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Investigation into the Effect of EDM Parameters on Tool Wear Rate during Machining Of AISI-1045 Steel

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Abstract

In the manufacturing industries, various machining processes are adopted for removing the material from the work piece to obtain finished product. Due to demands for alloy materials having high hardness, toughness and impact in aerospace and automotive industries; it is very difficult to use conventional machining methods to remove the material from the work piece. During the conventional machining process, direct mechanical contact between the tool and the work piece takes place to remove the material, which often causes undesired changes in the properties of work piece and tool wear, due to this cost of production increases. The innovative materials such as super-alloys, composites, ceramics and many other advanced materials, which are difficult to or cannot be machined by conventional machining methods, require new manufacturing technologies. In last few years the industries have seen growth in the development of very hard and not easy to machine materials such as alloys, stainless steel, carbides, HSTR alloys (high strength temperature resistant alloys), heat resisting steels, etc. These materials have found great application in the world of aerospace, defense, nuclear engineering, etc. The conventional machining is unable to machine these types of materials with great accuracy and fineness. So came the era of Nontraditional machining which include. Abrasive jet machining, Electron Beam machining, Electro Chemical machining, Electric Discharge machining, etc. The tool and work-piece is generally connected to a D.C. supply electrically. The tool is connected to the negative terminal of the supply making it work as cathode while the work piece is connected to the opposite terminal of the supply making it act as an anode. A gap is provided or maintained between tool and work piece which is generally of the range 0.005 to 0.05 mm known as 'spark gap' and a suitable dielectric fluid in slurry form is used between the gaps which is non-conducting at a pressure of 2 kgf/cm^2 or less.

When the voltage is applied in the range of 50 to 440V, the dielectric present is broken down and electrons start to flow from cathode to anode which makes the gap ionized.

Now days, due to global competitiveness, manufacturing industries are more concerned about the quality of their products with low TWR. These focus on producing high quality products in time at minimum cost.

Key Words: Electric Discharge Machining (EDM), AISI 1045 tool steel, ANOVA method, Micro Hardness, Principal Component Analysis, Material Removal Rate, Tool Wear Rate, Surface Roughness.

1. Introduction

In the manufacturing industries, various machining processes are adopted for removing the material from the work piece to obtain finished product. Due to demands for alloy materials having high hardness, toughness and impact in aerospace and automotive industries; it is very difficult to use conventional machining methods to remove the material from the work piece. During the conventional machining process, direct mechanical contact between the tool and the work piece takes place to remove the material, which often causes undesired changes in the properties of work piece and tool wear, due to this cost of production increases. The innovative materials such as super-alloys, composites, ceramics and many other advanced materials, which are difficult to or cannot be machined by conventional machining methods, require new manufacturing technologies. These engineering challenges facilitated the development of unconventional manufacturing processes.

2. Literature Review

Chow et al. (1998) studied the effect of added powder in kerosene for the micro-slit machining of Ti alloy by EDM. He employed Cu electrode and Kerosene, kerosene with Al powder, kerosene with Sic powder and studied the effect of different dielectric fluid on gap distance, expansion of slit, electrode wear, material removal depth, surface roughness. He also varied ton (pulse on-time) and powder concentration to know the effect on these responses. Result revealed that kerosene with Al or Sic powder added in EDM increases material removal depth and surface finish (i.e. decreases surface roughness value). Sic powder mixed produced better MRD than Al added to kerosene. Only kerosene showed lowest MRD & electrode wear rate and Al powder with kerosene was the best among the three dielectric- fluid to obtain superior surface roughness. Lin and Lin (2002) conducted an experimental study to compare the utility of grey relational analysis and fuzzy based Taguchi method to optimize the multiple response parameters (electrode wear ratio, material removal rate, and surface roughness) in electrical discharge machining. The pulse on time, duty factor, and discharge current have been considered as EDM parameters. Experimental results concluded that both approaches can optimize the machining parameters with considerations of the multiple responses effectively. They also concluded that the grey relational analysis is more straightforward than the fuzzy-based Taguchi method for optimizing the EDM process with multiple process responses.

3. Research GAP

The review of the research presented above reveals that work has been carried out to investigate the effect of EDM parameters on TWR during machining of different ferrous and non ferrous materials using Taguchi methodology. A little research has been made to obtain the relation between TWR and EDM parameters during machine materials like AISI 1045 steel. The AISI 1045 steel are extensively used for manufacturing punching tools, mandrels, mechanical press forging die, plastic mould and die-casting dies, aircraft landing gears, helicopter rotor blades and shafts, etc. The consistent quality of parts being machined in electric discharge machining is difficult because the process parameters cannot be controlled effectively.

The effect of machining parameters on AISI 1045 steel has not been fully explored. A study of TWR during EDM process on this material will be quite useful. In the present work design of experiments has been selected to investigate the effect of EDM parameters on TWR during machining of AISI 1045 steel. An effort has also been made to develop the relation between EDM parameters and TWR in machining of AISI 1045 steel.

4. Objectives

Thus objectives of the present study are:

1. Development of TWR prediction model using 2 level full factorial design.

2. To analyze the effect of EDM parameters (pulse on time, current and voltage) on TWR during machining of AISI 1045 steel.

5. Experimental Work

The process parameters that were chosen for experimentation are given as under:

1. Current
2. Pulse on time (μs)
3. Voltage

These are the main EDM parameters that affect the TWR. Also, machine operator can change these parameters at the time of machining. The levels of each input parameter were decided by studying the literature in detailed and according to machine limitations. Table 1.1 shows the levels of EDM parameters according to two level full factorial design.

Table 1.1: EDM parameters and their levels

Factor	Name	Units	Type	Subtype	Minimum (+1)	Maximum (-1)
A	Current	Ampere	Numeric	Continuous	10	20
B	Voltage	Volts	Numeric	Continuous	15	45
C	Pulse on	Microsecond	Numeric	Continuous	50	100

6. Formation Of Design Matrix

In the present work two level full factorial design has been used to plan the experiments. Total 14numbers of experiments has been finalized according to two level full factorial design. Out of 14 experiments, 8 are the factorial points and 6 are the centre points. The table 1.2 shows the design layout for experimentation.

Table1.2: Design layout for experimentation

Std	A:Current (ampere)	B:Voltage (Volts)	C:Pulse on time (Microseconds)
1	10	15	50
2	20	15	50
3	10	45	50
4	20	45	50
5	10	15	100
6	20	15	100
7	10	45	100
8	20	45	100

9	15	30	75
10	15	30	75
11	15	30	75
12	15	30	75
13	15	30	75
14	15	30	75

7. Experimental SET UP

In this experiment whole work was performed on electric discharge machine model TRESSMACH-330 SPARK GENERATOR (die sinking type) of 25 Ampere capacity with servo head system of constant gap. Negative polarity i.e. work-piece negative and tool positive was used to conduct the experiments.

Table 1.3: Properties of Work piece and Tool Material

Properties	**Work piece**	**Tool**
Melting Point Temp.	1371 -1399 ^{0}C	1083 ^{0}C
Elastic modulus(E)	193 GPa	123 GPa
Poisson ratio	0.3	0.26
Density	8.03 g/cm3	8.96 g/cm3

Table 1.4: Process Parameters

Input Factors	Responses, Measured units
Flow Rate	Material Removal Rate (MRR), g/sec
Peak Current (Ip)	Tool Wear Rate (TWR), g/sec
Pulse on time (Ton)	Surface Roughness (Ra), µm
Pulse off time (T_{Off})	Dimensional Tolerances (DT), mm2

8. Experimental Procedure

1. First-of–all the work piece was faced using lathe.

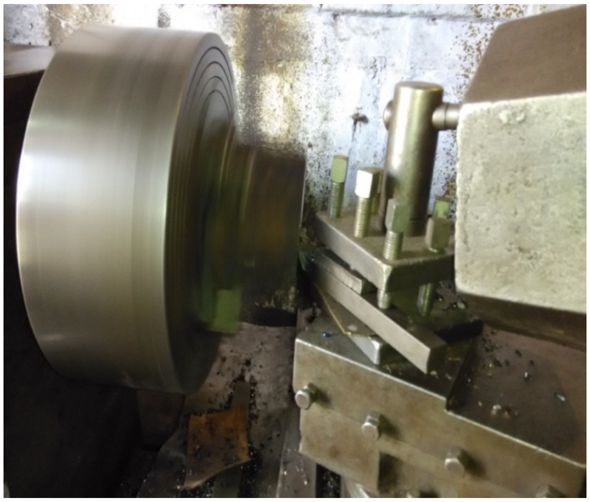

Figure 1.1: Facing of the plate

2. The tools were also machined to reduce its diameter from 12mm to 10mm in order to fit into the electrode holder which was of 10mm diameter.

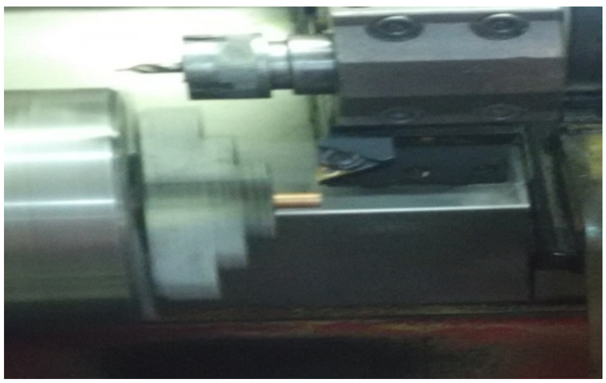

Figure 1.2: Machining of tool electrode from 12mm to 10mm

1. The weight of the each tool before machining and after machining was measured using a weighing machine which gives 3 value after decimal.
2. The experimentation was performed according to the array designed by the 2 level full factorial design.
3. The tool was firmly held into the tool holder.
4. The value of the parameters was fed into the machine manually with the help of buttons provided and the value selected appears on the screen.

Figure 1.3: Screen where levels of parameters are displayed and fed

9. Discussion

This chapter includes the development of tool wear prediction model, ANOVA analysis and effect of EDM parameters on tool wear. For this purpose, the results of all the experiments obtained after the measurement of tool wear have been input into the design expert software along with run order.

Diagnosis of assumptions of ANOVA

To check the assumption of ANOVA of normal distribution, the normal probability plot of the residuals is shown in figure 2.1.

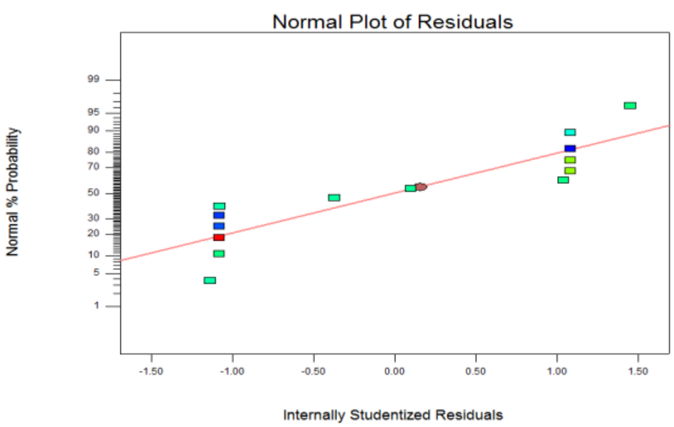

Figure 2.1: Normal probability plot for residuals of tool wear rate

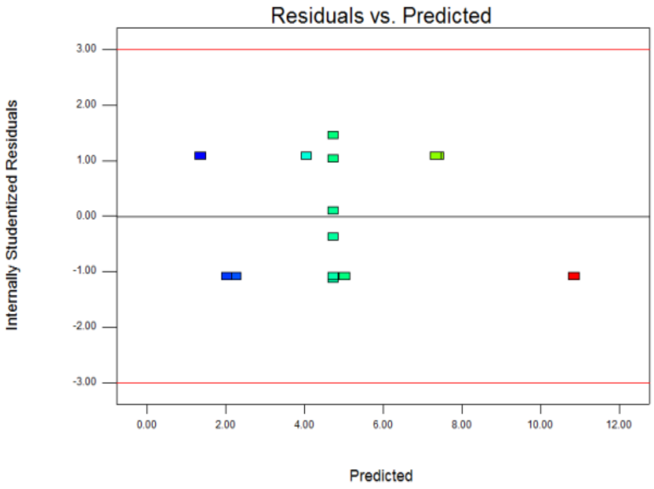

Figure 2.2: Plot between of residuals and predicted TWR

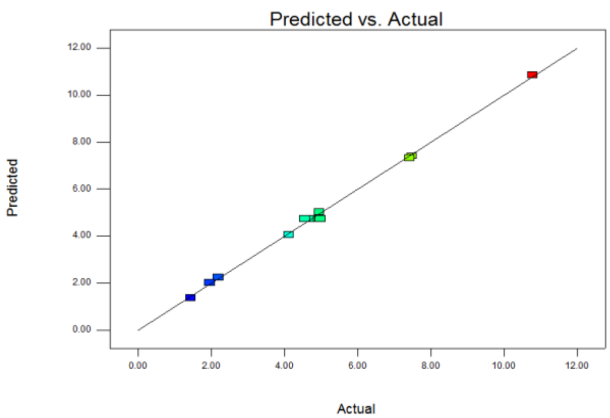

Figure 2.3: lot between the predicted TWR and actual TWR

Analysis of Experiment

The ANOVA was carried out for a significance level of $\alpha = 0.05$, i.e. for a confidence level of 95%. The ANOVA for tool wear rate is summarized in Table 2.1.

The table 2.1, shows that the value of "Prob. > *F*" for tool wear rate model is less than 0.0001 which is less than 0.05, that indicates the tool wear rate model is significant, which is desirable as it indicates that the terms in the model have a significant effect on the tool wear rate. In the same manner, the value of "Prob. > *F*" for main effect of voltage, current, pulse on, and two-level interaction of voltage and current; voltage and pulse on time; current and pulse on time are less than 0.05 so these terms are significant model terms.

The tool wear rate prediction model in terms of coded factors is given in equation 1.1.

$$(TWR) = 4.91 + 1.10 * A + 1.03 * B - 2.61 * C + 0.28 * A * B - 0.37 * A * C - 0.41 * B * C \quad (1.1)$$

While, the following equation is the tool wear rate prediction model in terms of actual factors

$$(TWR) = 3.26 + 0.33 * Current + 0.095 * Voltage - 0.026 * Pulse\ on + 0.0037 * current * Voltage - 0.003 * Current * Pulse\ on\ time - 0.001 * Pulse\ on * Voltage$$

10. Effect of EDM Parameters on Tool Wear Rate

The figure 2.4 shows the effect of current on TWR at constant voltage (30 Volts) and constant pulse on time (75 microseconds). The TWR increases as the current increases.

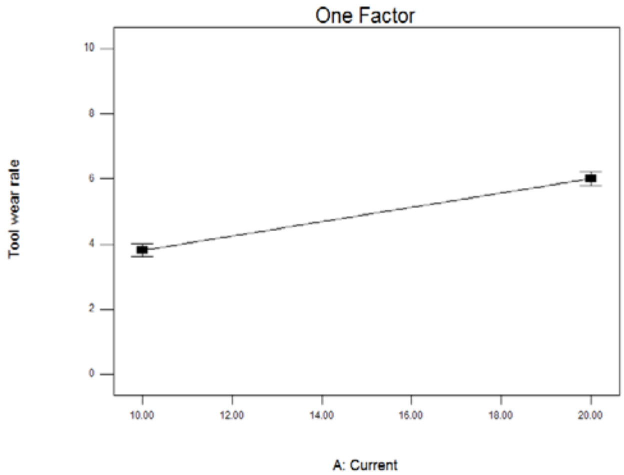

Figure 2.4: Plot between current and TWR at voltage (30 Volts) and pulse on time (75 microseconds)

The effect of voltage on TWR at constant current (15 A) and constant pulse on time (75 microseconds) is shown in figure 2.5. The plot shows that the TWR increases as the voltage increases.

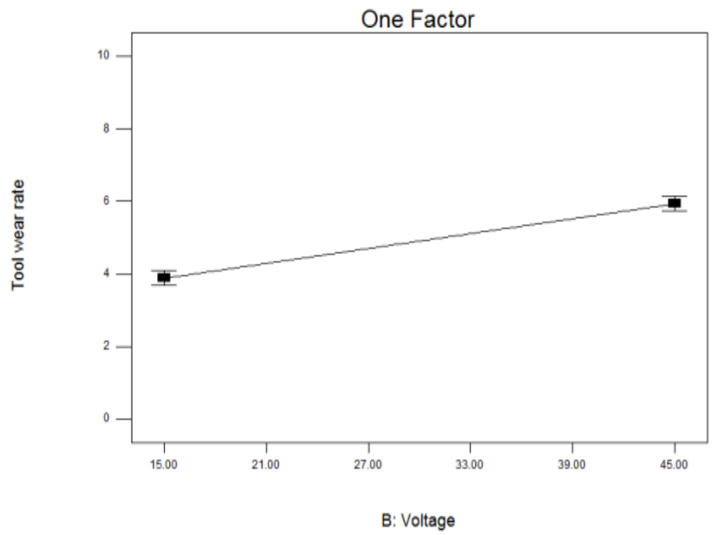

Figure 2.5: Plot between TWR and voltage at current (15 A) and pulse on time (75 microseconds)

The effect of pulse on time on TWR at constant voltage (30 Volts) and constant current (15 A) is shown in figure 2.5. It is clear from the plot that as the pulse on time increases, the value of TWR continuously decreases.

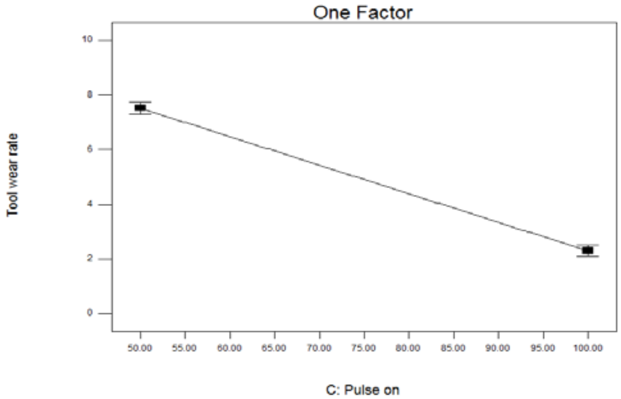

Figure 2.6: Plot between pulse on and TWR at voltage (30 Volts) and current (15 A)

The effect of interaction for TWR between voltage and current at pulse on time 75 microseconds is shown in fig 2.6.

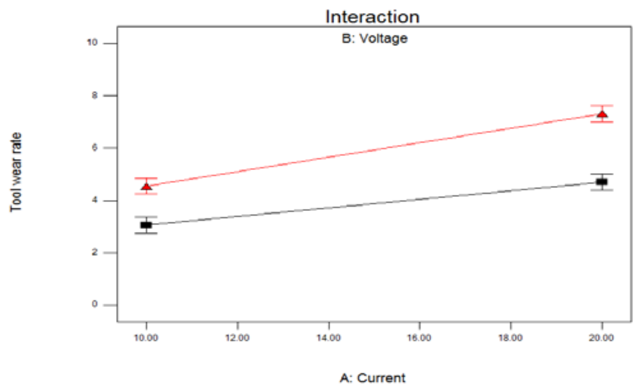

Fig.2.7: Interaction plot between voltage and current on TWR at constant pulse on time 75 microseconds

The figure 2.7 shows the interaction plot for TWR between pulse on time and current at constant voltage 30 V.

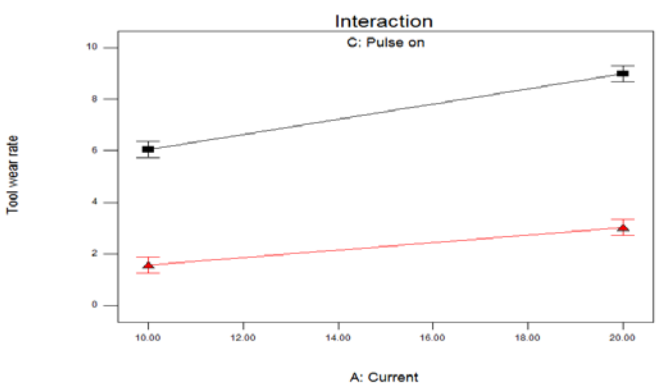

Fig.2.8 Interaction plot between pulse on time and current on TWR at constant voltage 30 V.

The figure 2.8 shows the interaction plot for TWR between pulse on time and voltage at constant current 15 A.

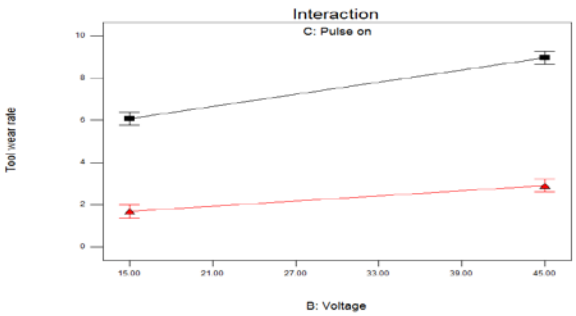

Fig.2.9 Interaction plot between pulse on time and voltage on TWR at constant current 15 A.

11.Conclusion And Future Scope

The important conclusions drawn from the present work are summarized as follows:

1.) The current, voltage and Pulse on time have been found significant parameters that affect the TWR.

2.) The interaction of current and voltage; current and pulse on time; voltage and pulse on time have been also found significant model term that affect the TWR.

3.) The pulse on time has been found most significant parameter that affect the TWR followed by current and voltage.

4.) The R- square values shows that developed model has good TWR prediction ability.

5.) The TWR increases with increase in voltage and current, while decreases with increase in pulse on time.

6.) The minimum TWR is achieved at low level of current, low level of voltage and high level of pulse on time.

7.) Face roughness and EDM parameters, MRR and EDM parameters have been developed. The predicted results are in good agreement with the measured ones. These relationships are applicable within the ranges of tested parameters.

In this study mathematical modeling and optimization has been attempted only for TWR. The work can be extended to consider more response variables like MRR, surface roughness etc. Also more parameters such as temperature, shape of electrode, type of fluids can be introduced to have a better insight into the process.

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