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Modeling and Optimization of WEDM Process Parameters on Machining of AISI D2 using RSM and Taguchi method

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Abstract: ***The objective of this research work is to investigate the effects of process variables like pulse on time, pulse off time, peak current, servo voltage and wire feed on performance parameters such as Material Removal Rate (MRR) and Surface Roughness (SR) in the WEDM machining process. The Taguchi technique is used to estimate the effects of the process parameters of WEDM process and to predict a set of optimal parameters for optimum performance of WEDM process. The response surface methodology (RSM) in conjunction with second order central composite rotatable design is used to develop the empirical models and relation for evaluation of performance variables. From the mathematical models developed and the confirmation experiments performed, it is found that they are within 95 % confidence level. ANOVA has been employed to see the level of significance of each process parameters in each case. Experimental verification of results achieved demonstrates that process performance can be improved significantly by this technique.***

Keywords: Surface Roughness, MMR, Response Surface Methodology, Taguchi, MINITAB 17, WEDM

1. Introduction:

Electro Discharge Machining (EDM) is an electro-thermal unconventional machining method, which make use of electric energy to generate electrical sparks and material removal is affected by thermal energy of the sparks so generated.

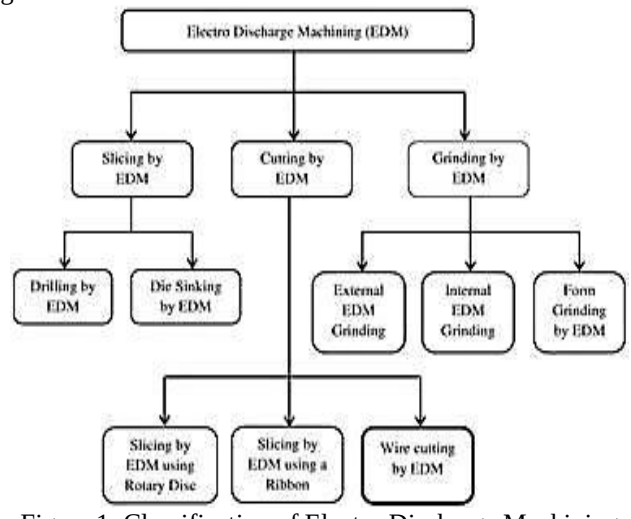

Figure 1: Classification of Electro Discharge Machining (EDM)

In Electro Discharge Machining (EDM), material is removed from the work piece through localized melting and vaporization of material. EDM process is classified into three main categories and eight sub-categories which are illustrated in Figure 1.

WEDM uses electro-thermal energy conversion mechanism to cut electrically conductive hard materials. In WEDM, a slowly moving wire electrode moves along a prescribed and programmed path between the support guides and removes material from the work piece.

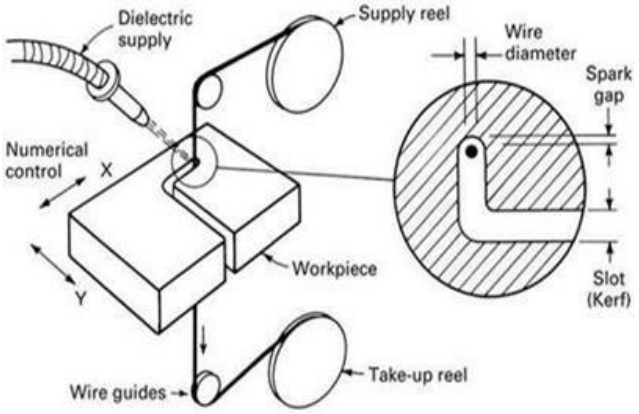

Figure 2: Schematic Diagram of Basic Principle of WEDM

2. Literature Review:

A literature review is a summary of a subject field that supports the identification of specific research questions. A literature review needs to draw on and evaluate a range of different types of sources including academic and professional journal articles, books, and web-based resources. A. Thillaivanan et at**.** In this paper the complexity of electrical discharge machining process which is very difficult to determine optimal cutting parameters for improving cutting performance has been reported. Optimization of operating parameters is an important step in machining, particularly for operating unconventional machining procedure like EDM. A suitable selection of machining parameters for the electrical discharge machining process reliesheavily on the operators' technologies and experience because of their numerous and diverse range. Machining parameters tables provided by the machine tool builder cannot meet the operators' requirements, since for unarbitrary desired machining time for a particular job, they do not provide the optimal machining conditions. An approach to determine parameters settingis proposed.[1]

Ashish Srivastava et al. Surface finish and Metal removal rate (MRR) is one of the most prime requirements of customer and it is also a significant tool to reduce the

cycle time of any machine operation as well as the overall cost of the production. In the recent years,quality of product is a essential demand of customer which turned to the fast and rapid technologies of production. This paper presents an experimental study on composite of Al2024 reinforced with SiC to investigate the effects of electric discharge machining (EDM) for three levels of each parameter such as current pulse on time and reinforcement percentage on surface finish and MRR. Response surface methodology (RSM) technique has been applied to optimizethe machining parameters for minimum surface roughness and maximum MRR.[2]

B. Bhattacharyya et. al. In non-traditional machining processing, electrochemical machining (ECM) has tremendous potential on account of the versatility of its applications and it is expected that it will be successfully and commercially utilized in modern industries, although the effective utilization of this machining technology will require the application of a system approach to solve some of the predominant machining problems. Because of various complex physico-chemical and hydrodynamic phenomena that occur in the machining gap during the course of machining, the machining rate at any instant depends not only on the end gap, but also on other process parameters [3]

Datta et al. In the present work, quadratic mathematical models have been derived to represent the process behavior of wire electrical discharge machining (WEDM) operation. Experiments have been conducted with six process parameters: discharge current, pulse duration, pulse frequency, wire speed, wire tension and dielectric flowrate; to be varied in three different levels. Data related to the process responses viz. material removal rate (MRR), roughness value of the worked surface (a measure of surface finish, SF) and kerf have been measured for each of the experimental runs; which correspond to randomly chosen different combinations of factor setting. These data have been utilized to fit a quadratic mathematical model (Response Surface Model) for each of the responses, which can be represented as a function of the aforesaid six process parameters.[4]

El-Taweel et. al. The present study investigates the relationship of process parameters in electro-discharge of CK45 steel with novel tool electrode material such as Al–Cu–Si–TiC composite produced using powder metallurgy (P/M) technique. The central composite second-order rotatable design had been utilized to plan the experiments, and response surface methodology (RSM) was employedfor developing experimental models. Analysis on machining characteristics of electrical discharge machining (EDM) die sinking was made based on the developed models. In this study, titanium carbide percent (TiC%), peak current, dielectric flushing pressure, and pulse on-time are considered as input process parameters. The process performances such as materialremoval rate (MRR) and tool wear rate (TWR) were evaluated.[5]

G. Rajyalakshmi & P. Venkata Ramaiah. In this paper, an effective approach, Taguchi grey relational analysis, has been applied to experimental results of wire cut electrical discharge machining (WEDM) on Inconel 825 with consideration of multiple response measures. The approach combines the orthogonal array design of experiment with grey relational analysis. The main objective of this study is to obtain improved material removal rate, surface roughness, and spark gap. Grey relational theory is adopted to determine the best process parameters that optimize the responsemeasures.[6]

S. Gopalakannan et al. The newly engineered metal matrix composite (MMC) of aluminums 7075 reinforced with 10 wt% of B4C particles were prepared by stir casting method. Experiments were carried out by adopting face cantered central composite design of response surface methodology. Analysis of variance was applied to investigate the influence of process parameters and their interactions viz., pulse current, gap voltage, pulse on time and pulse off time on material removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR). The objective was to identify the significant process parameters that affect the output characteristics and to develop for MRR, EWR and SR. [7]

2,1 Objective of Research Work:

- Optimizing the WEDM process
- Increasing the performance parameter

3. Modeling and Optimization Technique:

Response Surface Methodology:

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building. By careful design of experiments, the objective is to optimize a response (output variable) which is influenced by several independent variables (input variables).

An experiment is a series of tests, called runs,in which changes are made in the input variables in order to identify the reasons for changes inthe output response.

$$Y = \beta 0 + \beta 1x1 + \beta 2x2 + .,,,,,,,, + \beta nxn + \varepsilon \qquad (1)$$

Taguchi Method:

The Taguchi method is one of the best experimental methodologies used to find the minimum number of experiments to be performed within the permissible limit of factors and levels**.**

Optimization of Surface Roughness and MRR With Taguchi Method:

In this study, optimum turning parameters for AISI D2 material at the lowest possible surface roughness and maximum MRR possible value was calculated using Taguchi Method. Equation 8 derived by response surface method was taken as the objective function to be minimized for the lowest surface roughness value.

Machine Tool Used:

The experiments were carried out on a wire-cut EDM machine(Electronica Ultracut S2) of Electronica Machine Tools Ltd. (shown in figure 3) installed at M/s. Bhagwati Textiles (P) Ltd. Bhilwara (Raj.). The WEDM machine tool has the following specifications:

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Figure 3: Electronica Ultracut S2 WEDM Machine

4. Result and Discussion:

The experimental runs were performed based on the basis of orthogonal array consisting of 27 numbers of rows L27 (3^5). The parameters and their respective levels are found based on the literature review. Five process parameters (three levels of each process parameters) are taken for the experiment. Each experimental run was performed only one time so there are 27 numbers of experimental runs shown in figure. Stable machining conditions are achieved after cutting 7mm depth of cut. Apart from the parameters considered, there are other parameters/factors that can have an effect on the performance parameters.

Effect on Surface Roughness:

Figure 4 and 5 illustrates that the surface roughness increases with increase in pulse on time and decreases with the increase in pulse off time and servo voltage. The surface roughness first increases and then decreases with increases in wire feed. The peak current doesn't have any significant effect on the surface roughness. It is also evident that surface roughness is minimum at first level of pulse on time and maximum at third level of pulse on time.

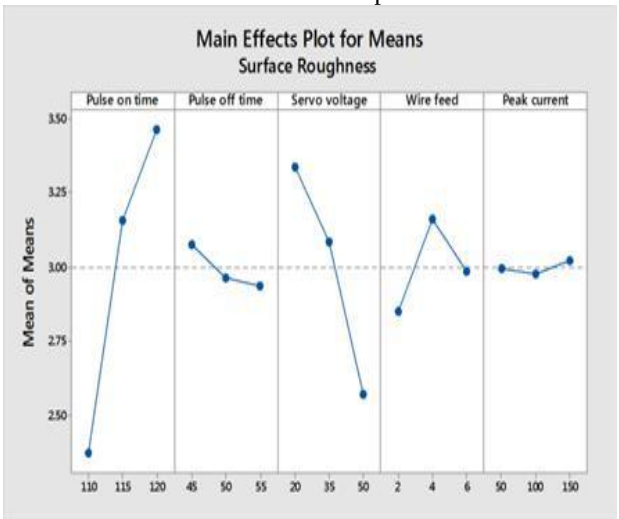

Figure 4: Effects of process parameters on surface roughness (raw data)

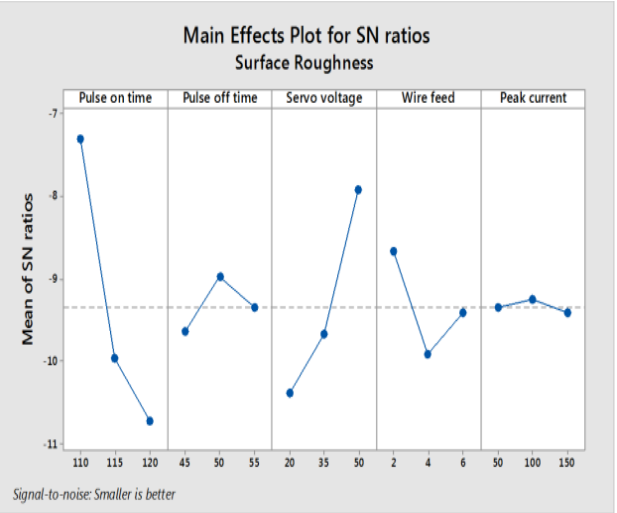

Figure 5: Effects of process parameters on surface roughness (S/N data)

4, Conclusions:

The surface roughness increases with increase in pulse on time and decreases with the increase in pulse off time and servo voltage.

The surface roughness first increases and then decreases with increases in wire feed.

The peak current doesn't have any significant effect on the surface roughness.

It is also evident that surface roughness is minimum at first level of pulse on time and maximum at third level of pulse on time show in Figure 4 and Figure 5

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