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Optimization of process parameters in WEDM by using GRA technique for machining Aluminum HE15WP

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Abstract— In recent days as the demand of Super alloys are increasing, there is a need of machining these materials with optimum conditions, so that it can be used in industries. The present work includes selection of process parameters while machining aluminum HE15WP alloy in WEDM, understanding the parameter which influences more on output responses such as MRR, Surface roughness and Hardness. Then the Optimum input parameters will be decided by GRA technique .The selected Input parameters are Pulse on time, Pulse off time, wire tension and servo voltage. The experiments will be designed by the help of Taguchi's orthogonal array Technique which will suggest the number of experiments to be performed and also it will suggest the values of input parameters to be chosen. .Then output responses for different experimental setups will be measured. After getting these output responses ANOVA analysis will be done by help of the design expert software to find out the influences of process parameters on the responses. Finally GRA analysis will be done to find out the optimum process parameters to be considered while machining ALUMINIUM HE15WP for getting better MRR, Surface finish and Hardness.

I. INTRODUCTION

Wire Electrical Discharge Machining (WEDM) is a non- traditional process of material removal from electrically conductive materials to produce parts with intricate shape and profiles. WEDM is revolutionized the tool and die, mold, punch, and metalworking and aerospace industries. It is considered as a unique adaptation of the conventional EDM process, which uses an electrode to initialize the sparking process.

However, WEDM utilizes a continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05–0.3 mm. which is capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. The wire work-piece gap usually ranges from 0.025 to 0.05 mm and is constantly maintained by a computer controlled positioning system. In setting the machining parameters, the main goal is the minimum surface roughness. The setting of machining parameters relies strongly on the experience of operators and machining parameters tables provided by machine tool builders.

It is difficult to utilize the optimal functions of a machine owing to their being too many adjustable machining parameters. The surface roughness has a vital influence on most important functional properties such as wear resistance, fatigue strength, corrosion resistance and power losses due to friction. Surface finish produced on machined surface plays an important role in production. Poor surface roughness will lead to the rupture of oil films on the peaks of micro irregularities, which lead to a state approaching dry friction and results in decisive wear of rubbing surface. Therefore finishing processes are employed in machining in order to obtain a very high surface finish. The metal removal rate has a vital role in the manufacturing process. We can get a good surface finish when it has a higher metal removal rate and the time taken for process will be decreases corresponding to MRR.

Analysis of variance (ANOVA)

This method was first developed by Sir Ronald Fisher in the 1930s as a way to interpret the results from agricultural experiments. ANOVA is a statistically based, objective decision-making tool for detecting any differences in average performance of groups of items tested. ANOVA helps in formally testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels.

$$SS_{(total)} = \sum (y_i - y_m)^2$$

Where n is the number of experiments in the orthogonal array and y_i is the mean S/N ratio for the experiment.

The WEDM process is more economical, if it is used to cut difficult to machine materials with complex, precise and accurate contours in low volume and greater variety. The selection of optimum machine setting parameters plays an important role for obtaining higher cutting speed or good surface finish. Improperly selected parameters may also result in serious consequences like short-circuiting of wire and wire breakage. Wire breakage imposes certain limits on the cutting speed that in turn reduces productivity. As surface finish and cutting speed are most important parameters in manufacturing, various investigations have been carried out by several researchers for improving the surface finish and cutting speed of WEDM process. However the problem of selection of cutting parameters in WEDM process is not fully solved, even though the most up to date CNC-WEDM machine are presently available. WEDM process involves a number of machine setting parameters such as applied voltage(V), peak current (I_p), pulse on-time (T_{ON}), pulse off-time (T_{OFF}), range of speed variation (s), servo-voltage(SV), servo-feed(SF), wire feed (WF),wire tension (WT), and water pressure (WP),. The material of work piece and its height (H) also influence the process. All these parameters influences on surface finish and cutting speed. During the last decade, WEDM has become an important nontraditional machining process, widely used in the aerospace, automotive and tool and die industries. WEDM has nearly obtained a monopoly position in some important areas, due to its capability of machining any material with minimum electrical conductivity can be machined with high cutting speed, high precision and satisfying surface finish. 5-axis CNC WEDM machine has been routinely employed in the machining of 3-dimensional complex shape and the surface roughness has improved up to better than 0.2mRa. The range of materials that are machined by WEDM has increased considerably, including now sintered carbides, polycrystalline diamond (PCBN, and specific ceramics).In this report an attempt has been made to analyze the process parameter of WEDM effects on surface roughness and MRR. The experiment have been carried out with Aluminum HE15 as work material, as it is used frequently for aerospace applications and has complex machining characteristics. The experimental design, based on Taguchi's L-9(3) orthogonal arrays, has been used in the present work.

GRA TECHNIQUE

It provides an efficient solution to the uncertainty, multi-input and discrete data problem. The relation between machining parameters and machining performance can be found out by using the Grey relational analysis. This kind of interaction is mainly through the connection among machining Parameters and the same conditions that are already known. In addition, it will indicate the relational degree between two sequences with the help of Grey relational analysis. Moreover, the Grey relational grade can use the discrete measurement method to measure the distance. When the range of the sequence is too large or the standard value is too enormous, it will cause the influence of some factors to be neglected. In addition, in the sequence, if the factors' goals and directions are different, the relational analysis might also produce incorrect results. Therefore, pre-processing of all the data is necessary. This process is the so-called as Grey relational generating. There are two different types:

Higher is better (HB)

$$x_i^*(k) = \frac{X_i^{(0)}(k) - \min X_i^{(0)}(k)}{\max X_i^{(0)}(k) - \min Xi^{(0)}(k)}$$

Lower is better (LB)

$$x_i^*(k) = \frac{\max X_i^{(0)}(k) - X_i^{(0)}(k)}{\max X_i^{(0)}(k) - \min Xi^{(0)}(k)}$$

II. LITERATURE REVIEW

H. Singh et al. , performed a process to determine the effects of various process parameters of WEDM like pulse on time (T_{ON}), pulse off time (T_{OFF}), gap voltage (SV), peak current (IP),wire feed (WF) and wire tension (WT) have been investigated to reveal their impact on material removal rate of hot die steel (H-11) using one variable at a time approach. The optimal set of process parameters has also been predicted to maximize the material removal rate. They observed that the material removal rate (MRR) directly increases with increase in pulse on time (TON) and peak current (IP) while decreases with increase in pulse off time (TOFF) and servo voltage (SV).

Parveen Kr et al. [2], investigate the effect of process parameters of WEDM on MRR of titanium alloy using Taguchi method. The experiment is conducted under different variables of dielectric conductivity, pulse width, time between pulses, maximum feed rate, servo control mean reference voltage, short pulse time, and wire feed rate, wire mechanical tension and injection pressure.

S V Subrahmanyam et al.[3] demonstrate the optimization of Wire Electrical Discharge Machining process parameters for the machining of H13 HOT DIE STEEL, with multiple responses Material Removal Rate (MRR), surface roughness (Ra) based on the Grey–Taguchi Method. taguchi'sL27(21x38) Orthogonal Array was used to conduct experiments, which correspond to randomly chosen different combinations of process parameter setting, with eight process parameters: TON, TOFF, IP, SV WF, WT, SF, WP each to be varied in three different levels.

Anurag Joshi[4], envisaged about the control parameters required for machining of tool steel. EN 31 is used vastly in engineering applications. The work roll of rolling mill and many tools like dies and punches are manufactured by EN 31 and En 31 modified and analyzes the cutting and metal removal rate of tool steel. The Metal removal rate can be controlled by machining parameters which can be controlled and set according to the hardness and cutting speed.

S Sivakiran,et al.[5] made an attempt to study the influence of various machining parameters Pulse on, Pulse off, Bed speed and Current on metal removal Rate (MRR). The relationship between control parameters and Output parameter (MRR) is developed by means of linear regression. Taguchi's L16 (4*4) Orthogonal Array (OA) designs have been used on EN-31 tool steel to achieve maximum metal removal rate.

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Manoj Rana[6] investigate the effects of the various WEDM process parameters on the machining quality and to obtain the optimal sets of process parameters so that the quality of machined parts can be optimized. The machining parameters investigated are Servo voltage, T-on and T-off. A series of experiments are conducted using WEDM. An orthogonal array (L9) has been used to conduct the experiments. The raw data and S/N analysis are employed to find the influence of selected parameters on MRR of D2 tool steel material for cutting on WEDM.

III. EXPERIMENTAL PROCEDURE

Experimental Levels of inputs:

Parameters	Level 1	Level 2	Level 3
Pulse ON time(Ton)	102	108	114
Pulse OFF time(Toff)	54	58	62
Wire Tension(Wt)	8	9	10
Servo voltage(Sv)	18	20	22

Design by Taguchi L9 orthogonal array:

Experiment No.	**Variable 1**	**Variable 2**	**Variable 3**	**Variable 4**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Experimental work is carried on CNC Wire cut EDM Machine shown in Figure. Aluminum HE15WP is chosen as work piece materials and Copper wire is chosen as Cutting Tool. Machining has been done as per the Design Matrix. In this current paper Pulse ON time, Pulse OFF time, Wire tension and Servo voltage are chosen as the influencing parameters for calculating Surface Roughness, MRR, Hardness values are decided after conducting trail experiments.

CNC WIRE cut EDM Machine:

IV. RESULT & DISCUSSIONS

Result table

S. No	**Ton**	**Toff**	**WT**	**SV**	**MRR (mm^3/min)**	**Surface Roughness (R_a)**	**Hardness (HRC)**
1	102	54	8	18	0.000743	2.52	54
2	102	58	9	20	0.000722	2.32	50
3	102	62	10	22	0.000619	2.18	54
4	104	54	9	22	0.00179	3.23	54
5	108	58	10	18	0.001641	3.19	53
6	108	62	8	20	0.001482	3.24	54
7	114	54	10	20	0.001932	3.82	52
8	114	58	8	22	0.002011	3.79	54
9	114	62	9	18	0.001978	3.72	54

ANOVA for metal removal rate (MRR)

Source of variation	DOF	SS	MS	F ratio	Contribution P%
T_{on}	2	0.0766	0.0383	0.823	45.05
T_{off}	2	0.0001334	0.0000667	0.0000143	0.07
Wt	2	0.0004902	0.000245	0.000526	0.28
Sv	2	0.0005715	0.0002857	0.000614	0.33
Error	20	0.093	0.0465	-------	---------
Total	26	0.1707	0.0853	-------	--------

ANOVA for surface roughness

Source of variation	DOF	SS	MS	F ratio	Contribution P%
T_{on}	2	3.121	1.56	12.73	62.13
T_{off}	2	1.618	0.58	4.73	32.211
Wt	2	0.023	0.0115	0.093	0.45
Sv	2	0.0115	0.0057	0.00465	0.22
Error	20	0.245	0.122	---------	----------

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			5	--	
Total	26	5.0185	2.2797	-----------	----------

ANOVA for Hardness

Source of variation	DOF	SS	MS	F ratio	Contribution P%
T_{on}	2	4.30	2.15	9.033	29.05
T_{off}	2	4.20	2.1	8.823	28.38
Wt	2	2.911	1.455	6.113	19.67
Sv	2	2.911	1.455	6.113	19.67
Error	20	0.476	0.238	---------	------------
Total	26	14.798	7.398		

Sample calculation for SS (total)

n=9, y mean=3.11

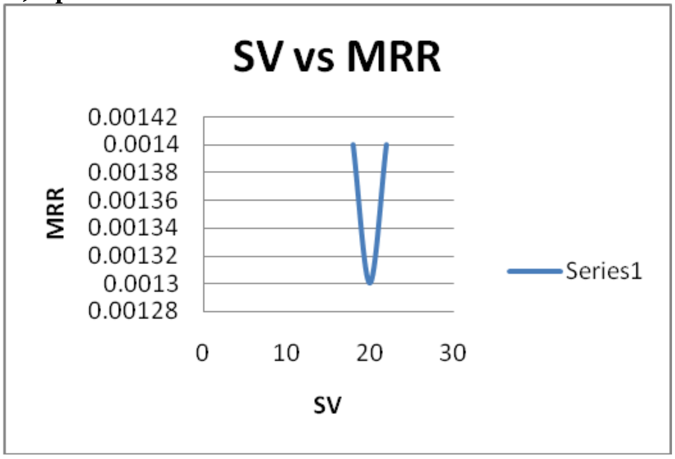
SS total=9.3654

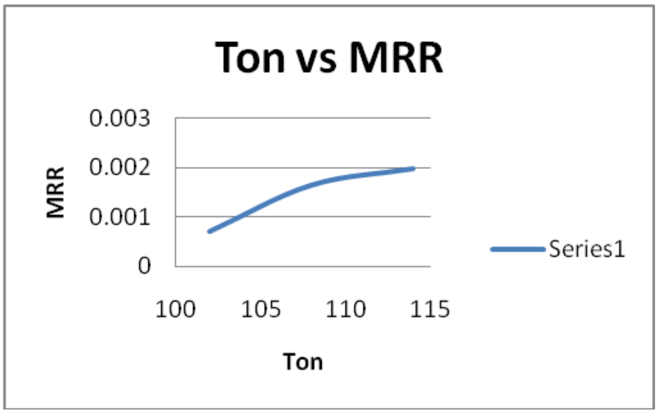
$SS(Ton)=3*((2.34-3.11)^2+(3.22-3.11)^2+(3.77-3.11)^2)=3.121$

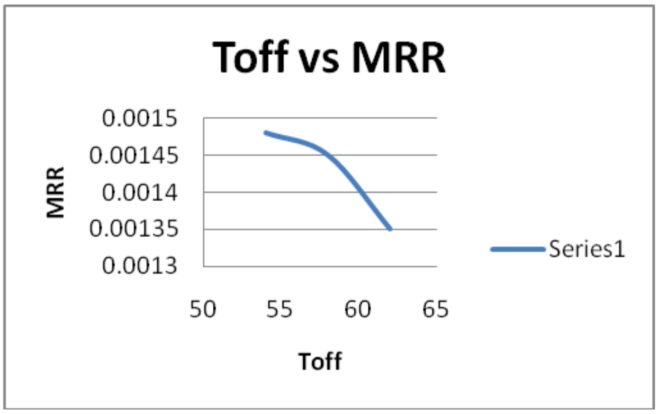
Similarly calculate SS(Toff), SS(WT) and SS(SV).

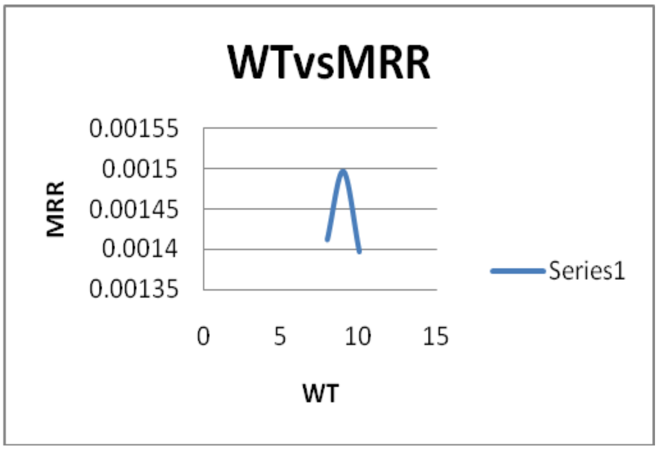
$SS_{error}= SS_{total}-(SS_{Ton}+SS_{Toff}+SS_{WT}+SS_{SV})$

S.No	MRR GRC 1	SR GRC 2	HARDNESS GRC 3	GRC	RANK
1	0.3372	0.3658	1	0.5676	5
2	0.3352	0.3495	0.6666	0.4504	9
3	0.3290	0.3378	0.7777	0.4815	8
4	0.4332	0.3931	0.8333	0.5525	6
5	0.4736	0.4231	0.7090	0.5354	7
6	0.4862	0.4465	0.8333	0.5886	4
7	0.5440	0.5256	0.7857	0.6184	3
8	0.6010	0.5799	0.8125	0.6644	2
9	0.6399	0.6135	0.8333	0.6955	1









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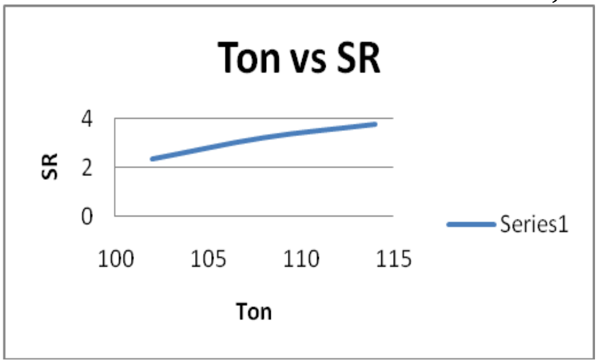

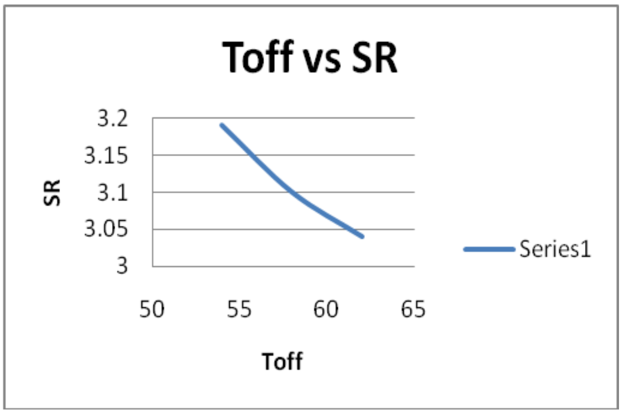

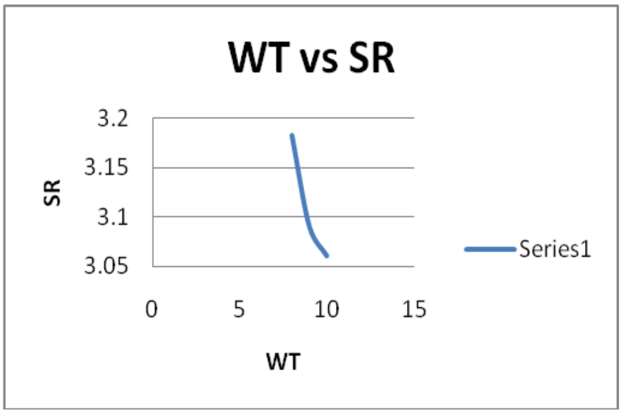

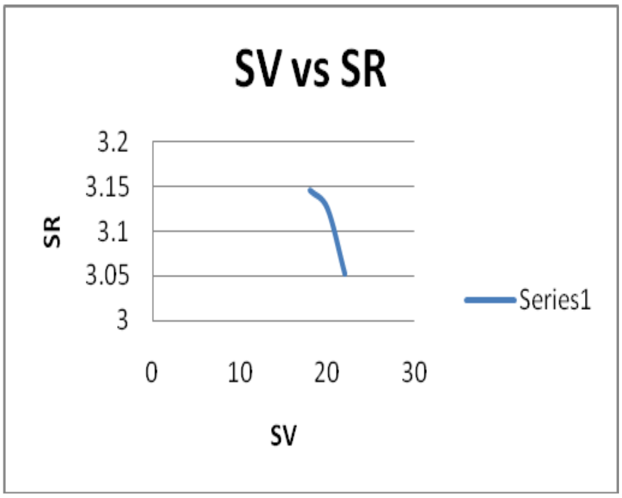

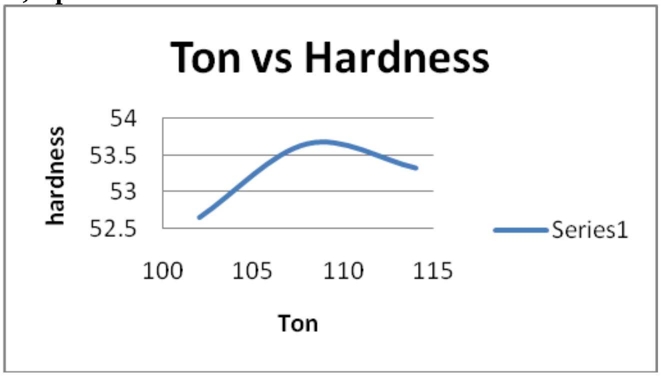

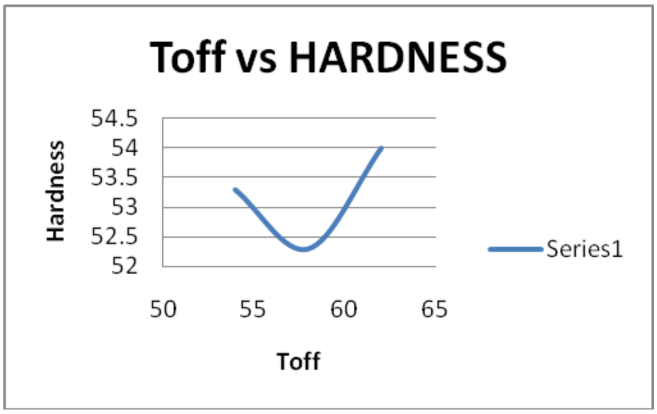

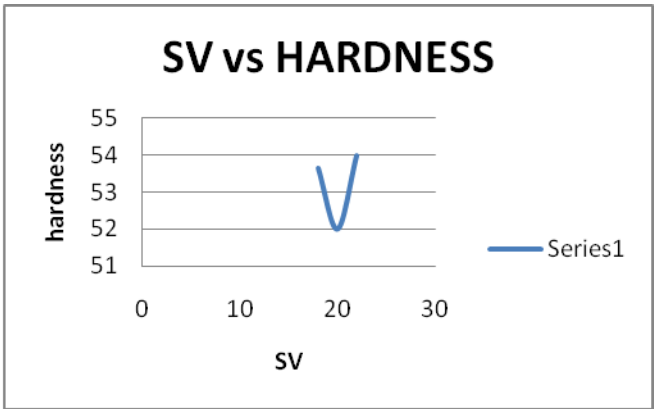

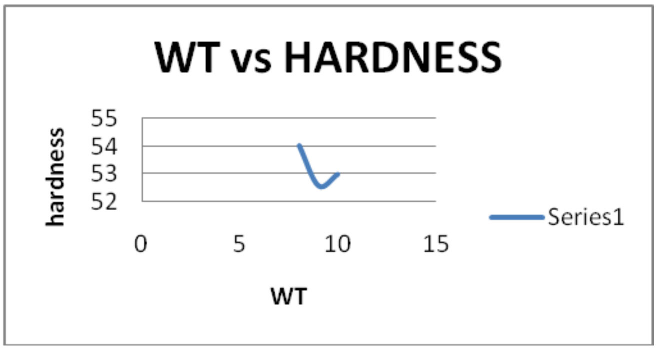

V. CONCLUSION

The present work has been carried out on a new material Aluminum HE15WP, and is a high temperature resistant and high strength to weight ratio alloy. In this study, an attempt was made to determine the significant machining parameters for performance measures surface roughness, MRR and Hardness in the WEDM process.

In GRA analysis, the optimal parameters found are in the experiment set up 9.

The optimized parametric combination is that of experiment 9 where the parameters are as:
Ton=114, Toff=62, WT=9, SV=18

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