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Experimental Analysis of effect of Process parameter on Surface roughness in EDM

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Abstract : *The paper presents the experimental analysis and multi-response optimization of EDM process parameters during machining of Nimonic 90 work material. The experiment has been conducted at different parametric setting considering discharge current, pulse-on-time and pulse off-time as process parameters. Taguchi L9 orthogonal array has been used for experimental design. The effect of various parameters on response such as material removal rate and surface roughness has been studied with the help of suitable plots. The Grey Relational Analysis has been utilized for obtaining the optimal parametric combination*

Keywords— Pulse-on-time, Pulse off-time , clattering and vibration, surface roughness, electrical discharge machining.

I. INTRODUCTION

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.

II. PROBLEM DEFINATION

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 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 Surface finish. If at some point amount of stock removed from the electrode becomes greater than the amount being removed from the work , 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 Grey Relational analysis used to set optimal set of parameters.

III. METHODOLOGY

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 4.2. 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.

2 Grey relational Analysis:

The grey analysis was first proposed many decades ago but has been extensively applied only on the last decade. Grey analysis has been broadly applied in optimizing the performances involving multiple responses.
The multi-objective problem can be converted into single objective optimization using GRA technique.

Fig 3.1 Grey relational analysis

In Grey relational analysis, experimental data i.e., measured features of quality characteristics are first normalized ranging from zero to one. This process is known as Grey relational generation. Next, based on normalized experimental data, Grey relational coefficient is calculated to represent the correlation between the desired and actual experimental data. Then overall Grey relational grade is determined by averaging the Grey relational coefficient corresponding to selected responses. The overall performance characteristic of the multiple response process depends on the calculated Grey relational grade. This approach converts a multiple response process optimization problem into a single response optimization situation with the objective function is higher Grey relational grade. The optimal parametric combination is then evaluated which would result highest Grey relational grade.

3.2.1 Steps in GRA

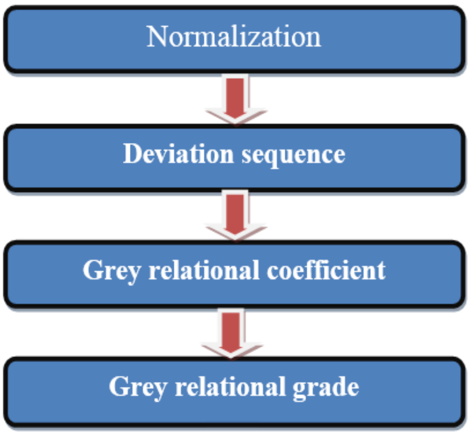

Fig 3.2 Steps in GRA

Normalization:

It is the first step in the grey relational analysis; a normalization of the S/N ratio is performed to prepare raw data for the analysis where the original sequence is transferred to a comparable sequence. Linear normalization is usually required since the range and unit in one data sequence may differ from the others. A linear normalization of the S/N ratio in the range between zero and unity is also called as the grey relational generation. Further analysis is carried out based on these S/N ratio values. When the range of the series is too large or the optimal value of a quality characteristic is too enormous, it will cause the influence of some factors to be ignored. The original experimental data must be normalized to eliminate such effect. There are three different types of data normalization according to whether we require the LB (lower-the-better), the HB (higher-the-better) and NB (nominal-the-best). The normalization is taken by the following equations.

(a) HB (higher-the-better)

$$x_i(k) = \frac{y_i - min\ y_i\ (k)}{\max y_i(k) - min\ y_i\ (k)} \quad \text{............(3.1)}$$

(b) LB (lower-the-better)

$$x_i(k) = \frac{\max y_i(k) - y_i\ (k)}{\max y_i(k) - min\ y_i\ (k)} \quad \text{............(3.2)}$$

(c) NB (nominal-the-best) :

$$X_i^*\ (k) = \frac{y_i\ (k) - y_i}{\max y_i(k) - y_i\ (k)} \quad \text{.......(3.3)}$$

Here, i= 1, 2… m; k=1, 2… n

Where x i (k) is the value after the grey relational generation, min y i (k) is the smallest value of y i (k) for the kth response, and max y i (k) is the largest value of y i (k) for the kth response. An ideal sequence is x0(k) for the responses. The purpose of grey relational grade is to reveal the degrees of relation between the sequences say, [x0 (k) and x i (k) , i = 1, 2,3.......,9].

(a) Determination of deviation sequences Δ_{0i}:

The deviation sequence is the absolute the reference sequence $x_0(k)$ and the comparability sequence $x_i(k)$ after normalization It is determined using = $|x_{0i}(k) - x(k)|$ ………………………………………………….……… (3.4)

(b) Calculation of grey relational coefficient (GRC)

If the two sequences agree at all points, then their grey relational coefficient is 1 everywhere and therefore, their grey relational grade is equal to 1. In view of this, the relational grade of two comparing sequences can be quantified by the mean value of their grey relational coefficients and the grey relational grade. The grey relational grade also indicates the degree of influence that a comparability sequence could exert over the reference sequence. Therefore, if a particular comparability sequence is more important than the other comparability sequences to the reference sequence, then the grey relational grade for that comparability sequence and reference sequence will be higher than other grey relational grades.

The higher value of grey relational grade corresponds to intense relational degree between the reference sequence $x_0(k)$ and the given sequence $x_i(k)$. The reference sequence $x_0(k)$ represents the best process sequence. Therefore, higher grey relational grade means that the corresponding parameter combination is closer to the optimal.

Based on Taguchi's L9 Orthogonal Array design, the predicted data provided can be transformed into a signal-to-noise (S/N) ratio; based on three criteria. The loss function (L) for objective of HB and LB is defined as follows

$$L_{HB} = \frac{1}{n}\sum_{i=1}^{n} \frac{1}{y_{MRR}^2} \quad \text{.......................(3.5)}$$

$$L_{LB} = \frac{1}{n}\sum_{i=1}^{n} y_{SR}^2 \quad \text{...............(3.6)}$$

Table 3.9: Grey relational Coeficient

Expt. No	Process Parameters				Grey Relational Grade
1	127	45	210	3	0.421565192
2	127	46	220	4	0.582971289
3	127	47	230	5	0.84999542
4	128	45	220	5	0.40368804
5	128	46	230	3	0.668728092
6	128	47	210	4	0.396119365
7	129	45	230	4	0.678749476
8	129	46	210	5	0.466474072
9	129	47	220	3	0.691686998

Table 3.10: Grey relational grade

Trial No	Daviation Sequence		Grey Relational coefficient	
	MRR	Ra	MRR	Ra
1	1	0.48078	0.333333	0.5097971
2	0.372	0.34385	0.573419	0.5925236
3	0.2143	0	0.699991	1
4	1	0.55476	0.333333	0.4740427
5	0.1041	0.48078	0.827659	0.5097971
6	0.5895	1	0.458905	0.3333333
7	0	0.89861	1	0.357499
8	0.5895	0.55476	0.458905	0.4740427

The larger the grey relational grade, the better is the multiple performance characteristics. However, the relative importance among the machining parameters for the multiple performance characteristics still needs to be known, so that the optimal combinations of the machining parameter levels can be determined more accurately. Table4.7, the optimal parameter combination was determined as A1(pulse on time)-B3(pulse off time)-C3(Input current)-D1(wire feed rate).

4.2.2 Confirmation Test:

The purpose of the confirmation experiment is to validate the conclusions drawn during the analysis phase. After determining the optimum level of process parameters, a new experiment is designed and conducted with optimum levels of CNC W-EDM parameters obtained.

	Predicted	Experimental	Error
MRR(gm/min	0.99	1.06	0.07
Ra(μm)	2.22	2.26	0.04

These values and percentage error between actual and predicted values of the responses are given in table. The percentage error between the actual and predicted values of the responses falls below 5%, which shows that the optimized value of CNC W-EDM process parameters obtained is good enough for achieving the target set during the experiment. The comparison again shows the good.

IV. CONCLUSIONS

Taguchi's L9 orthogonal array and Grey relational analysis were applied to improve the multi response characteristics such as MRR (material removal rate**)** and Surface roughness (Ra)

(a) The optimal parameter combination determined as A1(pulse on time)-B3(pulse off time)-C3(Input current)-D1(wire feed rate)
(b) Input Current(Ip) has maximum influence on both MRR and Surface Roughness.
(c) Surface Roughness increases with increase in Input Current (Ip).

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