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Effects of Process Parameters on Electrical Discharge Machining Performance Measures on D3 Steel

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ABSTRACT

One of the most significant factors to consider in the majority of manufacturing processes, particularly those involving Electrical Discharge Machining, is the proper selection of manufacturing conditions (EDM). It can machine geometrically complex or hard material components that are precise and difficult to machine, such as heat treated tool brass, copper, steels, composites, super alloys, ceramics, carbides, heat resistant steels, and so on. It is widely used in the die and mould making industries, aerospace, aeronautics, and nuclear industries.

According to the literature review, some study has been done to determine the ideal levels of machining parameters that provide the greatest machining quality in the machining of difficult-to-machine materials such as hot die steel H-11 and D3 STEEL.

H-11 hot die steel is widely utilised in hot-work forging, extrusion, punching tools, mandrels, mechanical press forging dies, plastic mould and die-casting dies, aviation landing gears, helicopter rotor blades and shafts, and other applications. A comparative examination of electro discharge machining (EDM) of D3 STEEL alloy employing brass electrodes was conducted as part of this project. Material removal rate (MRR) and overcut were used to evaluate the process' performance. During the testing, the pulse on time, pulse off time, and peak current were varied, and a brass electrode with a tubular cross section was used to cut through holes in a D3steel alloy workpiece. The machined surfaces were subjected to metallographic examination.

To limit the overall number of tests, a well-designed experimental system was adopted. The whale's optimization algorithm was used for some of the experiment.

The goal of this study was to look at the impact of various EDM process parameters on machining quality and to come up with the best set of process parameters to improve the quality of machined parts. The EDM process parameters' working ranges and levels are determined using a one-factor-at-a-time approach. The Taguchi technique was used to examine the effects of EDM process parameters and, as a result, forecast sets of ideal parameters for the best quality attributes. The empirical models for response characteristics were developed using response surface methodology (RSM) in conjunction with second order central composite rotatable design. Desirability functions were utilised to optimise multiple performance measurements at the same time. Confirmation experiments on the whale's optimization algorithm are also carried out to verify the results.

Keywords-- D3 Steel, Process Parameters, Electrical Discharge Machine

I. INTRODUCTION

History of Non Conventional Machining

Machinability, as we all know, refers to the ability of a metal to be machined to an acceptable surface polish with a high Material removal rate (MRR) and then converted into a completed product. Since the Second World War, a new and unusual machining demand that could not be addressed by traditional means has been called Non-Conventional Machining.

Steel is an engineering material that is commonly used. Steels come in a number of shapes and sizes, and they're employed in a wide range of applications. On the basis of carbon content, steel is classified as low carbon, medium carbon, or high carbon steel. D3 steel is a 1 percent Mo steel that has been air hardened. Oil-quenched Type D3 steel, while short portions can be gas quenched following austenitization with vacuum. As a result, during hardening, tools made of type D3 steel tend to be brittle. Among the group D steels, type D2 steel is the most commonly utilised. D3 steels have a carbon content of 1.5 to 2.35 percent and a chromium content of 12 percent. It is the most widely used type of steel because it has material qualities that are suitable for a wide range of applications.

Electric Discharge Machining

Now I'll talk about machining with an electric discharge (EDM)

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The demand for alloy materials with high hardness, toughness, and impact resistance is growing in tandem with the development of the mechanical sector. Drilling, milling, grinding, and other traditional machining procedures have been replaced by electric discharge machining (EDM), a "non-traditional machining method" that has become a well-established machining option in many industrial industries throughout the world. The working fluid affects the material removal rate and the qualities of the machined surface in electrical discharge machining (EDM), a process that uses the removal phenomenon of electrical discharge indielectric.

During World War II, Mr. and Mrs. Lazarenko worked on the first EDM application at the Moscow Technical Institute. The RC relaxation circuit, which allowed the first constant and trustworthy control of pulse times, was the first of two key advances, also carried out by these Soviet experts, that made it possible to elevate this electrical approach to the category of manufacturing process. The second advancement was the addition of a simple servo control circuit to automatically detect and maintain a gap. Despite these early trials and discoveries, EDM was virtually unknown until the 1950s. This strategy became popular in industrial marketing, primarily in the United States, around this time.

II. PRINCIPLE OF EDM

A potential difference is applied across the tool and w/p in pulse form in electrical discharge machining. Both the tool and the workpiece must be electrically conductive, with a minimal space between them. A dielectric medium is used to immerse the tool and workpiece (kerosene or deionized water). Electrons from the tool begin to migrate towards the workpiece as the potential difference is applied. The tool is negative, and the w/p is positive in this case. Electrons travelling from the tool to the w/p hit with dielectric medium molecules. It is transformed into ions due to electron collisions with the molecule. The concentration of electrons and ions in the gap between the tool and the w/p grows as a result. The electron is drawn to the w/p, whereas the ions are drawn to the tool. Plasma is an electric current that is set up between the tool and the w/p. When electrons and ions collide with the w/p and tool, their kinetic energy is converted into heat energy. The heat produced has a temperature of around 10000 degrees Celsius. The material from the workpiece vaporises and melts as a result of the heat. The current between the tool and the w/p stops flowing when the voltage drops. The molten material in the w/p is flushed out by the circulating dielectric medium, leaving a crater in its wake. Because a steady voltage is not delivered across the electrodes, the spark creation is not continuous. The voltage is delivered in a pulsed manner.

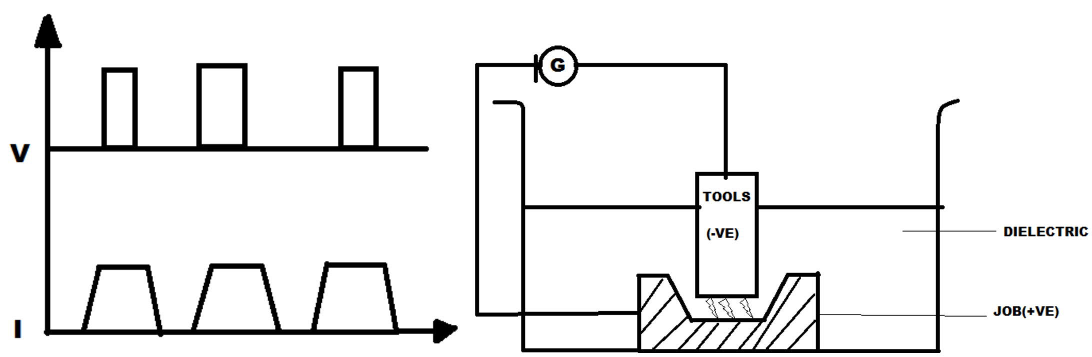

Figure 1: *Working principle of EDM process*

Working of Electrical Discharge Machining (EDM)

In EDM, the tool and workpiece are secured to the machine, respectively, by the tool holder and workpiece holder table. Then, using a servo mechanism, a small space (the width of a human hair) is maintained between the tool and the workpiece.

A dielectric medium is used to immerse the tool and workpiece (kerosene of deionized water).

Across the Electrode, a potential difference is applied. Between the tool and the workpiece, an electric spark is created. This spark produces a temperature of approximately 10000 degrees Celsius. The material from the workpiece begins to evaporate and melt as a result of the heat.

In electrical discharge machining, the spark generation is not continuous. The dielectric fluid washes away the molten components as the voltage breaks, leaving a crater behind.

This procedure continued as the workpiece was machined.

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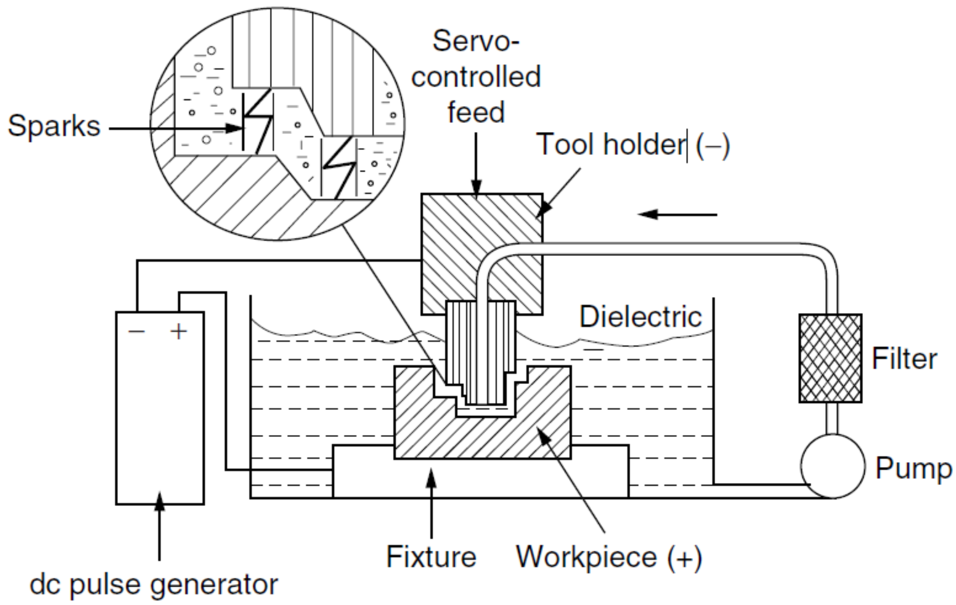

Figure 2: Schemetic Diagram of EDM

EDM's Critical Parameters

The amount of time (s) that the current is permitted to run every cycle (spark on-time, pulse time, or Ton). The amount of energy applied during this on-time is exactly proportional to the amount of material removed. The peak current and the length of the on-time are the primary determinants of this energy.

Spark The period of time (s) between the sparks is known as off-time (pause time or Toff) (that is to say, on-time). This gives the molten material enough time to solidify and wash out of the arc gap. This setting has an impact on the cut's speed and stability. As a result, if the off-time is too short, sparks will become unstable.

The Arc gap (or gap) is the distance between the electrode and the workpiece during the EDM process. It's also known as a spark gap. The servo mechanism can maintain the spark gap.

Current allowed to discharge (current Ip): Current is measured in amps per cycle. The rate of material removal is proportional to the discharge current.

The duty cycle () is a percentage of on-time compared to total cycle time. The on-time is divided by the entire cycle time to arrive at this value (on-time pulse off time).

$$\tau = \frac{Ton}{Ton + Toff}$$

Voltage (V): It is a potential that can be measure by volt it is also effect to the material removal rate and allowed to per cycle. Voltage is given by in this experiment is 50 V.

Diameter of electrode (D): It is the electrode of Cu-tube there are two different size of diameter 4mm and 6mm in this experiment. This tool is used not only as a electrode butalso for internal flushing.

Over cut – It is a clearance per side between the electrode and the workpiece after the machining operation.

Dielectric fluid - Material loss in EDM is mostly caused by heat evaporation and melting, as previously mentioned. Thermal processing must be carried out in the absence of oxygen in order to manage the process and avoid oxidation. Surface conductivity (electrical) of the work piece is frequently reduced by oxidation, preventing further machining. As a result, dielectric fluid should provide a machining environment devoid of oxygen. It should also have a sufficiently high dielectric resistance so that it does not overheat electrically while ionising when electrons hit with its molecule. Furthermore, it should be thermally robust when sparking.

Flushing method- In any electrical discharge machining operation, the most crucial function is flushing.

The process of flushing is the introduction of clean, filtered dielectric fluid into the spark gap. To effectively eliminate the metal particles, a variety of flushing procedures are used.

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Figure 3: Flushing Method

III. EXPERIMENTAL ANALYSIS

3.1 Machine Tool

The experiments were carried out on a wire-cut EDM machine (ELEKTRA SPRINTCUT 734) of Electronica Machine Tools Ltd. installed at Advanced Manufacturing Laboratory of Mechanical Engineering Department, H.I.T. Haldia,West Bengal India.

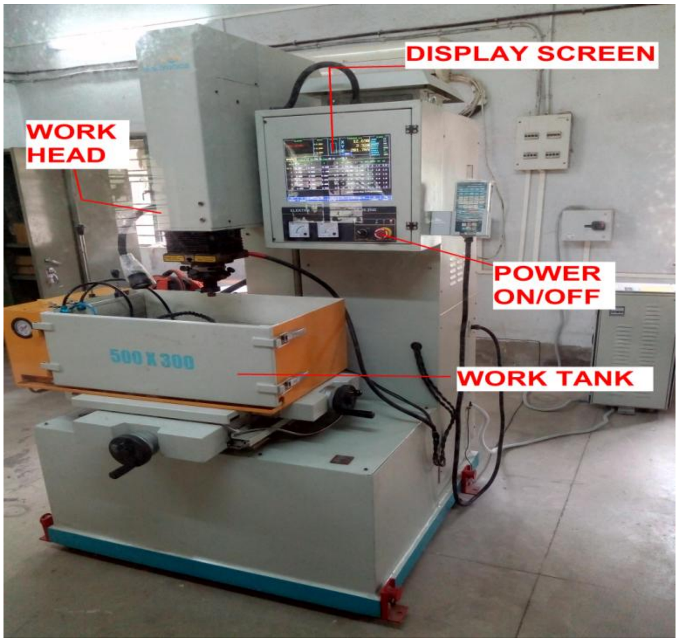

Figure 4: Set up of Electric discharge machining

To conduct the experiments, I utilised an Electric Discharge Machine model ELECTRONICA-ELECTRAPULS PS 50ZNC (die-sinking type) with servo-head (constant gap) and positive polarity for the electrode. D3 For my experiment, I used mild steel as my workpiece. With the use of a power Hack-saw from our central workshop, three pieces of mild steel were manufactured. A grinding machine was used to finish the object. The workpiece is approximately 35 mm in length and 35 mm in breadth. Three tests were carried out in all. Mild steel was machined on both sides. As a dielectric fluid, commercial grade EDM oil (specific gravity=0.763, freezing point=94C) was employed. Internal cleansing of Brass tool with 0.2 kgf/cm2 pressure. Experiments were carried out using electrodes with a positive polarity. In positive mode, the pulsed discharge current was applied in various phases. The test conditions are presented in the table 3.1.

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Work Piece and Tool Material

D2, D3, D4, D5, and D7 steels are high-carbon, high-chromium steels used in cold-work tooling. Except for D3, all group D steels are air hardened and contain 1% Mo. Oil-quenched Type D3 steel, while short portions can be gas quenched following austenitization with vacuum. As a result, during hardening, tools made of type D3 steel tend to be brittle.

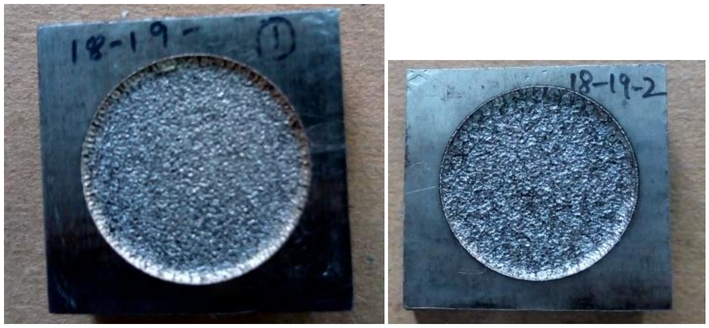


Figure 5: Machining on Workpiece

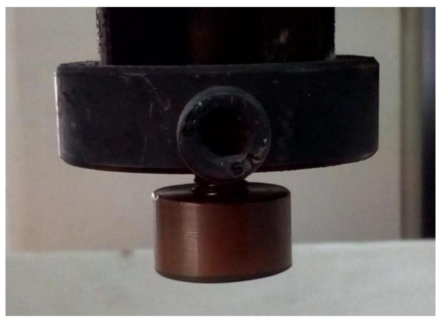


Figure 6: Tool holder with Workpiece and tool

Physical Properties of work piece

Properties	**Metric**	**Imperial**
Density	7.7 x 1000 kg/m3	0.278 lb/in3
Melting point	11421°C	2590°F

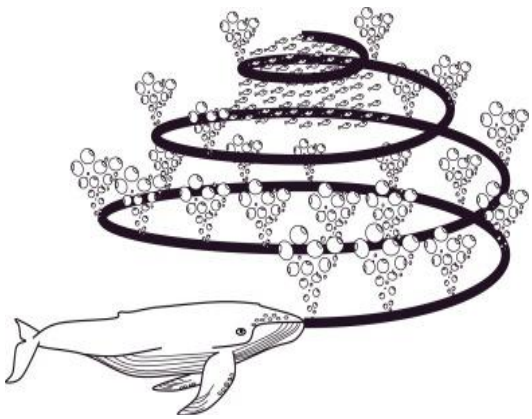
Chemical Composition of work piece

Elements `	Content(%)
C	2.00-2.35
Mn	0.6
Si	0.6
Cr	11.00-13.50
Ni	0.3
W	1
V	1
P	0.03
S	0.03
Cu	0.25

Whale's Optimization

Mirjalili first introduced WOA in the year 2016. This method is a simulation of a humpback whale's hunting process. The bubble-net foraging method is the name given to this unique hunting mechanism. While the humpback whales are circle the prey, they forage by blowing characteristic bubbles in a circular or '9-shaped' pattern. Humpback whales may dive to a depth of 10–15 metres, then create bubbles in a spiral configuration around their prey and swim up to the surface using unique movements. The flashing fins of the humpback whales envelop the prey, keeping it trapped and preventing it from fleeing.

The next part describes the mathematical model of encircling prey, spiral bubble-net foraging manoeuvre, and prey search:



IV. ANALYSIS

Electric Discharge Machining of D3 steel material interpenetrating synthesised at 1150oC/24 hour has been considered in my present research project. The studies were carried out on an Electric Discharge Machine model ELECTRONICAELECTRAPULS PS 50ZNC (die-sinking type) with servo-head (constant gap) and positive polarity electrodes. For my experiment, I chose D3 mild steel as my workpiece.

D3 parts were cut out with the use of a power hacksaw at our central workshop. A grinding machine was used to finish the object. The workpiece is approximately 35 mm in length and 35 mm in breadth. Three tests were carried out in all. Mild steel was machined on both sides. As a dielectric fluid, commercial grade EDM oil (specific gravity=0.763, freezing point=94C) was employed. Internal cleansing of Brass tool with 0.2 kgf/cm2 pressure. Experiments were carried out using electrodes with a positive polarity. In positive mode, the pulsed discharge current was applied in various phases. The experimental data was collected using electrical discharge machining on a D3 steel work piece with a brass tool.

Table 4.1: Summarises the results of the MRR and OC experiments.

l No	**ontrol Parameter**				**esponses**	
	p	**/**	**on**	**b**	**IRR gm/s)**	**C mm)**
	5	5	000		.4484	.901
	0	0	000		.5845	.821
	5	0	000		.7162	.051
	5	5	000		.2117	.751
	0	5	000		.0889	.121
	0	5	000		.8522	.971
	5	5	000		.9494	.891
	5	0	000		.2250	.041
	5	5	000		.5005	.191

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Estimation of surface roughness and material removal rate for the input parameters of Ip, Ton, V is known by the Table 2. And this experimental data is analyzed for their optimum values using mat lab and Minitab software's.

Regression Equation of D3 Material

The regression equation for D3 material becomes. The relationship between the input parameters and the output parameters can be obtained using the statistical tool of regression analysis. Minitab 16 was used for obtaining the relationship between MRR and input variables and also for obtaining the relationship between MRR & OC and the input variables.

MRR (mm3/s) = -0.2926 + 0.07662 Ip + 0.002597 V - 0.000260 Ton - 0.002597 Ib - 0.000000 Ip*V + 0.000000 Ip*Ton - 0.000000 V*Ton

OC (mm) = -0.2926+0.07662*x(1)+0.002597*x(2)-0.000260*x(3)-0.002597*x(4)

Result Analysis by using Whale's Optimization Algorithm(WOA)

According to experiment the result will be optimize by Whale's Optimization Algorithm and we get best and solution from the above data given in table no3

Best solution = The best solution will be analyze from WOA technique give in Table no10 .

Ip	V	Ton	b
25	55	1000	

Table 4.2: Best solution for MRR

Best job = 1.5005

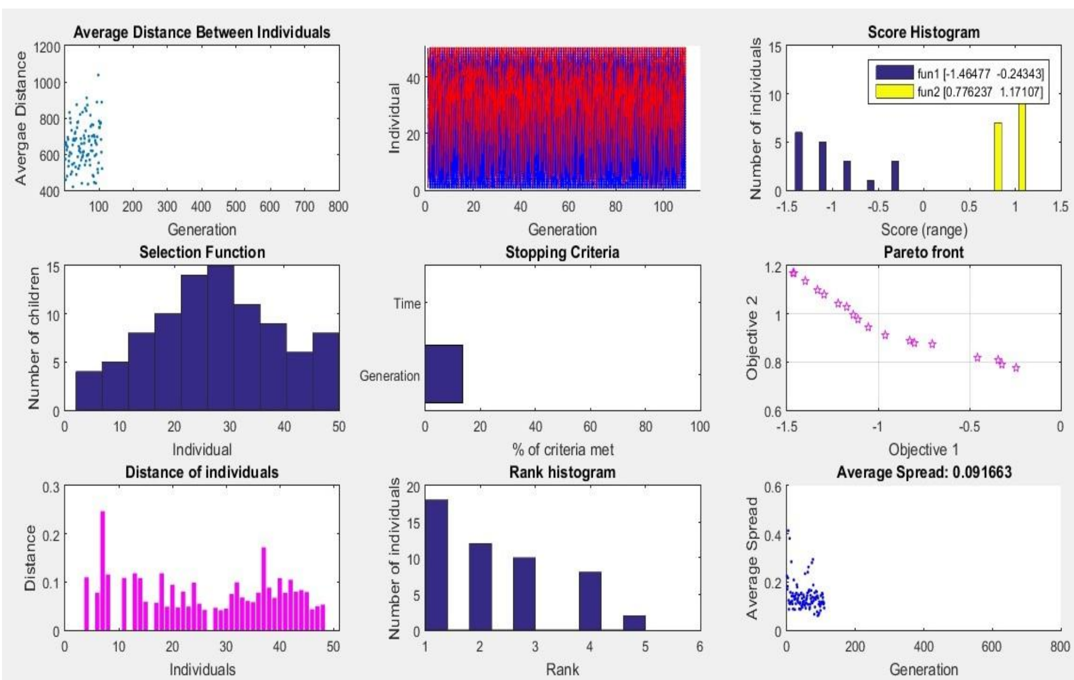
Similarly, According to experiment the result will be optimize by Whale's Optimization Algorithm and we get best and solution from the above data given in table no3

Best solution = The best solution will be analyze from WOA technique give in Table no11 .

Ip	V	Ton	Ib
15	45	3000	2

Best Solution for OC

Best job = 0.7512



V. CONCLUSIONS

The purpose of this paper is to validate and optimise the machining variables used in the EDM machining of D3 and EN24. The training, validation, and testing data suggest that the values of 'R' are almost one while evaluating the data using the Genetic Algorithm, WOA, Multi-Objective Optimization in order to obtain maximum MRR, decrease OC. This suggests that the outputs and targets have a precise relationship. The findings of EDM experiments on D3 tool steel show that current and pulse on time have a substantial impact on MRR and OC. MRR and OC have a direct relationship with pulse on time and current, although there is an inverse relationship with machining time.

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