EXPERIMENTAL INVESTIGATION OF MACHINING PARAMETERS ON WIRE EDM OF MONEL 400 NICKEL- COPPER BASED ALLOY BY USING MCDM-SMART

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ABSTRACT: The Wire EDM is one of the Non-Traditional machining process. Which is used for very hard and tough materials. Wire EDM was used for the fabrication of various components in automobile, aerospace, medical, electronic, nuclear and die making industries. A wire guide which is present in EDM helps in directing the wire to the desired location for cutting the part in different profiles.Virtually any conductive material can be cut using Wire EDM. This would include all metals like steels, aluminium, titanium, Monel, Inconel, Kovar, Hastelloy. Among all the metals Monel-400, a nickel-copper-based alloy have plenty of applications in ship building industries because of its corrosion resistance property. It has high strength and toughness over a wide temperature range and excellent resistance to many corrosive environments. This material can be hardened only by cold working.Among different Optimizing methods MCDA-SMART method was used to optimize the work material Monel 400 by using Wire EDM process. In this manner orthogonal Taguchi experimental layout was used with the input machining parameters wire tension, pulse on time, pulse off time, servo voltage gap and water pressure to determine material removal rate (MRR) and surface roughness as the optimized output parameters.

Keywords: Wire EDM, MCDM-SMART, Taguchi analysis, MRR and SR, Monel-400

I INTRODUCTION

Wire cut EDM is used to cut materials with fragile geometry and hard structure to make precision cuts this happens with no contact between tool wire and work piece which provides the capability of machining even the weak structured and delicate materials. A minute gap of range 0.025mm-0.5 mm is maintained by computer and a steam of dielectric fluid is filled in this gap and the dielectric fluid gets directed to working zone by upper and lower nozzles of diamond guides. Wire cut EDM is based on repetitive sparking cycles principle where both wire and work piece gets both melted and evaporated. Wire and work piece is placed on CNC work table where wire is fed through work piece by a microprocessor for machining to happen.

Wire EDM find applications in industries of automobile, sheet metal aerospace, semiconductor, tool and die making industries, especially in automobiles and sheet metal for the manufacturing of jigs, and fixtures. With the advent of Wire EDM process, CNC is able to machine hard metals through inaccessible locations by utilizing electrical sparks exist between tool and work piece.

Wire cut EDM is accepted as optimum method for manufacturing complex composite material profiles which can be used to obtain complicated shapes on hard tool steel. When supplier information is not sufficient it is difficult to choose parameters for SR and MRR. Selection of parameters for machining is an important role in Wire cut EDM because improper selection will lead to short circuit and wire breakage. This work attempts to choose optimum parameters for machining MONEL 400 NICKEL- COPPER BASED ALLOY by Wire cut EDM using MCDM-SMART method.

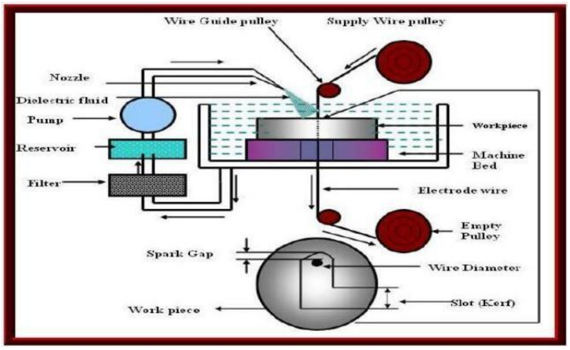

Fig: 1.1 Working of Wired EDM process

II LITERATURE REVIEW

In [1] SR and width are reduced by optimizing WEDM machining parameters utilizing Taguchi L_9 orthogonal array and grey relational analysis for single objective and multi objective optimization Wire EDM is performed on AISI 4140 material which is useful for defence applications because of its strength. Analysis of variance proved that pulse on time and servo voltage are the most influencing parameters for SR and width. Taguchi method decrease SR from 1.725 µm to 1.455 µm and kerf width from 0.341mm to 0.275mm respectively.

In [2] wire cut EDM for small and precision cuts is applied on AISI-304. Design of Experiment and Grey relational analysis are used to obtain optimal solutions for MRR and SR. The increase in pulse on time and spark gap results in increased MRR by increasing pulse-off time there is decrease in MRR. SR increase with increase in pulse off time, wire tension and gap voltage. There is decline in SR with increase in wire Speed and pulse-on time.

In [3] wire EDM is applied on magnesium material composite it is observed that pulse on time and wire feed rate increase MRR over duration while SR increase with pulse on time. Taguchi coupled GRA hybrid optimization is applied on control parameters to obtain trade-off between best MRR and minimum SR.

In [4] wire EDM is used for machining hybrid composite of Aluminium alloy (LM25), Graphite (Gr) and Boron carbide (B_4C). Stir casting process and Taguchi orthogonal design experiment are used to fabricate composite. It is observed that current effects MRR more whereas both current and pulse shows impact on SR.

In [5] finish cut WEDM is performed on titanium and characteristics were predicted using feed forward back propagation neural network. Taguchi L-18 orthogonal array is used for planning experimentation which contains seven process parameters and uses gradient descent, LM Levenberg Marquartd to evaluate machine rating and SR respectively. The mean square error decreased from 10^{-1} to 10^{-4} for machine rating and 10^{-1} to 10^{-3} for SR using LM training algorithm indicating perfect learning relationship obtained from ANN model.

In [6] method for decision support called SMART for multi-criterion decision making is presented. The method proposed is multi attribute rating technique based on approach that every alternative contains some criteria that have values and each criterion have weights that describe importance of a criterion when compared to other. It is observed that SMART method converges in small time, however if there is increase in number of constant alternatives then the computation time for SMART method will increase.

III EXPERIMENTAL WORKS

3.1. PRECISION LATHE MACHINE

The L18 design of experiments were conducted on Wire cut Electro Discharge Machine(SMART CUT) using brass wire as tool as show in Figure 3.1 below

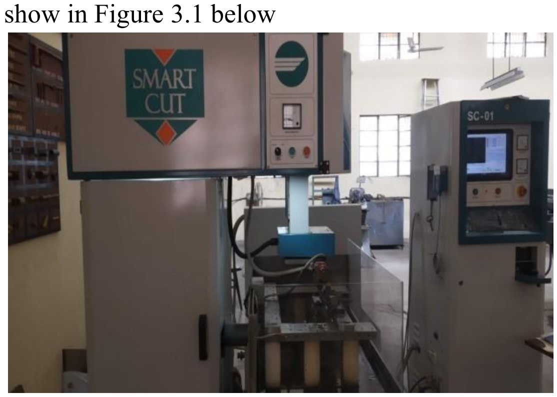

Figure.3.1 Wire cut Electro Discharge Machine

3.2 WORK MATERIAL

Monel 400 is used as work material and composition is tabulated in 3.2

Table 3.2 composition of Monel 400

Element	Composition
Cu	28-34
Fe	2.5
Mn	2
Si	0.5
C	0.3
S	0.024
Ni	remainder

3.3 CUTTING TOOL

Figure.3.3 EDM Brass Wire

In this present work 0.25mm diameter brass wire as in Figure 3.3 is used as a tool electrode. Brass an alloy of Copper and Zinc exhibits minimal cost, reasonable conductivity, high tensile strength, and improved flushability. A "high zinc" brass which is Cu60% Zn40% composition is mostly used EDM wire.

3.4 INPUT PARAMETERS AND THEIR LEVELS

The values of input parameters are considered taken using 3 levels are listed in table3.3

Level	1	2	3
Wire tension (wt)	4	8	-
Pulse on time(µs)	107	116	125
Pulse off time(µs)	40	50	60
Spark gap voltage(V)	30	40	50
Water pressure(wp)	89	94	99

3.5 SURFACE ROUGHNESS

The average surface roughness (Ra) is measured by using Talysurf surface roughness tester at three positions on the metal and the average value is taken for analysis as shown in Figure 3.5

Figure.3.5 Talysurf surface roughness tester

IV EXPERIMENTAL DESIGN

Experimental design is a decision making process which decides the validation of the desired response model to find optimal cutting parameters. This present research work is done using Taguchi design methods.

4 TAGUCHI ANALYSIS

Taguchi method is considered as influential procedure for parameter design which is useful to determine parameters for improvement of MRR and SR minimization in Wire EDM. Output parameters with higher value for machining performance of MRR is called 'higher is better' and where lower value for machining performance of SR is called 'lower is better'. Consequently, higher better for the material remove rate and lower the better for the SR were selected for finding optimum output parameters.

Taguchi method is utilized for speculating not only single factor interest furthermore their cooperation in the movement reaction. The principle impact plot and cooperation plot for sign to clamour proportion, standard deviations, and means is examined through Taguchi method. Leftover plot on histogram, ordinary plot, and lingering versus request, remaining versus fits are obtained through Taguchi method.

ANOVA

Analysis of Variance (ANOVA) is collection of statistical models and their respective estimation procedure. It is used to obtain the importance of input parameters for given experiment. ANOVA is performed, to model the influence of the machining parameters on the MRR and SR.

SMART Method

Simple Multi Attribute Rating Technique a decision support system for multi criteria by Edward in 1977 is based on that each alternative consists of some criteria that have values and each criterion have weights that describe how important compared to other criteria. Decision support systems utilize available resources with computing abilities to enhance decision results and decision-making is correlated with the uncertainty of the results of decisions taken. The decision making system requires information about the past, present and expected future conditions then process the information into several alternative problems solving as a material consideration in deciding the steps to be implemented the decision taken through this procedure is expected to provide maximum benefits with reduction in risk factor.

SMART method gather information about data related to various attributes and criteria in which the relationship between data one and other data so that the final result will get the best results solution, Weights in SMART method is used to compare and constrast each alternative to obtain the best choice. SMART is a linear additive model to predict the value of each option. The approach followed by SMART method is transparent

Formulae for calculating SMART method are:

$u(\mathbf{a}_i) = \sum_{j=}^{m}$ wi ui (ai), **i=1,2,…m** (1)

Information:

w_i = j-weighting criteria and k criteria.

u_i = i utility criteria value for criteria i

The order in using the SMART method is as follows [5]:

1. Used criteria determination
2. Determining the value for each criterion using the 1-100 intervals for each criterion with the most important priority
3. Normalization of each criteria by comparing the criteria generating values with their respective weights.
4. Parameter values of each criterion for each alternative.
5. Value of utility determination by converting criteria values on each criterion to standard data criteria values.
6. Final value of each criterion determination by diverting the value obtained from the normalization of the standard data criterion value with the normalization value of the criteria weight. Then adding the value of the multiplication.

Where **u ($\mathbf{a}_i$)** is the total alternative values, is the result of normalizing the criteria weight and **$u_i(a_i)$** is the result of determining the value of the utility

V EXPERIMENTAL RESULTS

Taguchi Analysis: MRR versus W T, Ton, T off, S G, W P

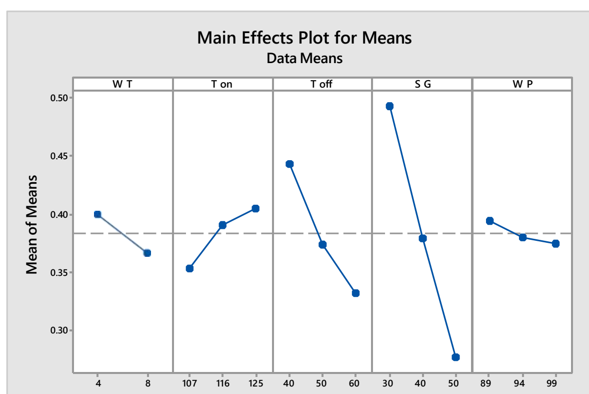

Figure 4.1 : MRR

The above Figure 4.1 shows that with increase in servo voltage gap (SG) and pulse off time (T_{off}) there is an increase in MRR resulting in powerful explosion with higher discharge energy. It is even observed that with increase in servo voltage gap there is raise in cutting speed.

Response Table for Means

Table 4.1

Level	WT	Ton	Toff	SG	WP
1	0.4000	0.3537	0.4439	0.4936	0.3947
2	0.3666	0.3911	0.3742	0.3798	0.3807
3		0.4050	0.3318	0.2765	0.3745
Delta	0.0334	0.0514	0.1121	0.2171	0.0202
Rank	4	3	2	1	5

The table 4.1 shows that as there is significant influence of SG and Toff on MRR there are ranked 1 and 2. The least influential factors of Ton, WT and WP are ranked 3, 4 and 5 respectively.

Taguchi Analysis: SR versus W T, Ton, T off, S G, W P

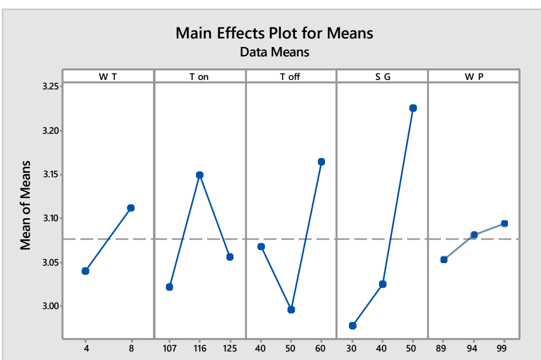

Figure 4.2 Surface Roughness

The Figure 4.2 shows that with increase in servo voltage gap (SG) and pulse off time (T_{off}) there is an increase smoothness of the material surface resulting in decrease in SR.

Response Table for Means

Table 4.2

Level	WT	Ton	Toff	SG	WP
1	3.040	3.022	3.068	2.977	3.053
2	3.112	3.150	2.996	3.025	3.081
3		3.056	3.165	3.226	3.094
Delta	0.072	0.128	0.169	0.248	0.041
Rank	4	3	2	1	5

The top factors influencing SR are SG and Toff which are ranked 1 and 2 where the factors of Ton, WT and WP show loss influencing hence ranked 3, 4 and 5 respectively.

General Linear Model: MRR versus W T, T on, T off, S G, W P

Table 4.3 Results of Anova for MRR

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
WT	1	0.0062	0.06%	0.00616	0.00616	0.27	0.620
Ton	2	0.6023	5.88%	0.60227	0.30114	12.99	0.003
Toff	2	1.6911	16.52%	1.69109	0.84555	36.47	0.000
SG	2	7.6914	75.15%	7.69137	3.84569	165.86	0.000
WP	2	0.0578	0.56%	0.05779	0.02889	1.25	0.338
Error	8	0.1855	1.81%	0.18549	0.02319		
Total	17	10.2342	100.00%				

Of all the influential factors servo gap (SG) contributes more to MRR with an amount of 75.15% as observed in Table 4.3

S.NO	W.T	T on	Toff	SG	WP	MRR	SR	Normalized MRR	Normalized SR	SMART	RANK
1	4	107	40	30	89	0.5438	2.7925	0.1815	1	0.4679	6
2	4	107	50	40	94	0.3344	2.8700	0.7223	0.8775	0.7766	18
3	4	107	60	50	99	0.2269	3.1250	1	0.1738	0.7108	15
4	4	116	40	30	94	0.6141	2.8750	0	0.8654	0.3028	2
5	4	116	50	40	99	0.3841	3.1025	0.5940	0.4956	0.5595	7
6	4	116	60	50	89	0.2512	3.4075	0.9372	0	0.6091	11
7	4	125	40	40	89	0.5197	3.0400	0.2453	0.5972	0.3684	3
8	4	125	50	50	94	0.2867	3.0250	0.8455	0.6216	0.7671	17
9	4	125	60	30	99	0.4391	3.1250	0.4519	0.4591	0.4544	4
10	8	107	40	50	99	0.2841	3.2850	0.8522	0.1990	0.6235	12
11	8	107	50	30	89	0.4187	2.9525	0.5046	0.7394	0.5867	10
12	8	107	60	40	94	0.3142	3.1075	0.7745	0.4875	0.6740	14
13	8	116	40	40	99	0.3852	3.0750	0.5911	0.5403	0.5733	8
14	8	116	50	50	89	0.2937	3.1725	0.8274	0.3819	0.6714	13
15	8	116	60	30	94	0.4183	3.2675	0.1153	0.2275	0.1545	1
16	8	125	40	50	94	0.3163	3.3400	0.7691	0.1097	0.5795	9
17	8	125	50	30	99	0.5274	2.8520	0.2239	0.9023	0.4613	5
18	8	125	60	40	89	0.3411	2.9550	0.7050	0.7354	0.7354	16

General Linear Model: SR versus W T, T on, T off, S G, W P

Table 4.4 Results of Anova for Ra

Source	DF	SeqSS	Contribution	AdjSS	Adj MS	F-Value	P-Value
W T	1	0.000271	4.67%	0.000271	0.000271	1.33	0.283
To n	2	0.000585	10.06 %	0.000585	0.000292	1.43	0.294
Tof f	2	0.000953	16.39 %	0.000953	0.000476	2.33	0.159
SG	2	0.002291	39.42 %	0.002291	0.001146	5.61	0.030
WP	2	0.000078	1.34%	0.000078	0.000039	0.19	0.830
Error	8	0.001634	28.12 %	0.001634	0.000204		
Total	17	0.005812	100.00 %				

There is a significant contribution of 39.442% by SG to SR forming the most influential parameter as observed in Table 4.4

VIII CONCLUSIONS

This work mainly focus on the selection of optimum process parameters in WEDM process by using MCDM-SMART method. The main contribution of study is mainly on the practical side for maximizing the material removal rate and for minimizing the surface. The method used for the present problem is a combined MCDM-SMART method is quite capable to solve for any type optimization problem involving any number of responses. The value from smart method are accurate, which are obtained normalized material removal rate and normalized surface roughness.

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