Process Parameter Optimization of WEDM Using Maraging Steels

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Abstract - *Accompanying the development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. Wire EDM machines are used to cut conductive metals of any hardness or that are difficult or impossible to cut with traditional methods. The machines also specialize in cutting complex contours or fragile geometries that would be difficult to be produced using conventional cutting methods. Machine tool industry has made exponential growth in its manufacturing capabilities in last decade but still machine tools are not utilized at their full potential. This limitation is a result of the failure to run the machine tools at their optimum operating conditions. The problem of arriving at the optimum levels of the operating parameters has attracted the attention of the researchers and practicing engineers for a very long time. The objective of the present work was to investigate the effects of the various WEDM process parameters on the machining quality and to obtain the optimal sets of process parameters so that the quality of machined parts can be optimized. The working ranges and levels of the WEDM process parameters are found using one factor at a time approach. The Taguchi technique has been used to investigate the effects of the WEDM process parameters and subsequently to predict sets of optimal parameters for optimum quality characteristics. The response surface methodology (RSM) in conjunction with second order central composite rotatable design has been used to develop the empirical models for response characteristics. Desirability functions have been used for simultaneous optimization of performance measures. Also, the Taguchi technique and utility function have been used for multi- response optimization. Confirmation experiments are further conducted to validate the results.*

***Key Words*: WEDM – Wire Cut Electric Discharge Machining**

1. INTRODUCTION

Accompanying the development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. Nevertheless, such materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining, electrical discharging machine (EDM) etc. are applied to machine such difficult to machine materials. WEDM process with a thin wire as an electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials can be machined irrespective to their hardness and toughness. Furthermore, WEDM is capable of producing a fine, precise, corrosion and wear resistant surface.

WEDM is considered as a unique adoption of the conventional EDM process, which uses an electrode to initialize the sparking process. However, WEDM utilizes a continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm, which is capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining.

1.1 Manufacturing

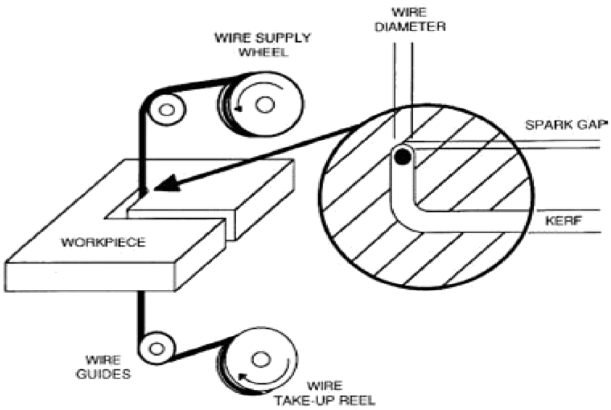
Wire electrical discharge machining (WEDM) technology has grown tremendously since it was first applied more than 30 years ago. In 1974, D.H. Dulebohn applied the optical-line follower system to automatically control the shape of the components to be machined by the WEDM process. By 1975, its popularity rapidly increased, as the process and its capabilities were better understood by the industry. It was only towards the end of the 1970s, when computer numerical control (CNC) system was initiated into WEDM, which brought about a major evolution of the machining process (Ho et. al., 2004).

Its broad capabilities have allowed it to encompass the production, aerospace and automotive industries and virtually all areas of conductive material machining. This is because WEDM provides the best alternative or sometimes the only alternative for machining conductive, exotic, high strength and temperature resistive materials, conductive engineering ceramics with the scope of generating intricate shapes and profiles (Kozak et.al., 2004 and Lok and Lee, 1997).

WEDM has tremendous potential in its applicability in the present-day metal cutting industry for achieving a considerable dimensional accuracy, surface finish and contour generation features of products or parts. Moreover, the cost of wire contributes only 10% of operating cost of WEDM process. The difficulties encountered in the die sinking EDM are avoided by WEDM, because complex design tool is replaced by moving conductive wire and relative movement of wire guides.

1.2 Principle of WEDM Process

The WEDM machine tool comprises of a main worktable (X-Y) on which the work piece is clamped; an auxiliary table (U-V) and wire drive mechanism. The main table moves along X and Y-axis and it is driven by the D.C servo motors. The travelling wire is continuously fed from wire feed spool and collected on take up spool which moves though the work piece and is supported under tension between a pair of wire guides located at the opposite sides of the work piece. The lower wire guide is stationary where as the upper wire guide, supported by the U-V table, can be displaced transversely along U and V-axis with respect to lower wire guide. The upper wire guide can also be positioned vertically along Z-axis by moving the quill.



A series of electrical pulses generated by the pulse generator unit is applied between the work piece and the travelling wire electrode, to cause the electro erosion of the work piece material. As the process proceeds, the X-Y controller displaces the worktable carrying the work piece transversely along a predetermined path programmed in the controller. While the machining operation is continuous, the machining zone is continuously flushed with water passing through the nozzle on both sides of work piece. Since water is used as a dielectric medium, it is very important that water does not ionize. Therefore, in order to prevent the ionization of water, an ion exchange resin is used in the dielectric distribution system to maintain the conductivity of water. In order to produce taper machining, the wire electrode has to be tilted. This is achieved by displacing the upper wire guide (along U-V axis) with respect to the lower wire guide. The desired taper angle is achieved by simultaneous control of the movement of X-Y table and U-V table along their respective predetermined paths stored in the controller. The path information of X-Y table and U-V table is given to the controller in terms of linear and circular elements via NC program. Figure 1.1 exhibits the schematic diagram of the basic principle of WEDM process (Saha et. al., 2004).

2. EFFECT ON SURFACE ROUGHNESS

In order to see the effects of process parameters on the surface roughness, experiments were conducted using L_{27} OA Table. The experimental data are given in Table. The average values of surface roughness for each parameter at levels 1, 2, and 3 for raw data and S/N data are plotted in Figures.

Table -1: Response Table for Cutting time(S/N Data)

Level	Ton	Toff	SV	IP
1	-9.1020	2.1166	-0.3168	-6.2837
2	-1.0344	-2.8373	-2.1612	-1.2522
3	2.3375	-7.0781	-7.0781	-0.2630
Delta	11.4395	9.1947	5.0040	6.0208
Rank	1	2	4	3

Table -1: Response Table for Cutting time (RAW Data)

Level	Ton	Toff	SV	IP
1	0.4015	1.5670	1.2796	0.5878
2	1.0822	0.8863	0.9944	1.1393
3	1.5485	0.5789	0.7581	1.3052
Delta	1.1470	0.9881	0.5215	0.7174
Rank	1	2	4	3

It is seen from the Figures that surface roughness increases with the increase of pulse on time, and peak current and decreases with increase in pulse off time, spark gap set voltage, and wire feed. The discharge energy increases with the pulse on time and peak current and larger discharge energy produces a larger crater, causing a larger surface roughness value on the work piece. As the pulse off time decreases, the number of discharges increases which causes poor surface accuracy. With increase in spark gap set voltage the average discharge gap gets widened resulting into better surface accuracy due to stable machining .The effects of wire tension are not very significant. It is noticed from Figures 5.9 and 5.10 that there is a slight interaction between pulse off time and spark gap set voltage while there is very weak interaction between all the other process parameters in affecting the surface roughness since the responses at different levels of process parameters for a given level of parameter value are almost parallel. Residual plots do not show any problem in the distribution of the data and model assumptions.

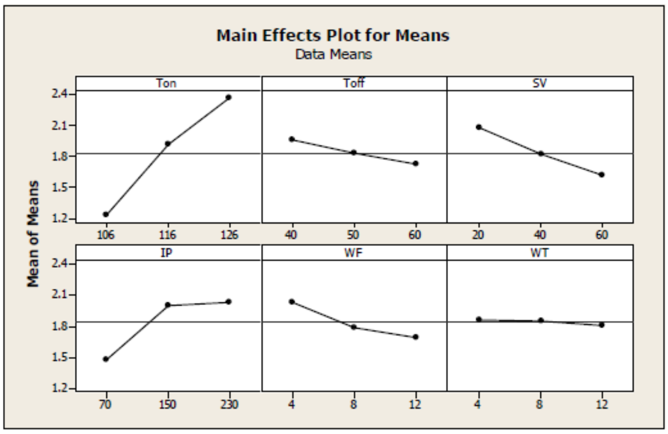


Figure 1: Effects of Process Parameters on Surface Roughness (Raw Data)

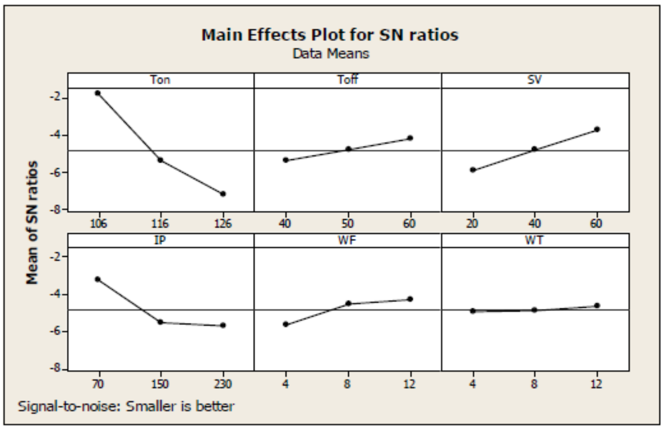


Figure 2: Effects of Process Parameters on Surface Roughness (S/N Data)

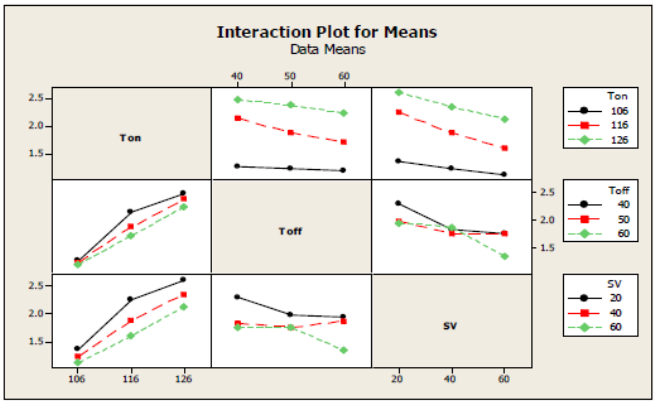


Figure 3: Effects of Process Parameters Interactions on Surface Roughness (Raw Data).

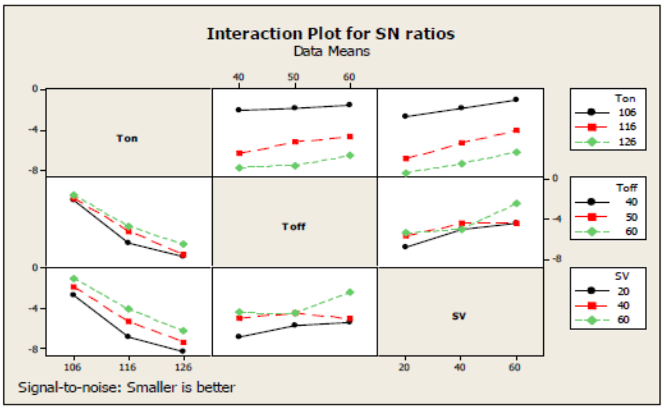


Figure 4: Effects of Process Parameters Interactions on Surface Roughness (S/N Data)

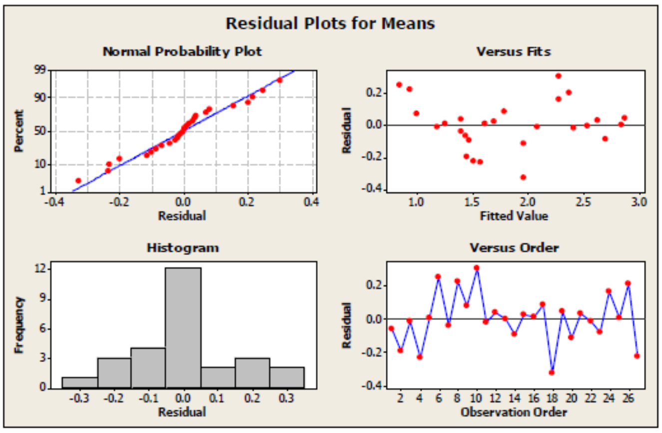


Figure 5: Residual Plots for Surface Roughness (Raw Data)

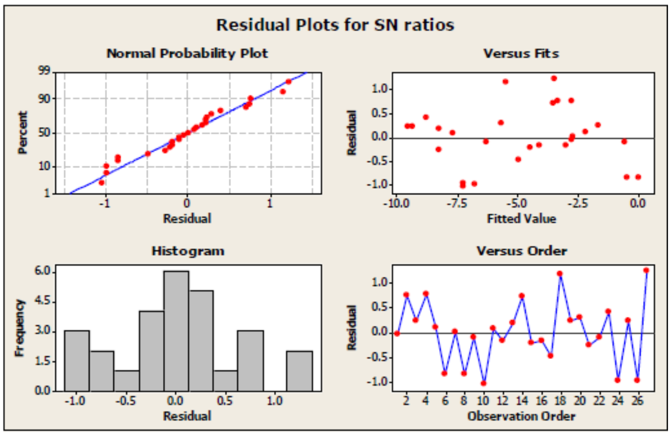


Figure 6.15: Residual Plots for Surface Roughness (S/N Data)

3. CONCLUSIONS

In this experiment, the focused study has been performed to detect various input forms which are necessary to perform an optimal job in WEDM. This study has termed a few parameters aforementioned relating the possibilities towards enhanced output from machining processes - which indirectly means the efficient consumption of power supply, and materialistic input being transformed to desired output. The TAGUCHI method – stands a logical sense to be used for comparing a range of iterations while performing the experiment and then retrieving out the faulty and unwanted manufacturing processes, which will lead to elimination of those futile processes and recovering some lead time loss and saving the net power consumed for the whole project by a considerable margin.

- Development of experimental set up providing varying range of input parameters in WEDM and measuring the various responses on-line and off-line
- Investigation of the working ranges and the levels of the WEDM process parameters (pilot experiments) affecting the selected quality characteristics, by using one factor at a time approach
- Investigation of the effects of WEDM process parameters on quality characteristics viz. cutting rate, surface roughness, gap current and dimensional deviation while machining Maraging 250 Optimization of quality characteristics of machined parts:
    - Prediction of optimal sets of WEDM process parameters
    - Prediction of optimal values of quality characteristics
    - Prediction of confidence interval (95%CI)
    - Experimental verification of optimized individual quality characteristics was done.

The Taguchi‟s parameter design approach used to obtain the above objectives successfully with help of minitab.

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