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Analysis of Machining Parameters in W-EDM for Inconel material Using Taguchi Method

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Abstract— *Productivity and quality are two important aspects have become great concerns in today's competitive global market. Every production/manufacturing unit mainly focuses on these areas in relation to the process as well as product developed. Electrical discharge machining (EDM) process, even now it is an experience process, wherein still these selected parameters are often far from the maximum, and at the same time selecting optimization parameters is costly and time consuming. Material Removal Rate (MRR) during the process has been considered as productivity estimate with the aim to maximize it. With an intention of minimizing surface roughness is been taken as most important output parameter. These two opposite in nature requirements have been simultaneously satisfied by selecting an optimal process environment (optimal parameter setting). Objective function is obtained by Regression Analysis and Analysis of Variance. Then objective function is optimized using Taguchi Grey Relational Analysis. The model is shown to be effective; MRR and Surface Roughness improved using optimized machining parameters.*

Keywords— ***Analysis of Variance; Electrical discharge machining (EDM Material removal rate (MRR); Taguchi, Surface roughness; Regression analysis.***

I. INTRODUCTION

1.1 Wire Electrical Discharge Machining Process:

Wire Electrical Discharge Machining (W-EDM) is widely used manufacturing process used to machine conductive materials due to its capability of producing intricate and complex shapes irrespective of hardness and toughness of material. It can produce more complex two and three dimensional shapes through conducting materials This process is extensively used in mould and die making industries, nuclear industry, aerospace industry etc. .

In WEDM (wire electrical discharge machining) material removal takes place due to electro thermal process. A series of electrical pulses generated by pulse generator unit is applied between the work piece and travelling wire electrode which generate series of discrete sparks between the electrode and work piece. While the machining is continued, the machining zone is continuously flushed with water passing through the nozzles on both sides of the work piece.

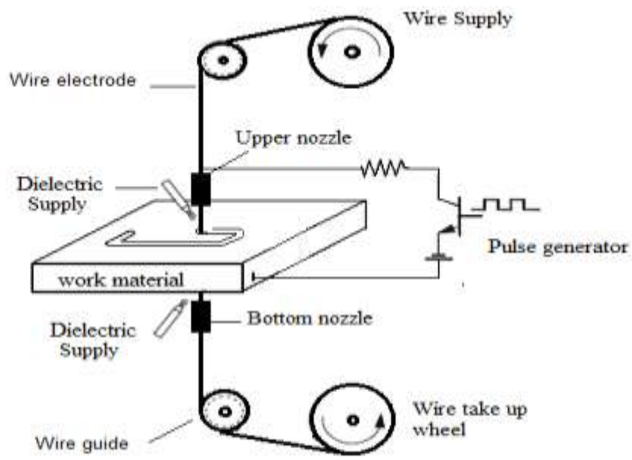

Fig 1.1: Schematic Representation of WEDM process

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II. PROBLEM DEFINITION:

In CNC Wire electrical discharge machine, Process parameters like pulse on time(Ton), pulse off time(Toff), Input Current(Ip), wire feed rate(Wf) play an important role as it affects the MRR (material removal rate) and Surface roughness. Most of the times this machines are operated by workers; If process parameters are not set properly then it results in low MRR as well as Surface finish. If at some point amount of stock removed from the electrode becomes greater than the amount being removed from the work piece, the wire electrode breaks and discharge is stopped. The overall objective is to produce high quality product at low cost to the manufacturer. Optimization is a process that finds a best, or optimal, solution for a problem of process parameters is the best way to solve this problem. Taguchi L9 Orthogonal array and Taguchi method used to set optimal set of parameters.

III. METHODOLOGY

3.1 Design of Experiment:

The design of experiments (or experimental design) is the design of any task that aims to describe or explain the variation of information under conditions that are hypothesized to reflect the variation. The term is generally associated with true experiments in which the design introduces conditions that directly affect the variation, but may also refer to the design of quasi-experiments, in which natural conditions that influence the variation are selected for observation.

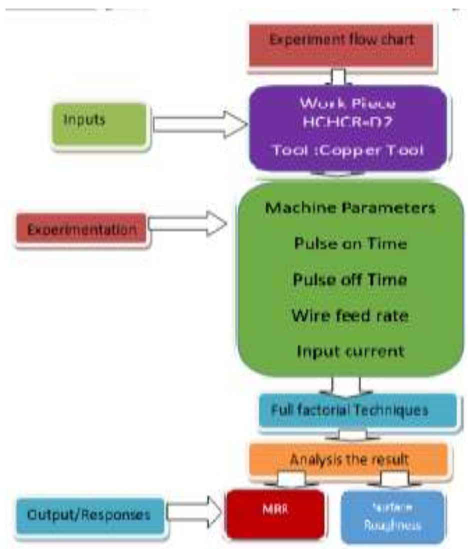

Fig :3.1 Methodology Flow Chart

3.2 Work piece Material:

The work piece material is Inconel with dimension (Diameter 40mm, Thickness 26mm, weight 230gm) is used for experimentation. The Brass wire with diameter 0.25mm is used as electrode. Pure distilled water is used as dielectric medium. Fig. 4.2 shows actual working zone of WEDM and Table 3.2 shows the Percentage of Composition of Inconel

Table 3.1
Shows the Percentage of Composition of Inconel

C	Mn	Cr	Si
2	0.2-0.35	12	0.2-0.35

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3.3 ELECTRA Wire Cut Electric Discharge Machine:

ELECTRA Wire Cut Electric Discharge Machine (Manufactured by Electronica Machines Tools Ltd) is used in this investigation. Once wire is wound on the wire drum, that particular amount of wire is used for all experiments of each material and it has been replaced once the material is changed. Work material is tightly clamped on working table with the help of suitable fixture so as to avoid any relative motion between the work piece and electrode. Constant dielectric flow is ensured during the experimentation.Fig.3 shows the CNC WEDM machine used for experimentation.

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Fig.3.2 Work piece

Fig.3.3: Working zone of Wire electrical discharge machining

IV. CASE STUDY

In experimental study 8mm hole is created in the work piece with brass wire. MRR (material removal rate) is calculated by measuring the difference in weight of work piece before and after machining and time required to create a through hole. Surface roughness (Ra) is calculated by MITUTOYO Surface Tester Master.

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4.1 Taguchi L9 Orthogonal Array:

Table 4.1 shows process parameters with their level for this experiment. The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer.

Table 4.1
Process parameters with their levels.

Sr. No	Process Parameters	Unit	Level 1	Level 2	Level 3
1	Pulse on time(Ton)	µs	127	128	129
2	Pulse off time(Toff)	µs	45	46	47
3	Input current(Ip)	A	210	220	230
4	Wire feed(Wf)	m/min	3	4	5

Taguchi Proposed to acquire the characteristics data by using orthogonal arrays, and to analyse the performance measure from data to decide the optimal process parameters. The designed matrix of input parameters with output parameters such as MRR (material removal rate) and Surface roughness (Ra) for HCHCR-D2 (High carbon high chromium steel) shown in table 5.4. Selection of a particular OA is based on the number of levels of various factors. Here, Number of levels (L)=3 and No of factors(f)=4 therefore Degree of Freedom (DOF) can be calculated by using Eq. as DOF = f x (L-1) =8,the orthogonal array should be equal to or greater than DOF ,here 9>8 hence L9. Each machining parameter is assigned to a column of OA and 9 machining parameter combinations are designed.

Table 4.2
L9 orthogonal Array

Trial No	Ton	Toff	Ip	Wf	MRR (gm/min)	Ra(µm)
1	127	45	210	3	0.66	1.9
2	127	46	220	4	0.92	2.1
3	127	47	230	5	1	2.7
4	128	45	220	5	0.66	1.8
5	128	46	230	3	1.06	1.9
6	128	47	210	4	0.82	1.3
7	129	45	230	4	1.12	1.4
8	129	46	210	5	0.82	1.8
9	129	47	220	3	1.12	1.5

4.2 Design of experiment using Full factorial

Full factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental unit take on all possible combinations of these levels across all such factors. A full factorial design also called as a fully crossed design. Such an experiment allows the examiner to study the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable. In the experiment using four factors and each are three levels then total number of trials to be showed is 9.

In this study, an L9 based on full factorial are used machining parameters like pulse current, pulse on time, duty cycle and voltage setting were diverse to conduct 9 different trials and the measurements weights of the work piece were taken for calculation of MRR. Minitab software was used to analysis the findings. In this experiment Minitab software design are selected

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is 3 level design and number of factors is four. The flow chart of the experiment is shown in Fig.1.Experimental observation data are described.

V. RESULTS AND DISCUSSIONS

5.1 Influence of MRR

The Main effect plot for of MRR is shown in Fig. 2. The Pulse on time (Ton) and Input Current(Ip) is inversely proportional to MRR in the range of 1 to 5A. This is expected because an increase in pulse current produces strong spark, which produces the higher temperature, causing more material to melt and erode from the work piece. The duty cycle and voltage have no significant effect on MRR. The residual plot of MRR is shown in Fig. 3, where each plot exhibits the error between four different machining parameters like Ip, Ton and Tau and V. This implies that the effect of one factor is dependent upon another factor. It is also confirmed by the ANOVA table (Table 3).

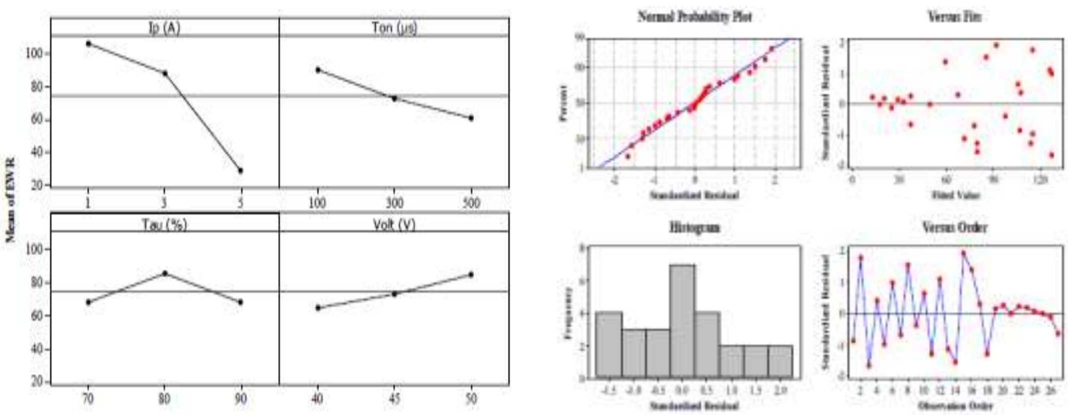

Fig 5.1 Influence of MRR

5.2 Influence of SR

In the process of machining minimum over cut is required for better result. The effect of various machining parameters such as discharge current, pulse on time, wire feed rate and Pulse on time(Ton) on over cut is presented in the main effect plot shown in Fig.3. and error are plotted are Fig 4. In the analysis of overcut discharge current, pulse on time and Pulse on time Ton has significantly affected. Voltage is not affected significantly that is confirm by ANOVA table of surface roughness

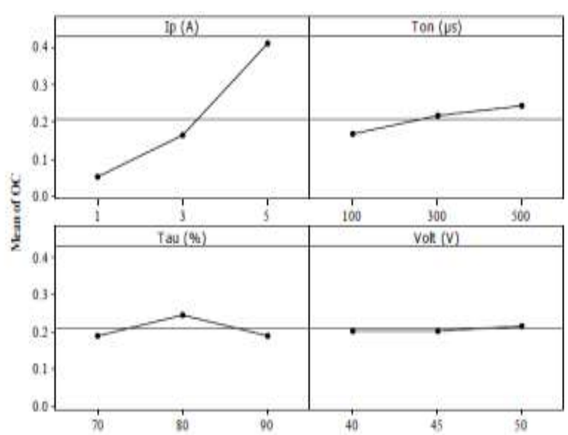

Fig 5.2 Influence of SR

VI. CONCLUSION

In the present work of study the effect of machining responses are Material Removal Rate and Surface Roughness of the HCHCR-D2 tool steel component using full factorial design with internal flushing system have been investigated for EDM process.

- Pulse current is most influencing factor for MRR and then pulse duration and the voltage and duty cycle has no significant affected.
- In the case of the dimensional accuracy, the measurement of Surface Roughness discharge current and pulse duration is given the significant effect. Then the input current (Ip) has slightly effect the dimensional accuracy, but wire feed rate(Wf) has no significant affected.

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