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Investigation And Optimization Of EDM Process Of AISI 4140 Alloy Steel Using Various Tool Electrodes: A Review Paper

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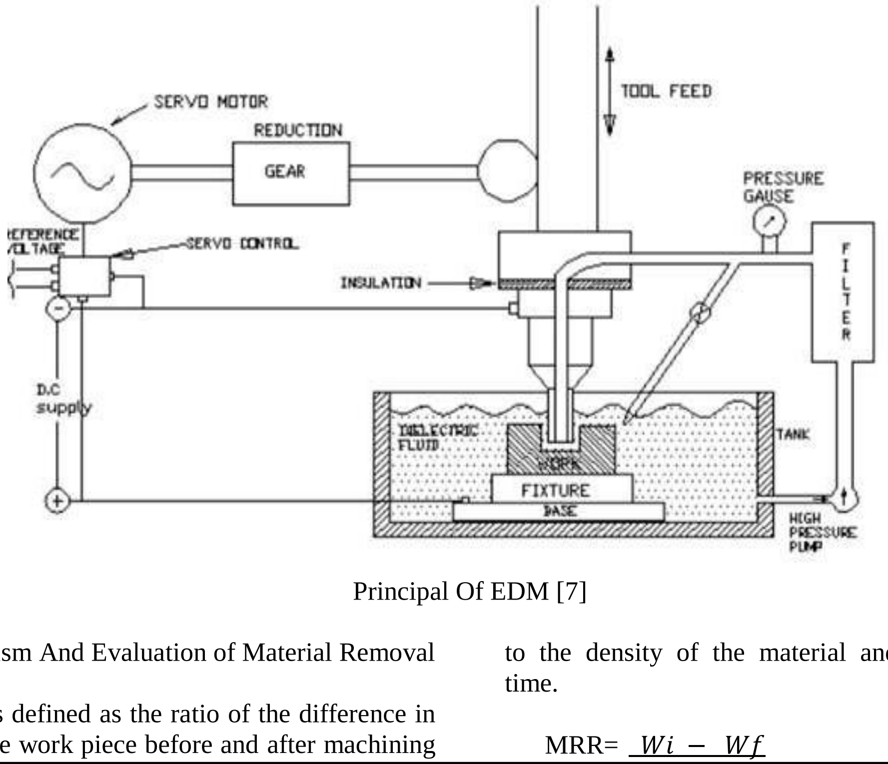
ABSTRACT
The purpose of this research work is to determine the optimized settings of key machining factors like pulse on time, discharge current and duty cycle for AISI 4140 alloy steel using various tool electrodes. The output responses will be measured are material removal rate (MRR),surface roughness(SR) and tool wear rate(TWR). Mathematical models are proposed for the above are L27 orthogonal array. The micro structural changes in the work piece after machining process will also be examined by the use of SEM.
***Keywords* -** Electrical Discharge Machine, Material Removal Rate, Scanning Electrode Microscope, Surface Roughness, Tool Wear Rate.

I. INTRODUCTION

Electrical Discharge Machining (EDM) is a unconventional manufacturing process based on removal of material from a part by means of a series of repeated electrical sparks created by electric pulse generators at short intervals between a electrode tool and the part to be machined immersed in dielectric fluid [18]. At present, EDM is a widespread technique used in industry for high precision machining of all types of conductive materials such as metallic alloys, metals, graphite, composite materials or some ceramic material. The selection of optimized manufacturing conditions is one of the most important aspects to consider 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). Taguchi Orthogonal Array technique to select the optimum machining conditions for machining AISI 4140 alloy steel using EDM.



Principal Of EDM [7]

A. Mechanism And Evaluation of Material Removal Rate -
The MRR is defined as the ratio of the difference in weight of the work piece before and after machining to the density of the material and the machining time.

MRR= $\underline{Wi - Wf}$

T* ρ

Where
W i = initial weight before machining
Wf = final weight after machining
T = machining time
ρ is the density

B. Mechanism And Evaluation of Tool Removal Rate-

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time. it is written as -

$$TWR = \frac{Wtb - Wtb}{T}$$

Wtb = weight of tool before machining
Wta = weight of tool after machining
T =Machining time

C. Mechanism and Evaluation of Surface Roughness

Surface Roughness is the measure of the texture of the surface. It is measured in µm. If the value is high then the surface is rough and if low then the surface is smooth. It is denoted by Ra.

D. Scanning Electron Microscope

A scanning Electron Microscope produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition.

II. AISI 4140 Alloy Steel -

AISI 4140 alloy steel is chromium, molybdenum, manganese, containing low alloy steel. It has high fatigue strength, abrasion and impact resistance, toughness, and torsional strength. The following table shows the chemical composition of AISI 4140 alloy steel,

Element	Content (%)
Iron, Fe	96.785 - 97.77
Chromium, Cr	0.80 - 1.10
Carbon, C	0.380 - 0.430
Silicon, Si	0.15 - 0.30
Molybdenum, Mo	0.15 - 0.25
Sulfur, S	0.040
Phosphorous, P	0.035
Manganese	0.75 - 1.0

Applications of AIS140I

Axles, conveyor parts, crow bars, gears, logging parts, spindles, shafts, sprockets, studs, pinions, pump shafts, rams, ring gears etc.

Tool Electrode Materials -

The electrode materials for optimization of AISI 4140 Alloy steel will be used are copper-tungsten electrode and Graphite electrode. Copper Tungsten (CuW) is a powder metal product designed to combine the best EDM properties of Copper and Tungsten. Copper Tungsten combines the high electrical conductivity of copper with the high melting point of tungsten. The combination of these two metals creates an electrode material with very good wear properties.

Graphite is the preferred electrode material for most of sinker EDM applications. Graphite has significantly lower mechanical strength properties than metallic electrode materials. It is neither as hard, as strong, nor as stiff as metallic electrode materials. Graphite is widely used due to its significant production advantages over metallic electrode materials. Graphite is faster than Copper in both roughing and finishing, usually by a factor of 2:1. Graphite usually wears less than Copper. With advances in dielectric, power supply electronics, and orbiting, achievable graphite finishes match those formerly only attainable with Copper. Graphite machines and grinds an order of magnitude faster than Copper, and can also have more detail easily machined into it. Graphite doesn't have to be de-burred like any metallic does, further reducing electrode fabrication costs.

Design Of Experiment -

The experimental work consist of formulation of L-27 Orthogonal array based on Taguchi Design, Orthogonal array reduces the total number of experiment, and has high degree of accuracy'

LITERATURE REVIEW

Vishwakarma et al., 2012 carried out results on AISI 4140 alloy steel considering following parameters.

Parameters	Range
Discharge current (I)	0-19/35/49 Amp
Pulse - On - Time (ton)	1-99 µs
Flushing Pressure	0-10 kg/cm2
Duty Cycle	1-9
Gap Voltage	1-20 volts

Voltage, spark gap and capacitance were constant, With analysis, it was observed that, with increase in voltage, the MRR also increases. This occurs because of the energy discharge from the electrode increases with increase in voltage. With increase in discharge energy, higher temperatures are generated between the electrodes. This results higher in MRR. The capacitance was also an influencing parameter in EDM.To study the effect in capacitance, other two parameters such as voltage and spark gap were kept constant. This is another scope for further study and analysis in EDM research. *Iqbal and Khan(2011)* concluded that the voltage and rotational speed of the electrode are the two significant parameters for EDM milling.

Puertas et al. (2004) showed that the intensity and pulse time factor were the most important in case of Surface Roughness while the duty cycle factor was not significant at all. The intensity factor was again influential in case of Tool Wear Rate. The important factors in case of MRR were the intensity followed by duty cycle and the pulse time. *Singh and Mehashwari(2004)* found that the input parameters such as current, pulse on time , voltage and work piece material quality influence overcut. It increases with the increase with the increase of current but only upto a certain limit. *Annamalai et al.(2009*) worked on RSM. They showed that increase in peak current increases the material removal rate significantly. The increase in pulse on time increases the material removal rate whereas there is no much impact when pulse off time is increased. The surface roughness values in μm increases when there is increase in peak current. When the pulse on time increases the roughness average values also increases. So for better surface finish the pulse on time must be optimum. There is no change in Ra value when the pulse off time was increased.

*Lingadurai et al. (2012***)** proved that applied voltage mainly affects Material Removal Rate. Wire feed rate and pulse on time mainly affects surface Roughness and kerf width respectively. *Choudhary(2012***)** revealed that the thickness of recast layer of the AISI D3 steel increases with the increase in gap current and with the percentage of SiC in copper matrix. *Rahman et al(2011)* investigated the effect of the peak current and pulse duration on the performance characteristics of EDM. M.M Rahman showed that the current and pulse on time greatly affected the Material Removal Rate , Tool Wear Rate and the Surface Roughness, the MRR increases almost linearly with the increasing current, the Tool Wear Rate increases peak current and decreased with increase in pulse on time, and Surface Roughness increases linearly with current for different pulse on time. *Pradhan et al.(2012)* found that the pulse duration is the most dominant factor for surface integrity followed by duty factor , pulse current , and discharge current. A hybrid optimization approach was used for the estimation of minimal surface integrity of surface created in electrical discharge machining (EDM). A new combination, response surface methodology coupled with the -grey relational analysis method has been proposed and used to optimize the machining parameters of EDM. The significant input parameters such as pulse current (Ip), pulse duration (Ton), duty cycle (Tau) and discharge voltage (V) were considered, and white layer thickness, surface roughness, and surface crack density have been considered as responses for this study. *Grey Rational Analysis* GRA is a decision-making technique based on grey system theory originally developed by Deng .In grey theory, black represents a system with deficient information, while a white system stands for complete information. *Hassan et al.(*2009**)**worked on Wire Electrical Discharge machine. Wire Electro Discharge Machining (WEDM) is one of the application of EDM. This machine uses a thin brass wire as the electrode, making it possible to cut most shapes and contour from flat plate material. *Hassan et al.(2009)* showed that SEM can be successfully applied to obtain a two dimensional scale in WEDM .A Sample of 40 x 40 mm^2 strip was mounted rigidly on the specimen holder called a specimen stub. The sample was placed in a small chamber which was at vacuum column through an air-tight door. Before that, all water, solvents or other materials that could vaporize while in the vacuum was removed. When a SEM was used, the column must was at vacuum. if sample in a gas filled environment, an electron beam cannot be generated or maintained because of a high instability in the beam. The final image is built up from the number of electrons emitted from each spot on the sample. *Hassan et al.(2009)* also proved that pulse on duration has major influence in defining the WEDM surface texture as compared to the pulsed current. This can be attributed to the fact that as the pulsed current decreases, discharges strike the surface of the sample less intensely, and the resulting better erosion effect leads to smoother surface. Furthermore, as the pulse-on duration decreases, the amount of heat energy transferred to the sample surface decreases, and so less material melts. The fact that the surface roughness decreases with decreasing discharge energy.

CONCLUSION-

The analysis in this area over past few decades reveals that EDM performance is generally evaluated on the basis of Material Removal Rate, Tool Wear Rate and Surface Roughness. The performance of work - piece and Tool Electrode is affected by discharge current, pulse on time, pulse off time, flushing pressure, duty cycle, wire feed and voltage. The review paper evaluates the areas and subareas where optimization technique have been employed. It also works on identifying parameters for optimization and suitable techniques for EDM mechanism.

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