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Optimization and Grey Relational Analysis of En 19 A Steel And Aluminium Using Parameters of Wirecutelectric Discharge Machine

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ABSTRACT - Technologically advanced industries like aeronautics, nuclear reactors, automobiles, etc have been demanding materials like high temperature resistant alloys having "high strength to weight" ratio. This also needs the development of improved cutting tool materials so that the productivity is not hampered From the existing papers in this project work we perform an experimental investigation to determine the parameters setting during the machining of Hardened EN 19 A steel 60HRC. And aluminum material The parameters of the model such as pulse-on time, flushing pressure, input power, thermal diffusivity and latent heat of vaporization have been determined through design of experiment methodology. From experimental results the significant factors are determined for each machining performance, such as the metal removal rate, surface roughness, Cylindricity and spark gap (gap width). Considering these significant CNC wire cut-EDM parameters, verification of the improvement in the quality characteristics for machining Hardened EN 19 A steel 60HRC, aluminum material was made with a confirmation test with respect to the chosen initial or reference parameter setting. Mathematical models relating to the machining performance are established using the linear regression for the effective machining of Hardened EN 19 A steel 60HRC, aluminum material. The determined optimal combination of CNC-wire cut-EDM parameters obtained from the study satisfy the real requirement of quality machining of Hardened EN 19 A steel 60HRC, aluminum material in practice. In the presented work, experiments are carried out for material removal rate and surface roughness with variables as pulse on time, pulse off time and servo voltage. There are 27 experimental readings taken for all variables to conduct the parametric study.

Keywords - STEEL, ALUMINIUM, WIRECUTELECTRIC DISCHARGE MACHINE.

I. INTRODUCTION

1.1 Material Selection:

The material selected for this process is EN-19A steel, which is an high carbon- chromium steel. This steel offers high measure of hardness with compressive strength and abrasion resistance. These steels retain their hardness up to a temperature of 4500c.

1.1.1 CHEMICAL COMPOSITION OF EN-19A STEEL

ELEMENT	METRIC
Tensile Strength	750 N/mm2
Yield stress	450 N/mm2
Reduction of Area	0.45
Elongation	0.3

1.2 Wire Electric Discharge Machining (WEDM)

WEDM is considered as a unique adoption of the conventional EDM process which comprises of a main worktable, wire drive mechanism, a CNC controller, working fluid tank and attachments. The work piece is placed on the fixture table and fixed securely by clamps and bolts. The table moves along X and Y-axis and it is driven by the DC servo motors. Wire electrode usually made of thin copper, brass, molybdenum or tungsten of diameter 0.05-0.30 mm, which transforms electrical energy to thermal energy, is used for cutting materials. The wire is stored and wound on a wire drum which can rotate at 1500rpm. The wire is continuously fed from wire drum which moves though the work piece and is supported under tension between a pair of wire guides located at the

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opposite sides of the work piece. 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. Also, the work piece and the wire electrode (tool) are separated by a thin film of dielectric fluid that is continuously fed to the machining zone to flush away the eroded particles. The movement of table is controlled numerically to achieve the desired three- dimensional shape and accuracy of the workpiece.

II. LITERATURE REVIEW

- Jagannath Munda. [2018] investigated the electrochemical micromachining through response surface methodology approach by taking MRR and ROC as separate objective measures, developed mathematical models and analyzed with reference to machining parameters.
- D. Chakradhar developed [2016] the multi-objective optimization models for electrochemical machining by grey relational analysis while machining EN31 steel with electrolyte concentration, feed rate and voltage as process parameters.
- Lokeswara Rao [2013] describes the optimum cutting parameters for Titanium Grade 5 (Ti-6Al-4V) using WEDM. The response of MRR and surface roughness are considered for improving machine efficiency. The experimentation has been done by using Taguchi's L 25 Orthogonal Array (OA) for 6 process parameters namely pulse on, pulse off, peak current, wire tension, servo voltage and servo feed settings. The optimal parameters are obtained by using Taguchi method.
- Kruth, et. al. [2010] of Katholieke University, Belgium studied and experimentally tested several compositions of wires, with high tensile core and several coatings. They have found that, while cutting with prototype wires, a significant rise in accuracy is obtained, especially in corner cutting, while the cutting rate is at a comparable level as commercial reference wire.
- Prohaszka et al [2006] proposed the requirements of the materials that can be used as WEDM electrodes and will lead to the improvement of WEDM performance. He discussed the material requirements for fabricating WEDM electrodes for improving WEDM performance. Experiments were carried out regarding the choice of suitable wire electrode materials, the effects of the material properties on the machinability of WEDM. He evaluated the influence of the various materials used for the fabrication of wire electrodes on the machinability of WEDM. A series of experiments have been conducted on a standard EDM unit. Negative polarity rods of pure magnesium, tin and zinc, of a diameter of 5.0 mm were used as the tool electrodes.
- Tarng et al. [2003] formulated a neural network model and simulated annealing algorithm in order to predict and optimize the surface roughness and cutting velocity of the WEDM process when machining SUS–304 stainless steel materials.

III. DESIGN OF EXPERIMENT

3.1 WEDM Process Parameters and Response Variables

The main goals of WEDM are to achieve a better stability and higher productivity. As newer and more exotic materials are developed, and more complex shapes are required, conventional machining operation will continue to reach their limitations and the increased use of WEDM in manufacturing will continue to grow at an accelerated rated . However, due to a large number of variables in WEDM, it is difficult to achieve the optimal performance of WEDM processes and the effective way of solving this problem is to establish the relationship between the response variables of the process and its controllable input parameters.

3.3.2 Steps to perform Taguchi design of the experiment

Fig. 4.1 Sprint cut Wire Cut EDM

Fig. 4.3 Control Cabinet

1. Identify the main function, side effects, and failure mode.

2. Identify the noise factors, testing conditions, and quality characteristics.

3. Identify the objective function to be optimized.

4. Identify the control factors and their levels.

5. Select the orthogonal array matrix experiment.

6. Conduct the matrix experiment.

7. Analyze the data; predict the optimum levels and performance.

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8. Perform the verification experiment and plan the future action. Identify the main function, side effects, and failure mode.

3.4 WORK MATERIAL USED

The different sets of experiments were performed using a 5 axis Charmless ROBOFIL 240CC wire cut EDM machine, Component Material is Hardened Stainless steel EN 19A 40HRC. Aluminium material. The electrode (wire) used is an ACTCUT 500 Brass wire of 0.25mm diameter.

IV. EXPERIMENT WORK AND MEASUREMENT

The experimental setup and the experiment is designed and carried out at the Vinayaka wire cut which is placed at old Airport Road Hyderabad**.** The primary goal of the dissertation work is to predict the Material Removal Rate and surface roughness. The work is carried out in sprint cut wire cut electro discharge machine of EN-19A HCHCR material by varying machining parameters.

Sr. No.	Machining process parameter	Level 1	Level 2	Level 3
1	Pulse on Time (µs)	110	120	130
2	Pulse Off Time (µs)	45	55	65
3	Servo Voltage (volt)	20	30	40

WORK TABLE

Design	**Fixed column, moving table**
Table size	**440 x 650 ×300 mm**

MAX.WORK PIECE DIMENSION

Max. work piece height	**200 mm**
Max. work piece weight	**500 kg**
Main table traverse (X,Y)	**300 x 400 mm**
Aux. table traverse (U,V)	**80 x 80 mm**
Wire electrode diameter	**0.25 mm (std.) 0.15, 0.20 mm (opt.)**

PULSE GENERATOR

Pulse Generator	**ELPULS-40 A DLX**
Pulse peak voltage	**1 Step**
CNC Controller	**EMT 100W-5**
Input power supply	**8.3 phase, AC, 415 V , 50 Hz**
Connected load	**10 kVA**
Average power consumption	**6 to 7 kVA**

DIELECTRIC SYSTEM

Dielectric Unit	**DL 25 P**
Dielectric fluid	**Deionized water**
Tank capacity	**250 Liters**
Cooling system	**1700 k Cal**

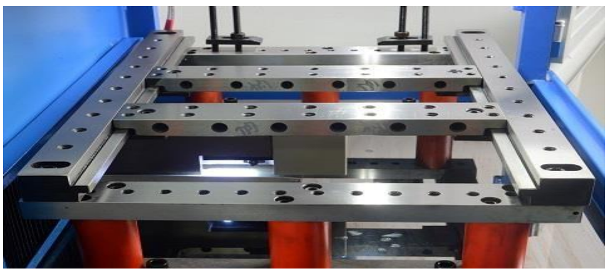

Fig. 4.4 Work Table

Machining profile

The wire tool moves in a circular path following the inner periphery of the spool bore of a Type II EHSV i.e. The internal profile of the spool bore is measured. The wire should as close as possible to the wall of the spool bore without making contact with it. The wire tool will trace a circular path. A single experiment consists of four complete circular passes. Two clockwise and two anticlockwise. The first run is anticlockwise which performs a roughing operation, followed by 3 runs of finishing operation where the runs occur in the order clockwise, anti clockwise and clockwise respectively. It is represented in the table below.

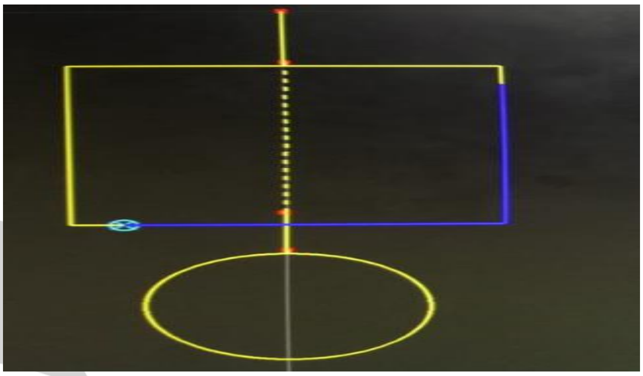

Fig 4.6 Machining profile

Fixed Parameters

1. Work piece Material-Hardened Stainless Steel 40HRC
2. Wire Material-Brass
3. Wire Diameter-0.25mm
4. Dimensions/Shape of the work piece
5. Injection pressure

Response Parameters

1. Cylindricity (µm)
2. Surface roughness (µm)
3. MRR (mm^3/sec)
4. Spark gap (mm)

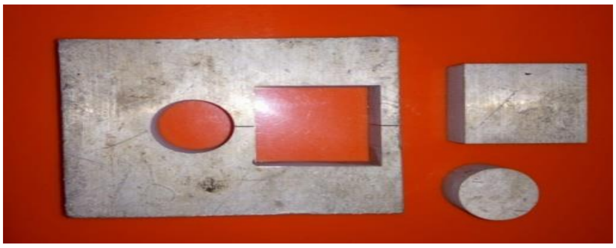

Fig. 4.7. Aluminium Tested Specimen

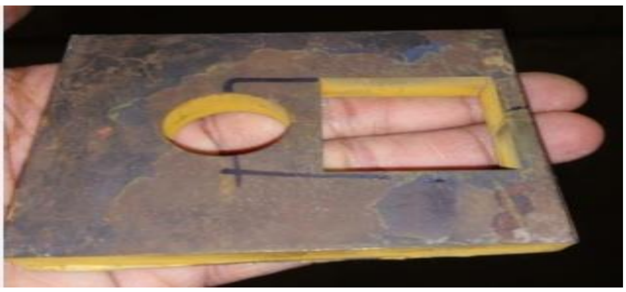

Fig. 4.7. EN19a Tested Specimen

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V. ANOVA ANALYSIS:

5.1 Introduction

The analysis of variance is the statistical treatment most commonly applied to the results of the experiment to determine the percent contribution of each factors. Study of ANOVA table for a given analysis helps to determine which of the factors need control and which do not. Once the optimum condition is determined, it is usually good practice to run a confirmation experiment. In case of fractional factorial only some of the tests of full factorial are conducted. The analysis of the partial experiment must include an analysis of confidence that can be placed in the results. So, analysis of variance is used to provide a measure of confidence. The technique does not directly analyse the data, but rather determines the variability (variance) of the data. Analysis provides the variance of controllable and noise factors. By understanding the source and magnitude of variance, robust operating conditions can be predicted.

Table 5.1 Control parameter

5.1.1 Table for factor with level

EN 19A MATERIAL:

M- cond	min	max
Ton	1	3
Toff	1	30
Ip	1	1
Vp	0	1
Wp	0	3
Wf	0	2
Wt	0	9
Sv	0	10
Sf	0	120
CDL	0	2
CC%	0	5
GOP Vg	24	25
Gop Ig	15	16
Pressure	0	8
Cutting speed	0	8.2

Total no of runs = n = 27

Total degree of freedom = f_T = n-1 = 26

Aluminum material:

M- cond	min	max
Ton	1	15
Toff	1	62
Ip	1	1
Vp	0	1
Wp	0	15
Wf	0	2
Wt	0	8
Sv	0	20
Sf	0	100
CDL	0	2
CC%	0	5
GOP Vg	85	90
Gop Ig	15	1.6
Pressure	0	2
Cutting speed	0	13

VI. MULTI RESPONSE OPTIMIZATION

6.1 Grey relational analysis for multi objective optimization

In grey relational analysis, the function of factors is neglected in situations where the range of the sequence is large or the standard value is enormous .However, this analysis might produce incorrect results if the factors ,goal and directions are different .therefore one has to pre-process the data which are related to a group of sequence ,which is called "grey relational generation "data pre-processing is a process of transferring the original sequence to a comparable sequence for this purpose the experimental result are normalized in the range between zero and one the normalization can be done from three different approaches

- ANOVA for GRG of brass wire electrode shows Toff and SV are most significant parameters and contributes with 30.9894% and 29.9966% respectively, SV is insignificant parameter and contributes24.9449%. The error between Grey theory prediction design using software and experimental values using Grey relational analysis for GRG is 0.14999% which shows that model developed is significant.

VII. DEVELOPMENT OF MATHEMATICAL MODELS

The experimental results are used to obtain the mathematical relationship between process parameters and machining outputs. The coefficients of mathematical models are computed using method of multiple regressions. In this study, SPSS, Minitab17 (Software Package for Statistical Solutions), for regression analysis custom made software created by the author was used for the regression analysis. This software is used to test several models, viz., and linear, exponential, power series

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(user-defined). Out of all models tested, the model that has high coefficient of multiple determination (R^2) value is chosen. The relationship between response variable(s) and process parameters can be expressed as

EXP.NO	Ton	Toff	SV	MRR	SR
1	110	55	20	0.0339	3,1970
2	130	55	40	0.0668	3.4692
3	110	65	30	0.0338	3.0250
4	120	45	40	0.0669	3.3808
5	120	45	20	0.0540	3.3575
6	120	65	20	0.0472	3.2907
7	120	55	30	0.0475	3.2907
8	130	65	30	0.0670	3.4890
9	130	55	20	0.0618	3.4578
10	120	55	30	0.0475	3.2907
11	120	55	30	0.0475	3.2907
12	120	65	40	0.0535	3.3496
13	110	45	30	0.0365	3.1919
14	110	55	40	0.0325	3.0145
15	130	45	30	0.0683	3.4416

Table No: 7.1 BOX-BEHNKEN design of experiments

VIII. CONCLUSION

On the basis of experimental results, the following conclusions are drawn for the effective machining of Hardened Stainless Steel EN 19A 40HRC, aluminium by the CNC-wire cut EDM process:

In the presented work, experiments are carried out for material removal rate and surface roughness with variables as pulse on time, pulse off time and servo voltage. There are 27 experimental readings taken for all variables to conduct the parametric study.

Finally, it can be concluded that:

- The ANOVA analysis is conducted to know the percentage contribution of the input parameters on output parameters. ANOVA analysis results that the percentage contribution of pulse on time is 87.2%, pulse off time is 1.81% and servo voltage is 1.81% for material removal rate, which shows that the influence of Pulse off time is very less compare to other parameters. The percentage contribution of Pulse on time is 74.2%, Pulse off time is 1.01% and Servo voltage is 15.9% for Surface Roughness which shows that the influence of Pulse off time is very less compare to other parameters. The error and percentage contribution of interaction terms found in ANOVA analysis is 9.18% for material removal rate and 8.89% for surface roughness.
- Grey relational analysis is done to find out optimal parameter levels. After grey relational analysis, it is found that optimal parameter levels are pulse on time at level 1 (110 µs), pulse off time at level 2 (55 µs), servo voltage at level 3 (40 volts). The results of optimum parameters are material removal rate of 0.0698 mm3/min, surface roughness of 3.4925 µm.
- Process parameters do not have some little effect for every response. Significant parameters and its percentage contribution changes as per the behavior of the parameter with objective response.
- Increase of Pulse on time generates more spark energy as the length of time that electricity supply increases. MRR and SR all response increasing with pulse on time. Pulse on time found most significant parameter in all response. Surface roughness also increases with increase of pulse on time because the increases of pulse on time produce crater with broader and deeper characteristic.

IX. FUTURE SCOPE

- The mathematical model can be developed with different work piece and electrode materials for EDM and WEDM processes.
- Responses like Kerf width, roundness, circularity, Cylindricity, machining cost etc. are to be considered in further research.

The developed mathematical model can be further optimized using state of art techniques like Teacher Learner Based Optimization (TLBO) and Particle Swarm Optimization (PSO).

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