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Experimental Study of Electro Discharge Machining (EDM) on Mild Steel (E-250) using Copper Electrode

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Abstract: Electro-discharge machining is used for machining different types of hard materials which are electrically conductive and these materials are particularly challenging to manufacture using any other machining method. In electro-discharge machining electrical energy is transformed into thermal energy which is approximately 8000 to 12000 degrees Celsius and due to high thermal energy material melting and vaporising. In electro-discharge machining, three types of electrode materials are used which are copper, brass and graphite, Of all three materials, graphite has the highest electrical conductivity and brass has the lowest electrical conductivity. Electro-discharge machining process suitable for generating complex shapes and profiles. In this paper, a Copper electrode was used for machining mild steel (E-250) and analysed the MRR and Ra with a variation of discharge current keeping other variables constant and studying the consequence of different discharge currents on MRR and Ra.
Keywords: EDM, MRR, Ra, Copper Electrode, Discharge Current.

I. INTRODUCTION

J. Priestly discovered the EDM procedure in near about1770. The goal of the study is to determine how electric discharges affect machining. The earliest efforts to use this machining technique on metals and diamonds were made in the year 1930. This method was known as "spark machining" at the time [1]. The Lazarenko brothers worked diligently on Electro-discharge machining at Moscow University in 1943. [2]. Later, as this technology continued to advance, it gained widespread recognition on a global scale for the machining of every sort of conducting material in any form and with any degree of hardness. Pulse-on-time control and servo-controlling systems were created for the first time using the invention of the RC circuit around 1950. The interelectrode gap (IEG) may be detected automatically thanks to this servo system, making the procedure efficient and straightforward. [3]. With the advent of CNC in EDM in the 1980s, the procedure became more reliable, and with the assistance of several discharges that occur in the middle of the two electrodes while they are submerged in a dielectric media, the material removal mechanism harnesses the electrical power converts it into the thermal energy. [4]. Along the two electrodes, a fictitious plasma column is produced. As a result of this thermal energy[5] ranging from 8000 to 120000 degrees Celsius [6] may reach 20000^0c [7]. Any substance may simply melt at this high temperature regardless of its hardness. When the DC energy source is pulsed at a frequency of 20 to 30 thousand Hz, the plasma channel collapses and is turned off [8]. The molten metal is removed from the hole or crater by the dielectric, which causes tiny debris to develop [1] and exposes the new workpiece surface to sparks. Each discharge removes between 10^{-6} and 10^{-4} mm^3 of material, while the MRR ranges from 2 to 400 mm^3/min [1]. Electrode forms their replica on the w/p during the EDM process, which shapes tools [9]. Additionally, EDM yields tolerance and precision levels substantially higher than any other non-conventional or conventional machining techniques. The quantity of energy applied to the workpiece as heat has a significant impact on the MRR [10,11]. High-kinetic-energy electrons and ions strike the tool's and workpiece's surface, causing thermal energy flow. This thermal energy flow creates an area of greater temperature (above 10,000 ^{0}C) around the contact between the w/p and the electrode, which results in confined melting [12].MRR and TWR values rise as the input current value rises; also, the surface becomes rougher as a result. A tool rotation approach that improves MRR and surface quality with low discharge current levels can be used to solve this issue [13].

Nomenclature

EDM	Electro-discharge machining
MRR	Material removal rate
Ra	Surface Roughness
W/p	workpiece

II. LITERATURE REVIEW

Research on castek-03 was done by Tzeng et al.[14] utilizing medium carbon steel and an EDM machine. They claimed that the input current at low voltage, discharge current at high voltage, and ton significantly impacted EDM. They also claimed that low voltage and tonnage had an impact on machining speed. By analysing the effects of input variables like pulse on time, pulse off time, wire speed, and wire feed on response characteristics including MRR and SR while processing an AlSiC (20%) plate using molybdenum wire, Kumar et al.[15] have worked on process parameters of WEDM. RSM regression equation model chose to track how variables respond to their original values. Reducing Ra (SR) using the Taguchi technique is common practice. It was found that important factors in MRR and SR include Ton, Toff, WS, and WF. When a 0.3mm thick circular hollow cylindrical electrode is employed, M. Kunieda [16] study the impact of pulse on time and the ratio of volumetric removal (VR) of work material to tool material volumetric wear (VW). In the air, the tool wear ratio always equals 0 and is unaffected by the length of the pulse. In other circumstances, such as oil, the tool wear ratio increases dramatically when the pulse length is decreasing. The impact of process factors such as time on, time off, input Voltage, and wire feed rate on MRR, SR, and Kerf was examined by Prajapati et al. [17]. As a workpiece; the AISI A2 tool steel square bar was employed. To optimize and analyse the performance of the experiment, response surface methodology (RSM) was utilized. According to research, Ton and Toff are the process variables that have the greatest influence on CR and Ra (SR). For kerf, the spark gap voltage (SGV) is important. When machining HSLA using brass wire as an electrode, Sharma et al.[18] investigated the impact of process variables such as discharge current, Time on, Time off and supply voltage, on MRR and SR. A mathematical model was created using RSM, and the input variable for MRR and SR was optimized. MRR was impacted by time on, and time off and Ra was affected by Time on. In trials on conductive ceramic Boron carbide, Puertas et al.[19] optimized several machining settings for SR, electrode wear, and MRR ZrB2-Cu composite electrode, produced by Khanra et al. [20], exhibits greater MRR and lower TWR than pure Cu. Singh et al. [21] have studied how different types of electrodes affect EN-31 tool steel. It was discovered that whereas Copper-tungsten electrode exhibits better surface quality with low TWR, Copper and Aluminium exhibit Lower diametrical overcut and high MRR. Discharge current and operating voltage have a significant impact on MRR, according to Hu et al. [22]. The behaviour of the Graphite electrode was used on the Inconel workpiece. investigated by Datta et al.[23] It was shown that by increasing the discharge current, MRR also rises. The surface crake density rises with the discharge current up to a specific value and then rises as the discharge current increases up to a certain point before remaining constant.

This paper investigates the consequence of discharge current on MRR and Ra using Copper Electrode as a Tool and mild steel (E-250) as the workpiece. During the experiment value of the discharge current is changed and the study consequence of the change is of discharge current on MRR and Ra.

III. EXPERIMENTAL WORK

Sparkonix ZNC (Z axis numerical Control Machine) 2008, model number S 50 ZNC electrical discharge machine used for experimentation.

Table No. 1

Discharge Current	1.5, 3, 4.5, 6, 9, 12, Ampere
Ton	90 µs
Toff	30 µs
Polarity	Straight
Dielectric	EDM oil 500PL

Mild steel (E-250) material was used for the experiment and a Copper electrode was used as a tool for machining.

Table no.2 gives the chemical composition of Mild steel E -250, and Table no.3 gives some properties of Copper electrodes.

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Table No 2
Chemical composition of Mild steel (E-250)

Elements	Percentages
P	0.050
C	0.23
Si	0.40
Mn	1.50
S	0.05

Table 3.
Copper Electrode Properties

material	Density (gm/cm^3)	Specific electrical Resistance (ohm-m)	Thermal conductivity (W/mK)	liquefaction point (◦C)
Copper	8.96	1.69×10^{-8}	391	1083

$$MRR = \frac{(M_i - M_f) \times 1{,}000}{\times t} \frac{mm^3}{min} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq (1)} \; \rho$$

M_i – Initial weight in grams (w/p)

M_f – final weight in grams (w/p).

ρ – Density in gram/cc (w/p)

t- Total machining time (min)

IV. RESULTS AND DISCUSSIONS

The consequence of discharge current on MRR was analysed during the experiment and a detailed analysis is given below

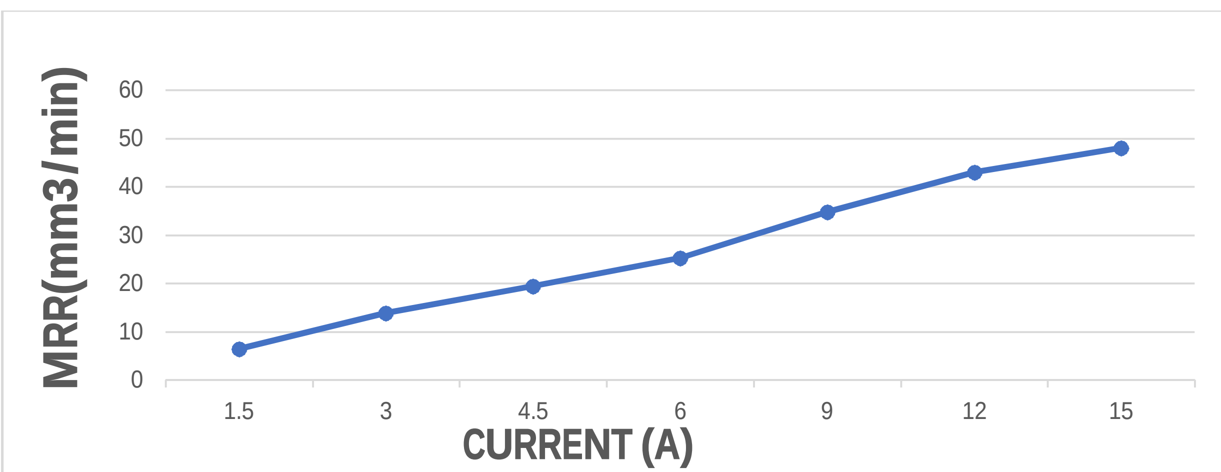

Figure No. 1 Graph Between Current and MRR

Figure no. 1 clearly shows that MRR continuously rises with increasing the discharge current because when discharge increases then spark energy also increases which increases the temperature due to this higher melting and vaporisation taking place which increases the MRR and also increases the discharge current, frequency of sparks become higher and it increases the number of sparks per unit time which increase the MRR.

The consequence of the discharge current on Ra was analysed during the experiment and a detailed analysis is given below

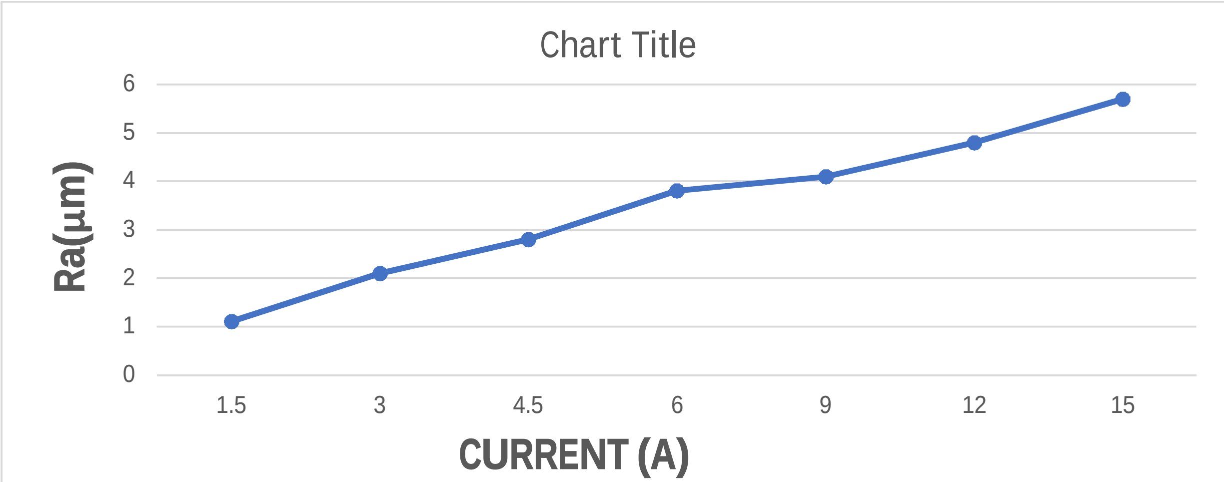

Figure no.2 Graph between Current and Ra

Figure no.2 clearly shows that when the discharge current increases during the experiment, Ra also increases because when the discharge current increases, the spark energy and frequency of the spark also increase, which creates larger craters and deeper grooves on the machined surface, increasing the Ra. In the electro-discharge machining surface, roughness depends on various process parameters. Discharge current is a major factor in which Ra depends on variations of discharge current.

V. CONCLUSIONS

By the analysis of the above experimental results, some important conclusions are given below

1) Discharge current is the major factor on which the MRR depends. MRR increases when the value of the discharge current is increased at a certain limit and after that MRR becomes constant or decreases and this value of the discharge current is called the Saturation Current for the MRR
2) Ra (Ra) is increased when the discharge current increases at some certain value after that no change in Ra further increases the discharge current and this value of the discharge current is called Saturation current for Ra.
3) Saturation Current for Ra is lower than the saturation current for MRR.
4) Saturation current depends on the workpiece material and electrode material.

Based on the above conclusions in the electro-discharge machining, MRR and Ra increase with increasing the discharge so when required high MRR the discharge remains high and keep discharge current value is low when good surface quality is machined Surface.

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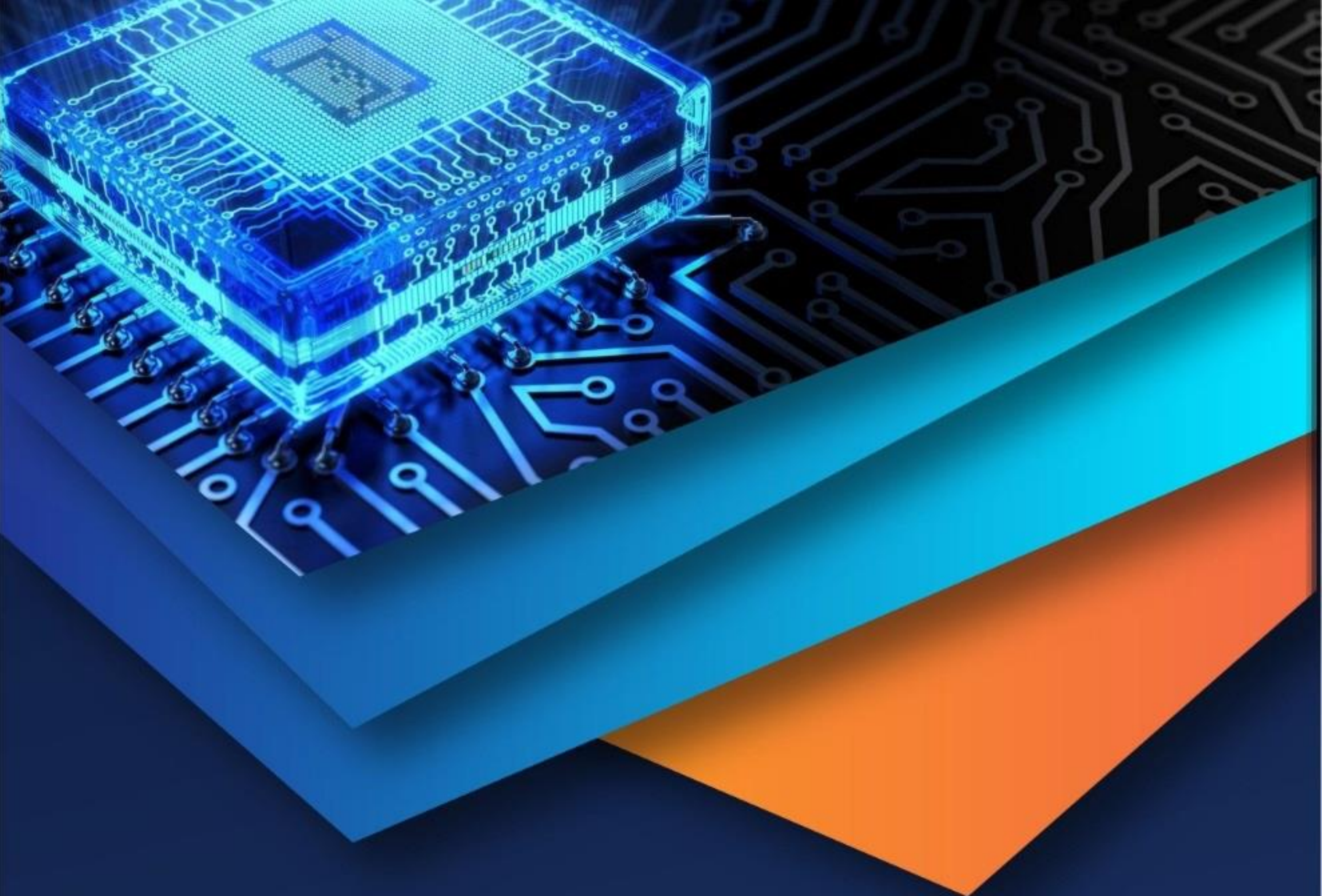

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