A) and high (T-on) of (200 µs). While the min. MRR was (95.8351 $mm^3.min^{-1}$) got with a low (I) of (10A), and low (T-on) of (100 µs).

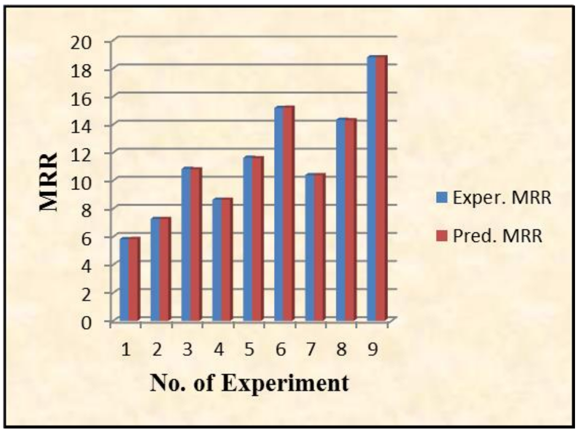

Figure (9): Comparison MRR between experimental and ANFIS for E shape.

7.Conclusions

The important conclusions which can be noted from this work can be summarized as follows:

1. From the experiments, the max. MRR got (31.5648 $mm^3.min^{-1}$) with a higher current value of (30A) and high (T-on) of (200 µs) at the (C) shape.
2. From the experiments, the min. MRR was (3.6624 $mm^3.min^{-1}$) get with a low current value of (10A), and low (T-on) of (100 µs) at the (D) shape.
3. From the comparison between experimental and ANFIS results, the min. error is (0.0006) was obtained in shape (B).
4. From the comparison between experimental and ANFIS results, the max. error is (-0.0252) was obtained in shape (C).

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