

# Investigation on the Influence of Machining Parameters When Machining AISI P20 Nickel Tool Steel using EDM

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**ABSTRACT:** Electrical Discharge Machining (EDM) is one of the important non-traditional machining processes and it is widely accepted as a standard machining process in the manufacture of forming tools to produce molds and dies. Since its introduction to manufacturing industry in late 1940s, EDM became a well-known machining method. The method is based on removing material from a work piece by means of a series of repeated electrical discharges, produced by electric pulse generators at short intervals, between an electrode (tool) and a part being machined in dielectric fluid medium. This paper is devoted to a study of the influences of EDM Parameters on Material Removal Rate (MRR), Surface Roughness(SR), Electrode Wear Rate (EWR) for machining of AISI P20 nickel tool steel which is widely used in the production of plastic mold and die. The selected EDM parameters were discharge current (3, 5, and 7A), pulse ON time (2, 3, and 4 $\mu$ s) and pulse OFF time (3, 4 and 5 $\mu$ s). It was observed that Material Removal Rate, surface roughness of work piece and electrode were influenced by discharge current and pulse ON time, higher values of these parameters increased Material Removal Rate and surface roughness. Lower current, lower pulse time and relatively higher pulse pause time produced a better surface finish.

**KEYWORDS:** Electrical Discharge Machining, Material Removal Rate, Surface roughness, Electrode wear rate.

## I. INTRODUCTION

Electric discharge machining (EDM) is one of the most popular non-traditional material removal processes and has become a basic machining method for the manufacturing industries of aerospace, automotive, nuclear, medical and die-mold production. The theory of the process was established by two Soviet scientists B.R. and N.I. Lazarenko in the middle of 1940s. They invented the relaxation circuit and a simple servo controller tool that helped to maintain the gap width between the tool and the workpiece. This reduced arcing and made EDM machining more profitable and produced first EDM machine in 1950s. Major development of EDM was observed when computer numerical control systems were applied for the machine tool industry. Thus, the EDM process became automatic and unattended machining method [1]. The process uses thermal energy to generate heat that melts and vaporizes the workpiece by ionization within the dielectric medium. The electrical discharges generate impulsive pressure by dielectric explosion to remove the melted material. Thus, the amount of removed material can be effectively controlled to produce complex and precise machine components. However, the melted material is flushed away incompletely and the remaining material resolidifies to form discharge craters. As a result, machined surface has microcracks and pores caused by high

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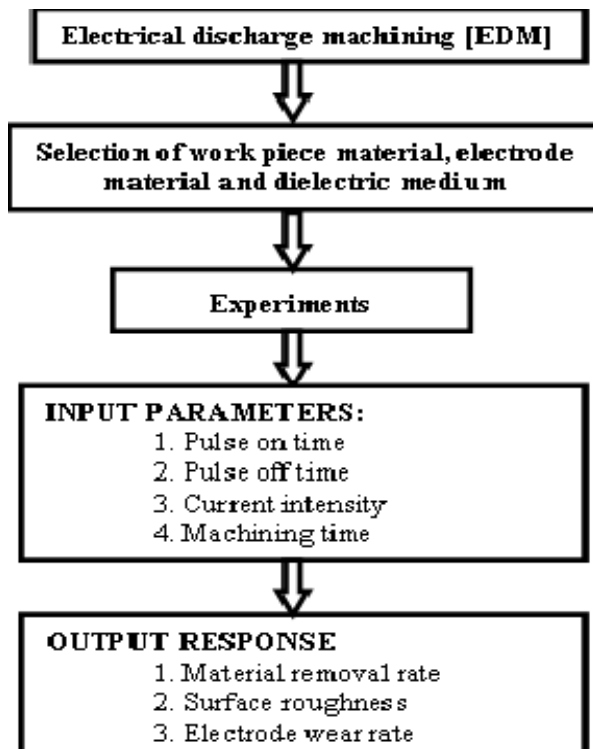
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temperature gradient which reduces surface finish quality. There have been many published studies considering surface finish of machined materials by EDM.

## II. RELATED WORK

It was noticed that various machining parameters influenced surface roughness and setting possible combination of these parameters was difficult to produce optimum surface quality. The influences of some machining parameters such as pulsed current [2–9], pulse time [2–6,8,9], pulse pause time [2,5,9], voltage [4,6], dielectric liquid pressure [4,6,8,10] and electrode material [11] have been examined. One study examined P20 tool steel and provided useful information the effects of some machining parameters on surface roughness, but the selected of pulsed current values was very low 1–8A [12]. The adequate selection of manufacturing conditions is one of the most important aspects to take into consideration in the die-sinking electrical discharge machining (EDM) of conductive steel, as these conditions are the ones that are to determine such important characteristics: surface roughness, electrode wear (EW) and material removal rate (MRR). In this paper, a study will be performing on the influence of the factors of peak current, pulse on time, interval time and power supply voltage [13]. EDM has become an indispensable process in the modern manufacturing. Materials of any hardness can be cut as long as the material can conduct electricity. Therefore, in the present era industries are looking for the low electrode wear and high surface finish and thereby improving the productivity. The aim of the studies reported on herein can be defined thus: The present work is focused to determine the best machining parameters such as material removal rate, surface roughness and electrode wear rate for machining AISI P20 nickel tool steel by EDM using suitable electrode and dielectric medium.

## III. METHODOLOGY



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## Selection of work piece

In this experiment AISI P20 nickel tool steel plates of size 22 x 22 x 14 mm are chosen for conducting the experiment. Tool steels are steels that are primarily used to make tools used in manufacturing processes as well as for machining metals, wood and plastics. In other words, tool steels are alloys designed to provide wear resistance and toughness combined with high strength. Tool steels are generally ingot-cast wrought products and must be able to withstand high specific loads as well as be stable at elevated temperatures. Typical applications are end mills, drills, lathe tools, planer tools, punches, reamers, routers, taps, saws. Tool steels have property of hot hardness.

## Selection of electrode material

In this experiment electrolytic copper 19 x 19 x 14 mm is used. It is a ductile metal with very high thermal and electrical conductivity. Pure copper is soft and malleable; a freshly exposed surface has a reddish orange color. It is used as a conductor of heat and electricity, a building material, and a constituent of various metal alloys.

## Input Parameters

The following are the input parameters or variables which influence the performance of the EDM process and their test values are as stated below

MACHINING PARAMETERS	symbol	Unit	Levels		
			Level 1	Level 2	Level 3
<b>Current Intensity</b>	I <sub>p</sub>	A	3	5	7
<b>Pulse On Time</b>	T <sub>on</sub>	μs	2	3	4
<b>pulse Off Time</b>	T <sub>off</sub>	μs	3	4	5

## Formula of MRR calculation

MRR is calculated as the proportion of the change of weight of the work piece before and after machining to the product of machining period and density of the material.

$$MRR = \frac{W_{bm} - W_{am}}{t \times \rho}$$

where:

W<sub>bm</sub> = Weight of work piece before machining.

W<sub>am</sub> = Weight of work piece after machining.

t = Machining period = 20 min.

ρ = Density of AISI P20 nickel tool steel work piece = 7.85g/m

## Formula of EWR calculation

Electrode Wear has been defined as the ratio of the wear weight of the electrode to the wear weight of the work piece after machining.

Electrode Wear Ratio,

$$(EWR) = \frac{\text{Wear Weight of Electrode}}{\text{Wear weight of work piece}} \times 100\%$$

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$$= \frac{E_{WB}-E_{WA}}{WP_{WB}-WP_{WA}}$$

where,

$E_{WB}$  = electrode before machining

$E_{WA}$  = electrode after machining

$WP_{WB}$  = work piece before machining

$WP_{WA}$  = work piece after machining

Experimental set up:

The whole experiment was conducted on Electrical Discharge Machine which is a die sinking type EDM machine of model ELECTRONICA -ELECTRAPLUS PS 50ZNC. The operating voltage is set as 40V. The polarity of work piece is set as positive (anode) and electrode as negative (cathode). EDM oil is taken as dielectric fluid. Dr. Genichi Taguchi's approach or DOE is highly effective wherever and whenever it is suspected that the performance of a part or process is controlled by more than one factor. The main purpose is to give a clear understanding to make the DOE technique more effective in applications, and how to relate the outcome of the technique to improve the quality of products and processes. AISI P20 nickel tool steel material plates of 22 x 22 x14 mm size were machined using die-sinking type PS50 ZNC EDM machine (figure 3.6). Marketable grade EDM oil (specific gravity= 0.763, freezing point= 94°C) was used as dielectric liquid. Side flushing with nozzle was used to flush away the eroded materials from the sparking zone. 27 plates were machined for various combinations of input parameters. The weight of the material removed was calculated by using electronic weight balance machine. The range of the machine is up to 300 g with a resolution of 0.001 g.

## IV. RESULTS AND DISCUSSIONS

The EDM is carried for 27 set of varied input parameters with the copper electrode. Among the 27 runs of machining for Run number 2 the Surface roughness is minimum (2.166  $\mu\text{m}$ ), for Run number 5 the Electrode wear Ratio is minimum (7.57%) and for Run number 25 the Material Removal rate is maximum (0.0407  $\text{mm}^3/\text{min}$ ). The output parameters for the three runs 2, 5 and 25 are (0.0259  $\text{mm}^3/\text{min}$ , 2.166 $\mu\text{m}$ , 46.71%), (0.0361  $\text{mm}^3/\text{min}$ , 2.352 $\mu\text{m}$ , 7.75%) and (0.0407  $\text{mm}^3/\text{min}$ , 3.069 $\mu\text{m}$ , 87.67%) respectively. From the above stated results, the parameters for Run No. 5 has the high material removal rate, low surface roughness and electrode wear rate. So the workpiece 5 has been optimized from the conducted experiments. From the experimental data collected, the effects or influence of machining parameters, i.e. discharge current ( $I_p$ ), pulse on time ( $T_{on}$ ) and pulse off time ( $T_{off}$ ) on Material Removal Rate (MRR), Surface Roughness (SR), Electrode Wear Rate (EWR) when machining AISI P20 nickel tool steel work piece with electrolytic copper electrode were analyzed using Design of Experiments to find out the most influencing parameter. From the tabulated results the following graphs are plotted.

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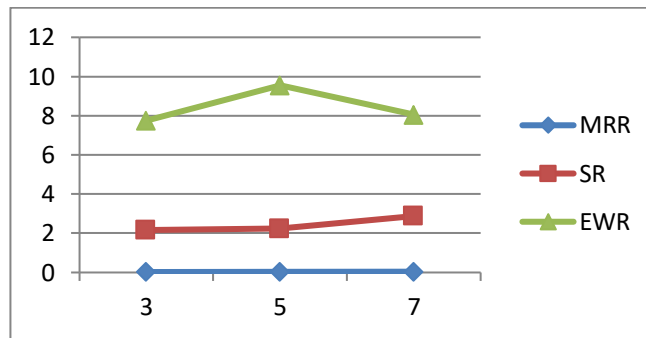


Fig.1: Discharge current vs MRR, SR and EWR

The graph in fig.4.1 is the plot of discharge current ( $I_p$ ) versus MRR, SR, EWR from which it is understandable that the metal removal rate increases, reaches a peak value and again declines. Also it is clear that when the discharge current is increased, the surface roughness increases gradually. Also it can be predicted from the graph that an increase in discharge current, increases the electrode wear ratio.

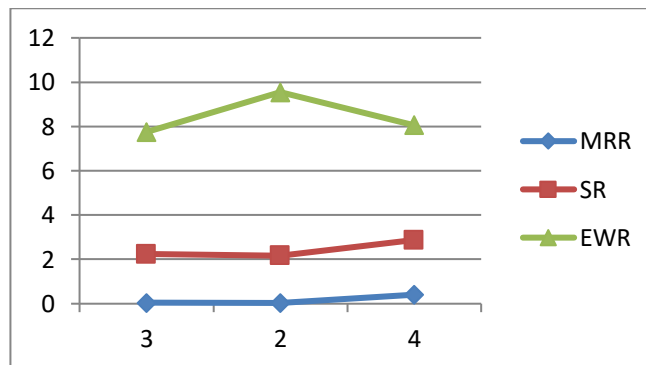


Fig.2: Pulse on time vs MRR, SR, EWR

When pulse on time is increased, the material removal rate increases. When pulse on time is increased, the SR will also increase. When pulse on time is increased, the EWR is initially increases and then decreases.

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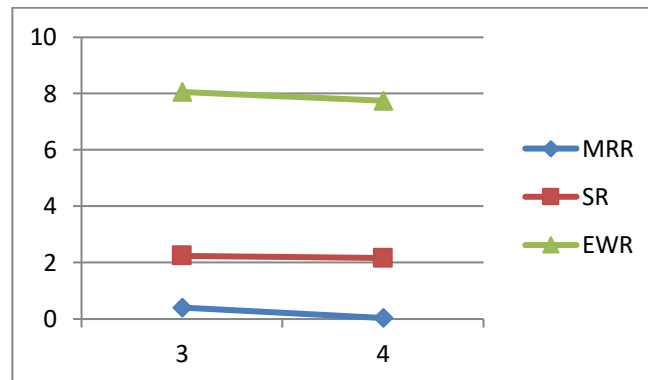


Fig.3: pulse off time (Toff) vs MRR, SR, EWR

When pulse off time is increased, the MRR, SR and EWR are decreased. From the experimental result at the following parameters values, high material removal rate of 0.0407 mm<sup>3</sup>/min achieved when, discharge current I<sub>p</sub> (7), pulse on time T<sub>on</sub> (4), pulse off time T<sub>off</sub> (3) and machining time 20 mins. From the experimental result at the following parameters values, low surface roughness of 2.166 μm achieved when, discharge current I<sub>p</sub> (3), pulse on time T<sub>on</sub> (2), pulse off time T<sub>off</sub> (4) and machining time 20 mins. From the experimental result at the following parameters values, low electrode wear ratio of 7.75 mm<sup>3</sup>/min achieved when, discharge current I<sub>p</sub> (3), pulse on time T<sub>on</sub> (3), pulse off time T<sub>off</sub> (3) and machining time 20 mins.

### Material characterization of machined workpiece:

#### X-Ray Diffraction(XRD):

X-Ray Diffraction (XRD) is used to analyze the phase composition of the machined work piece for any changes in phase composition happened due to machining. X-Ray Diffraction studies are applied to Nanocrystalline materials not only in the form of metals and alloys but also to drugs, minerals, organics, inorganics, ceramics, zeolites and catalysts. The XRD test results for material characterization values of P20 Nickel Tool Steel obtained from the standard values.

#### Phase composition of AISI P20 nickel tool steel

Composition	Min %	Max %
C	0.35	0.45
Mn	1.30	1.60
P	-	0.030
S	-	0.030
Si	0.20	0.40
Cr	1.80	2.10
Mo	0.15	0.25
Ni	0.90	1.20

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### *Scanning Electron Microscope (SEM):*

Material characterization is to be done using SEM in order to analyze the Heat Affected Zone(HAZ) and microstructure of the work piece. SEM can be used in metallurgical studies: surface topography of fracture metals, corroded specimens, polished surface. During SEM there are three layers can be formed: Re-cast layer, Heat Affected Zone, Converted Zone or Converted layer. The SEM images of machined specimen are shown in the following figures.

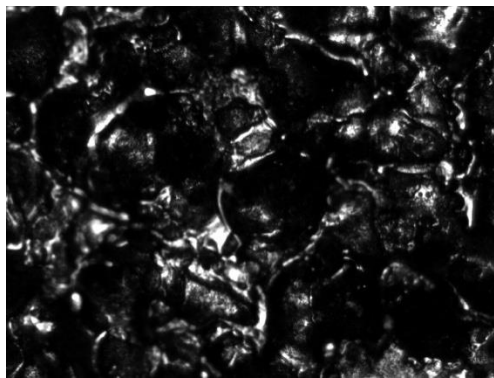


Fig.4 work piece 2 (MRR=0.0259 mm<sup>3</sup>/min, SR= 2.166(μm), EWR= 46.71 mm<sup>3</sup>/min)

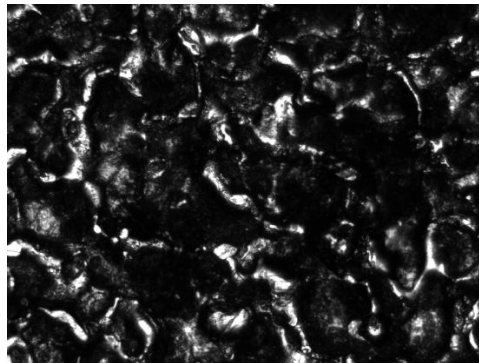


Fig.5 work piece 5 (MRR=0.0361 mm<sup>3</sup>/min, SR= 2.352(μm), EWR= 7.75 mm<sup>3</sup>/min)

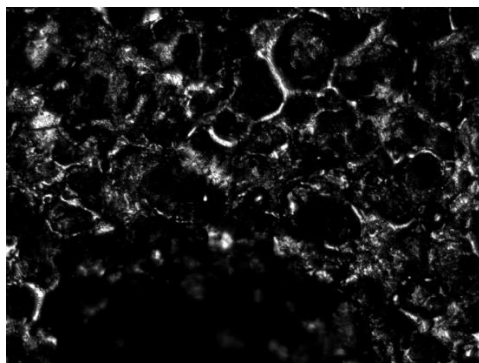


Fig.6 work piece 25 (MRR=0.0407 mm<sup>3</sup>/min, SR= 3.069(μm), EWR= 87.67 mm<sup>3</sup>/min)

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## V. CONCLUSION

AISI P20 nickel tool steel plates were machined using Electric Discharge Machining (die sinking type) using electrolytic copper as electrode with the aim to find out Material Removal Rate, Surface Roughness and electrode wear ratio and the effects of the input variables on these characteristics. Discharge current ( $I_p$ ), Pulse On time ( $T_{on}$ ) and Pulse Off time ( $T_{off}$ ) are the input variable parameters. Based on analysis of the experimental data the following conclusions were drawn:

The MRR ( $\text{mm}^3/\text{min}$ ), SR ( $\mu\text{m}$ ) and EWR values for different work pieces of Run Nos.2, 5 and 25 are (0.0259, 2.166, 46.71), (0.0361, 2.352, 7.75) and (0.0407, 3.069, 87.67) respectively. Though MRR for specimen 25 is more comparison of SEM images of Specimen 2, 5 and 25 reveals that for the specimen 25 more craters are found which is because of non-uniform distribution of heat. For other specimens the micro-cracks and porous nature are not vivid. From the stated results, the parameters for Run No. 5 has the optimum values and the optimal performance parameters for Electro Discharge Machining of AISI P20 nickel tool steel with copper electrode are at a discharge current rate of 3A, pulse ON time  $3\mu\text{s}$  and pulse OFF time  $4\mu\text{s}$ .

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