Optimization of Process Parameter in WEDM of Ti6Al4V by Using Taguchi based Grey Relational analysis

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ABSTRACT- Titanium based alloy material has high strength to low weight ratio and excellence corrosion resistance because of this property, titanium is highly usable in Aerospace and Medical industries. Ti6Al4V grade alloy is most usable titanium alloy. The present work has been carried out to Optimization of Process Parameter in Wire Electric Discharge Machine of Ti6Al4V by Using Taguchi based Grey Relational analysis. Different machining parameter which is investigate in this experiment are Material Removal Rate (MRR) and Surface roughness (R_a). Control parameters are Pulse on time (T_{ON}), Pulse off time (T_{OFF}), Wire tension (W_T), Wire feed (W_F). In this experiment Taguchi technique (L_9 orthogonal array) was used as design of experiment and Taguchi method is used for optimization. Each experiment was conducted under the different conditions of pulse on time, pulse off time, wire feed, and wire tension. The Wire EDM process parameters can be adjusted to achieve better metal removal rate and surface finish simultaneously. Result of response of material removal rate (MRR), surface roughness (R_a) is considered for improving the machining efficiency. Optimal combinations of process parameters were obtained by using Taguchi's L9 orthogonal array

Keywords: ***Ti6Al4V, Taguchi Method, S/N Ratio, Grey Relational Analysis.***

I. INTRODUCTION

Wire Electric Discharge Machining (WEDM) is a non-traditional machining process. In recent development in manufacturing industry needed more toughness and hardness material which could sustain high amount of force or tension with low weight specially in aerospace industry which needed low weight material. This type of material is very difficult to cut by non-conventional machining process. Now a day we used non-conventional machining process to machine these types of material generally by Electrochemical Machining (ECM), Ultrasonic Machining (USM), Electric Discharge Machining (EDM), Abrasive Jet Machining (AJM), Wire Electric Discharge Machining (WEDM). Wire electric discharge machining is used cut to conductive materials which having any amount of hardness. In this process generally brass coated electrode wire are used. In this process there will be no contact between the workpiece and wire. The wire converted electric energy to the thermo electric spark or thermal energy which eroded the workpiece material but there will be a small gap between the electrode wire and workpiece where spark will generate. In this process mechanical stress will not developed, wire will keep in tension with the help of mechanical support. Wire Electric Discharge Machining (WEDM) can cut conductive material by predefined controlled CNC path and there is no mark left by the wire electrode in the workpiece compare to the drilling, milling cutter and grinding wheel.

Wire Electric Discharge Machining (WEDM) is mainly used in tool and die making industry. Alloy having high strength and toughness are normally machined by the help of wire electric discharge machining, for example Steel, Aluminum, Hastelloy, Titanium, Carbide, Inconel, Polycrystalline diamond compact and ceramic type alloy.

In wire electric discharge machining (WEDM) electrical energy is converted into the thermal energy by a series of spark with the help of spark generator. Spark are formed through the rapid generation of pulse by the help of power supply machine. Spark is formed an ionization channel under extremely high pressure and heat in which the particle flow between the workpiece and electrode material, resulting in the vaporization or thermal erosion on the localized section. The wire is feed in the workpiece by the help of pair of rollers. Both the electrode and workpiece are immersed in the continuously flowing dielectric fluid, dielectric fluid act as cooling agent and act as an insulator till a threshold voltage is reached. It also flushes the debris away from the machining zone.

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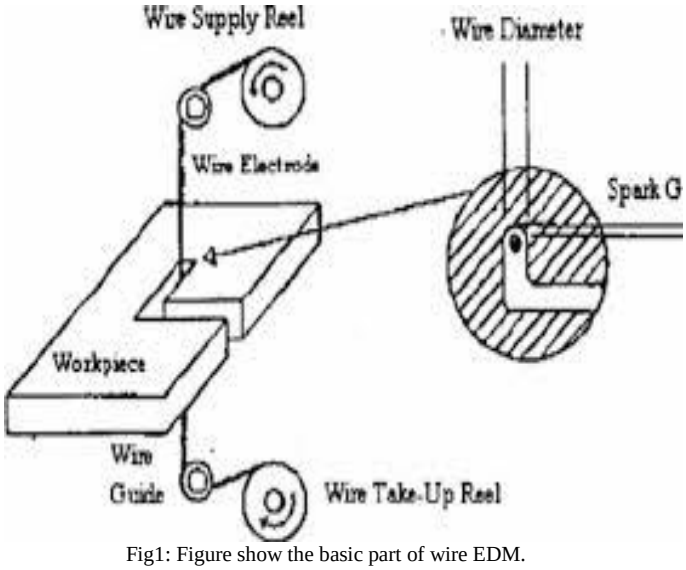

Fig1: Figure show the basic part of wire EDM.

Wire Electric Discharge Machining (WEDM) is a one-step machining process so there is no need to any secondary operation. Most of the workpiece out the machine is a finishing part. This process is the best non-conventional machining process to generate intricate and difficult profile of the material.

II. EXPERIMENTAL SETUP

This experiment was carried on Wire cut EDM machine (JOEMARS WT355) at (CENTRAL TOOL ROOM AND TRAINING CENTRE) GOVERNMENT OF INDIA SOCIETY MINISTRY OF MICRO, SMALL AND MEDIUM ENTERPRISES GOVERNMENT OF INDIA.

Titanium alloy (Ti6Al4V) of size 150mmx 50mm x 5mm is placed on the Joemars WEDM machine tool. A proper requirement it was fitted and make position for the cutting process. All the process parameter is taken for the cutting, and then specimen cut surface is 7mm x 5mm. which are shown in the figure 3.

Fig 2: Wire EDM machine tool

Fig 3: Material after cutting on various parameters.

III. EXPERIMENTAL METHODOLOGY

Experiment were conducted on the material Titanium Alloy (Ti6Al4V) of grade 5 in short, we can say that Ti6Al4V by using wire EDM. For the study of MMR and surface roughness the experiment is executed on WEDM. The various parameter is taken for the machining of specified alloy. The control parameter is pulse on time, pulse off time, wire feed and the wire tension.

3.1 Grey Based Taguchi method

Grey based Taguchi method implement the techniques to change the way of the designing of experimentation. By this method it established the important ideal approach and help into improve the quality. This methodology gives another exploratory technique where in adjusted and institutionalized design of experiment. Taguchi technique create an idea in which parameter configuration is run to diminish the wellsprings of minor departure from the quality attributes of item and achieve an objective of procedure robustness. Taguchi plans analyses utilizing uniquely developed tables known as "orthogonal array" (OA). it uses into the DOE (Design of experiment) hypothesis to consider the more variables and have the smaller number of the experiment. This DOE is feasible machine for executing and directing the trials with the minimum requirement. Orthogonal array is measuring method for qualifying parameters the element and the levels. In this L9 orthogonal array activity is Implemented to utilize all the control parameter by the execution of wire electric discharge machining. The Grey relational gives multidisciplinary approaches to manage assessment and one of a kind exhibiting of framework for which the information is obliged, divided and depicted by arbitrary vulnerability. The Grey based relation examination researches all effect of different components and their association, which is built up as brightening of factor connection. It uses the information from the grey structure to dynamically take a gander at each factor quantitatively.

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The standardized of Taguchi-based experimental design is used in this study is L9 orthogonal array. The normalized output parameter relating to the larger and better criterion which can be formulated as (Eqn.1)

$$Z_{ij} = \frac{y_{ij} - \min(y_{ij}, i=1,2,3,\ldots n)}{\max(y_{ij}, i=1,2,3,\ldots n) - \min(y_{ij}, i=1,2,3\ldots n)} \quad (1)$$

The grey relational coefficient is found out to expresses the connection between the best and genuine institutionalized preliminary come to fruition. Deviation arrangement for the reference and similarity succession are found

3.2 Statistical Analysis

Researching tests were directed according to L9 symmetrical exhibit, entrusting various estimations of the stage to the procedure factors and outcomes were found. Depiction of S/N Ratio esteems from the yield esteems was the starting development. The initial stage to be complete that show the correct response in the term of s/n ratio using two distinct steps as for the highest MMR value is larger the better Eqn.2 and for the lowest surface roughness value is smaller the better Eqn. 3 has been used. and from the Eqn. 4 the deviation sequence and the grey relational coefficient which can be calculate after solving the normalized value of s/n ratio that create direct understanding between best qualities and standardized test results.

$$S / n_{HB} = -10 \log\left[\left(\frac{1}{n}\right)\left(\frac{1}{y_{ij}^2}\right)\right] \quad (2)$$

$$S / n_{LB} = -10 \log\left[\left(\frac{y_{ij}^2}{n}\right)\right] \quad (3)$$

$$\xi_i(k) = \frac{\Delta_{\min} + \xi\Delta_{max}}{\Delta_{oi\,(k)} + \xi\Delta_{max}} \quad (4)$$

Where deviation sequence is Δ0i (k) which required for reference and comparability sequence.

$$\Delta_{oi(k)} = \|y_o\,(k) - y_i\,(k)\| \quad (5)$$

$$\Delta_{min} = \min_{\forall j \varepsilon i} \min_{\forall k} \|\, y_o\,(k) - y_i\,(k)\| \quad (6)$$

$$\Delta_{max} = \max_{\forall j \varepsilon i} \max_{\forall k} \|y_o(k) - y_j\,(k)\| \quad (7)$$

ζ is recognizing or distinguished coefficient and large taken as 0.5, y0(k) and are unique grouping and equivalence succession separately. At that point was assurance of grey relation grade by likening the grey relational grade identifying with every presentation basis as Eqn.8.

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i\,(k) \quad (8)$$

IV. RESULT AND DISCUSSION

Selection of Orthogonal Array

The trial of configuration is done dependent on the Taguchi Method which is procedure dependent on symmetrical cluster of analysis. This method is broadly utilized in various fields of designing to streamline the procedure parameters. Taguchi strategy can diminish innovative work costs by improving the proficiency of age data expected to structure framework that are concentrated to use condition, fabricating variety. Thus, advancement time can be abbreviated fundamentally. The control factors which are consider for the investigation are Pulse on schedule (Ton), Pulse off time (Toff), Wire feed and last one is Wire strain. Components that are to be utilized. In light of number of control variables and their levels, L9 symmetrical exhibit is chosen. The procedure parameter is renamed as elements and they are given in the adjoining section. The degrees of the individual procedure parameters/factors are given in the Table 4.1

Table 4.1 Control factor and Levels

Factors	Level 1	Level2	Level 3
TON	6	8	10
TOFF	8	10	13
WT	6	8	10
WF	7	9	11

Table 4.2 Output parameter (MRR, Ra)

Exp no	Ton	Toff	WT	WF	MRR	Ra
1	6	8	6	7	3.147	2.444
2	6	10	8	9	3.049	2.859
3	6	13	10	11	3.506	3.107
4	8	8	8	11	4.265	3.519
5	8	10	10	7	4.858	2.909
6	8	13	6	9	4.020	2.983
7	10	8	10	9	6.521	2.726
8	10	10	6	11	6.421	3.201
9	10	13	8	7	5.497	3.005

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The value for S/N ratio for different output like material removal rate and surface roughness. The normalized MRR and the surface roughness are shown in the Table 4.3

Table 4.3 S/N Ratio normalize value and deviation sequence

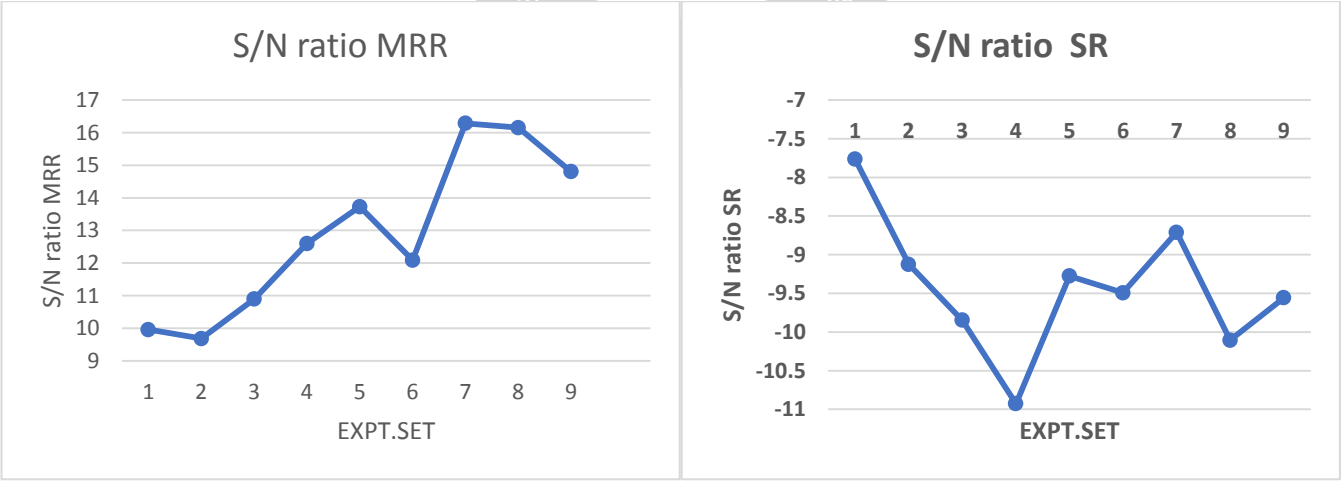
Exp no	Ton	Toff	WT	WF	S/N Ratio MRR	S/N Ratio Ra	Normalize MRR	Normalize Ra	D.S MRR	D.S Ra
1	6	8	6	7	9.957	-7.762	0.0416	0.0000	0.9584	1.000
2	6	10	8	9	9.683	-9.124	0.0000	0.4302	1.0000	0.569
3	6	13	10	11	10.896	-9.846	0.1837	0.6584	0.8163	0.541
4	8	8	8	11	12.598	-10.928	0.4415	0.9999	0.5585	0.000
5	8	10	10	7	13.729	-9.275	0.6127	0.4777	0.3873	0.522
6	8	13	6	9	12.086	-9.493	0.3640	0.5466	0.6360	0.453
7	10	8	10	9	16.286	-8.710	1.0000	0.2995	0.0000	0.700
8	10	10	6	11	16.154	-10.105	0.9801	0.7401	0.0199	0.259
9	10	13	8	7	14.802	-9.557	0.7753	0.5668	0.2247	0.433

From the above table I have mention the S/N ratio, normalized value and Deviation sequence for MMR and surface roughness. Now in next table Grey Relational Coefficient, Grey relational grade and their Rank. Which is shown in the Table 6.4

Table 4.4 Grey Relational Coefficient, Grade and Rank

Exp no.	Ton	Toff	WT	WF	MRR	Ra	Grc MRR	Grc Ra	Grade	Rank
1	6	8	6	7	3.147	2.444	0.342	0.333	0.338	9
2	6	10	8	9	3.049	2.859	0.333	0.467	0.400	8
3	6	13	10	11	3.506	3.107	0.379	0.594	0.487	7
4	8	8	8	11	4.265	3.519	0.472	1.000	0.736	2
5	8	10	10	7	4.858	2.909	0.563	0.489	0.526	5
6	8	13	6	9	4.020	2.983	0.440	0.524	0.482	6
7	10	8	10	9	6.521	2.726	1.000	0.416	0.708	3
8	10	10	6	11	6.423	3.201	0.961	0.658	0.809	1
9	10	13	8	7	5.497	3.005	0.689	0.535	0.612	4

The graph is plotted between the S/N ratio of MRR and the Experimental set. The given figure shows that at experiment no 07, the s/n ratio for MRR is maximum and for the experiment no 02, the s/n ratio for MRR is minimum. At experiment no 07, the value of input parameter is Ton =10, Toff = 8, WT = 10 and WF= 9, and that point the value of MRR is 6.521.



V. CONCLUSION

The experiment is conducted to optimize the different machining parameter, and for the experiment Titanium alloy of grade 5 has taken and the tool for this experiment brass wire has been used of 0.25mm diameter. The model is optimizing with Taguchi method and further for statistical analysis applied to calculate s/n ratio for both material removal rate and surface roughness.

To get the best result for both maximum MRR and the minimum surface roughness a criterion has been used is known as multi-objective criterion and has been solved by using Taguchi method of grey relational analysis process. It

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is found that highest grey relational grade, indicating the initial process parameter set of Ton = 8, Toff = 8, WT = 8, WF = 11, for the best multiple performance characteristics among the experiments.

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