Investigation Of Parameters Influencing AL6351 Surface Finish And Material Removal Rate By CNC Wire EDM

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Abstract-**The objective of this work is to machine the AL6351 composite alloy and analyze the effect of machining parameters like pulse on time, pulse off time, peak current on the material removal rate and surface roughness of work piece by using Taguchi's orthogonal 12 arrays and then segregating the parameters as per the performance relative rank by ANOVA technique and predicting the results for improving the surface finish at different parameters.**

Keywords—(WEDM,MRR, surface roughness, AL6351)

I. INTRODUCTION

Aluminium is a widely used material because of its low weight ratio and good thermal conductivity, aluminium 6351 alloy is used for making scuba diving cylinders and this alloy has never been investigated by wire EDM machining. Aluminium alloy has special characteristics like of good thermal conductivity. Wire EDM is considered as the advancement to the conventional EDM where in case of wire electric discharge machining all kind of shapes can be cut with required surface finish and the wire is of 0.25 mm dia. It consists of main worktable, wire drive-mechanism, a CNC controller, working fluid tank and attachments. Breakdown of the cutting tool is due to higher stresses applied behind the cutting edge because normal stresses on the tool are roughly twice as high for machining nimonic alloy as for machining steel under the same cutting parameters [4].The work piece is placed on the fixture table and it‘s clamped properly for machining. The table can move in x and y direction and it‘s driven by DC motors. Wire electrodes usually used are copper, brass, molybdenum or tungsten of diameter range from 0.05-0.30mm, which converts electrical pulses into thermal energy through which material is cut or removed. The wire is wounded around the wire drum and is made to allow rotating at maximum 1500 rpm. The wire is fed from wire drum which moves through the work piece and is supported under wire tension between a pair of wire guides located at the opposite sides of the work piece. During whole WEDM there is no mechanical contact between the wire (electrode) and the work piece take place thus completely eliminates the mechanical stresses during machining (S. Kim 2005) [3]. The main goals of wire electrical discharge machining (WEDM) manufacturers and users are toachievea better stability and high productivity of the manufacturing process. The investigation on machinability of Aluminium Matrix Composite (AMC) using Wire-cut Electric Discharge Machining (WEDM) machine is constructed

II. LITERATURE REVIEW

The present study focused on the Taguchi experimental design technique of Friction Stir Welds of dissimilar aluminum alloys (AA2024-T6 and AA6351-T6) for tensile properties. Effect of process parameters, rotational speed, Traverse speed and axial force, on tensile strength was evaluated. Optimized welding conditions for maximize tensile strength were estimated in order to improve the productivity, weld quality. Non-linear regression mathematical model was developed to correlate the process parameters to tensile strength. The results were verified by conducting the confirmation tests at identified optimum conditions. [1]

This paper focuses on the effect of post weld heat treatment (PWHT) on microstructure and mechanical properties of dissimilar friction stir welding (FSW) of AA2024-T6 to AA6351-T6. FSW is getting widened to be used to join the aluminum alloys. PWHT of AA2024 and AA6351 aluminum alloys are not reported so far even though these alloys are widely used in aerospace and automobile industries. A post weld solution treatment and subsequent ageing resulted in improvement in mechanical properties (hardness and tensile strength)[2]

The main goals of wire electrical discharge machining (WEDM) manufacturers and users are to achieve a better stability and high productivity of the manufacturing process. The investigation on machinability of Aluminium Matrix Composite (AMC) using Wire-cut Electric Discharge Machining (WEDM) machine is constructed. The aim of this project to determine the most optimum machining parameter that will be increased the machinability of AMC based on material removal rate (MRR). A series of experiments have been performed on AMC reinforced 5 % alumina (Al_2O_3) with dimension 100mm x 3 mm x 4 mm. The test specimens have been cut by using different machining parameter combinations on the Sodick AQ327L WEDM machine in the Teaching Factory of Universiti Malaysia Perlis (UniMAP).The Full Factorial Design of Experiment approach with two levels was used to determine the combination of machining parameter based on Pulse-off time (µs), Servo Voltage (V), and Wire Tension (gf/mm). The result of calculated MRR was analyzed using Regression Analysis Method to determine the mathematical model between machining parameter and machining characteristics. [3]

This paper presents the influence of machining parameters such as cutting forces and surface roughness on the machinability of LM6/ SiCp metal matrix composites at

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different weight fraction of SiCp. Machining tests were carried out at different cutting speed (i.e.30, 68 &103 m/min) and different depth of cuts (i.e.0.5, 1.0 & 1.5mm) at constant feed rate i.e. 0.05 mm/rev to study the machinability of as cast composites. It is observed that the depth of cut and the cutting speed at constant feed rate affects the surface roughness and the cutting forces during dry turning operation of cast MMCs. It is also observed that higher weight percentage of SiCp reinforcement imparts a higher surface roughness and needs high cutting forces. This experimental analysis and test results on the machinability of Al/SiC-MMC will provide essential guidelines to the manufacturers.[5]

Existing manufacturing industries are fronting challenges from these advanced nascent materials viz. Nano material ,ceramics, super alloys, and metal matrix composites, that are hard and difficult to machine, requiring high accuracy, surface quality excellence which affects and increases machining cost. To meet these tasks, unconventional machining processes are being used to achieve optimum metal removal rate, better surface finish and greater dimensional correctness, with a reduced amount of tool wear. Electric Discharge Machining (EDM), a unconventional process, has a extensive applications in automotive, defense, aerospace and micro systems industries plays an outstanding role in the development of least cost products with more consistent quality assurance. Die sinking EDM, Wire electrical discharge machining (WEDM), Dry EDM, and Rotary disk electrode electrical discharge machining (RDE- EDM) are some of the alternate methods of EDM. This paper reviews the recent developments and advances in the field of high performance manufacturing environment using Die Sinking EDM, WEDM, Dry EDM and RDE-EDM. The review is based on prominent academic publications researches. [6]

The improved mathematical model for surface roughness (Ra) prediction in end milling of Al/SiCp MMC. The impacts of spindle speed, feed rate, depth of cut and various percentage weight of silicon carbide are studied on surface roughness. The result obtained using Response Surface Methodology (RSM) gives a good prediction of surface roughness when compared with actual surface roughness[7]

The main objective of this work is to 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. Data related to the each response viz. material removal rate (MRR), surface roughness (Ra) have been measured for each experimental run; With Grey Relational Analysis Optimal levels of process parameters were identified. The relatively significant parameters were determined by Analysis of Variance. The variation of output responses with process parameters were mathematically modeled by using non-linear regression analysis. The models were checked for their adequacy. Result of confirmation experiments showed that the established mathematical models can predict the output responses with reasonable accuracy. [8]

Mathematical and artificial neural network models has been developed relating the machining performance and process parameters. The study shows that the Taguchi's method is suitable to solve the stated problem with minimum number of trails as compared with a full factorial design [9]

III. PROBLEM IDENTIFICATION

From the literature studied so far little has been done on aluminum surface roughness which has lot of scope for machining parameters optimization.Different techniques can be performed for optimum results which would prove effective in future machining.By machining of work piece flushing pressure is curtailed to be constant while doing machining flushing pressure can be varied for avoiding breakage of wire and research can be done on optimizing the value of flushing pressure for future research.Many researchers have encountered a problem of wire breakage; this problem is taken in right direction by applying optimization of factors affecting the wire breakage.

IV. MATERIAL AND METHOD

4.1 Work piece Material

In the experimentation work, material selected is AL6351 which is an alloy, the material is chosen on the basis of very insignificant work especially in machining by WEDM. Total Sixteen experiments or runs are performed on the chosen work piece.

Table1**:** Size of Work piece

S.No	Dimensionns	Units
1	Length	100mm
2	Breadth	86mm
3	Height	33mm

Composition of al6351 includes Si, Fe, Cu, Mn, Mg, Zn, Ti and rest aluminum.

The aluminum 6351 alloy is used in manufacturing tubes and pipes.Aluminum is a silverish white metal that has a strong resistance to corrosion and like gold, is rather malleable. It is a relatively light metal compared to metals such as steel, nickel, brass, and copper with a specific gravity of 2.7. Aluminum is easily machinable and can have a wide variety of surface finishes. It also has good electrical and thermal conductivities and is highly reflective to heat and light.

The typical elastic modulus of aluminum alloys at room temperature (25°C) ranges from 70 to 79 GPa. The typical density of aluminum alloys ranges from 2.6 to 2.8 g/cm3. The typical tensile strength varies between 230 and 570 MPa. The wide range of ultimate tensile strength is largely due to different heat treatment conditions.

4.2 Taguchi Method

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on "ORTHOGONAL ARRAY" experiments which gives much reduced "variance" for the experiment with "optimum settings "of control parameters. Thus the marriage of Design of Experiments with optimization of control parameters to

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obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results. Taguchi suggests signal to noise (S/N) ratio as the objective function for matrix experiments (Phadke 1989, Ross 1996) [10].

Table2: Material Composition andproperties aluminium 6351 alloy

Elements	%	Material properties	Thermal properties
Si	0.70-1.30	Tensile strength-250Mpa	Density:2.6-2.8 g/cm3
Mg	0.40-0.80	Yield strength-150Mpa	Thermal conductivity(k)-176 w/mk
Mn	0.40-0.80	%Elongation-20	
Fe	0.50(max)	Hardness-95	
Zn	0.20(max)	Elastic Modulus:70-80 Gpa	
Ti	0.20(max)	Shear strength-200Mpa	
Cu	0.10(max)		
Cr	0.05(max)		
others			
Remainder	aluminum		

V. EXPERIMENTAL DETAILS

A work piece of dimension 100×86×33 mm3 is placed on the worktable of wire EdM machine and square size 0f 10 mm is programmed to be removed from the work piece. When the reference point is chosen from software and manually placing the work piece the machining can be performed. Basically a set of specimens are cut as per the chosen orthogonal array taguch's design.The machine which is used for conducting experiment is SPRINCUT WEDM CNC incorporated with copper wire

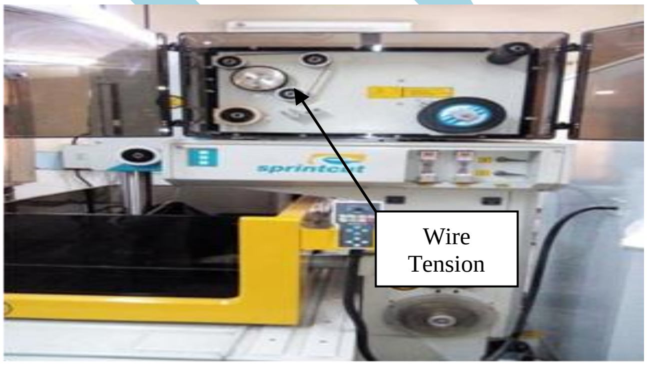

Fig 5.1 WEDM Schematic

The determination of which factors to investigate depends on the responses of interest. The factors which affect the responses were identified using cause and effect analysis, brainstorming and pilot experimentation. The factors selected can be summarized as follows:

a. Two levels of peak current
b. Two levels of pulse on-time
c. Two levels of pulse off-time

The work piece of size (100×86×33) mm is mounted on the work table and then it's clamped to the work table, suitable height of machine tool is set to 38mm for spark generation to the work piece. Square size 0f 10 mm is programmed to be removed from the work piece. When the reference point is chosen from software and manually placing the work piece the machining can be performed. Basically a set of specimens are cut as per the chosen orthogonal array taguch's design. And are shown in fig 2

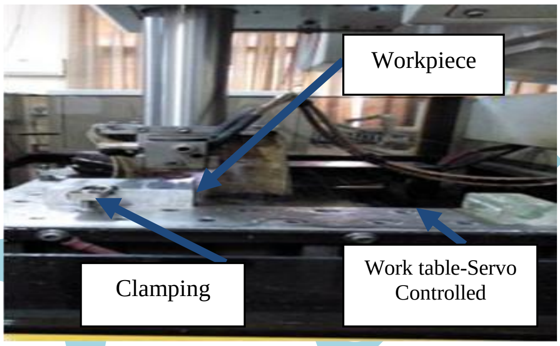

Fig 5.2 Experimental Set up

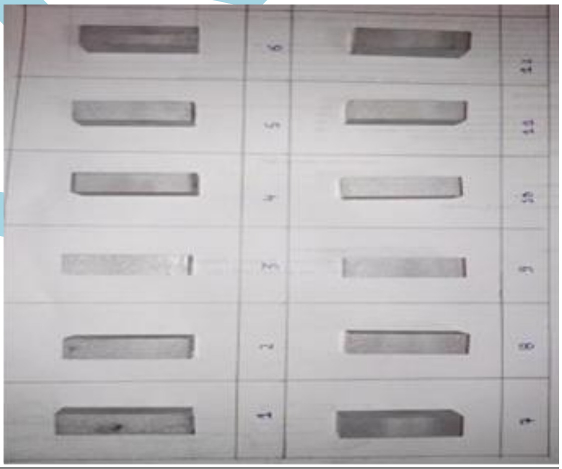

Fig 5.3 Schematic of specimens after experiment

5.1 Measurement of Material removal rate and surface roughness

It is calculated in gm/min which is weight of the material before experiment minus weight of material after the experiment to the time of machining. The machining time can be calculated from either display reading or by using stop watch for taking accurate reading.

Mathematical formula is given as

$$\mathbf{MRR} = \frac{W_1 - W_2}{T}$$

Where, W1= weight of work piece before experiment,
W2=weight of work piece after experiment
T= time taken by the machining of work piece

Surface roughness

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It's the measure of how rough the surface texture. It's checked by the deviations from the ideal surface of the texture. If these deviations are large the surface is rough and if small then the surface will be called finish. Surface roughness is denoted by SR in this project report.The surface roughness in present work is measured by mitutoyo surf test machine which measures the surface roughness on the shop-floor type measurement and it can calculate the surface roughness by stylus placed on the work piece. The results are shown in µm as a reading of surface roughness.

VI. VI. RESULTS AND DISCUSSION

6.1 Results and analysis for SR (surface roughness)

The response table 3 is shown below which gives the result for the 12 runs of experiment for surface roughness and the surface roughness is plotted by the mitutoyo instrument and evaluation profile is generated through instrument. The result table for surface roughness is thus shown below for surface roughness readings.From the results it can easily be predicted what parameter is most significant in achieving the surface finish when doing machining**.**

Table 3: Results for MRR and Surface roughness

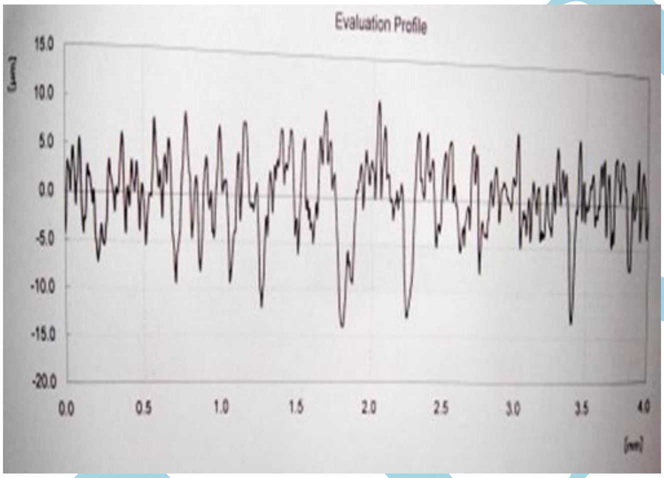

Fig 6.1 Evaluation profile of surface roughness

In the above fig 6.1 which shows the mean value of surface roughness from the ideal value and this value is a measure of how smooth the texture of machined surface.These values are interpreted with the help of response and signal to noise ration for means.

6.2 Results on scatter plots for surface roughness versus pulse on time,pulse off time and peak current

The scater plots are the depiction of how variables are variating with the increase of parameters like pulse on time,pulse off time and peak current and fig 5.2 below shows the plot for effect of increase in pulse on time on the surface roughness whereas fig 5.3 shows the effect of increasing pulse off time on the surface roughness and fig 5.4 shows the effect of increasing the peak current on the surface roughness.

Surface roughness vs pulse on time

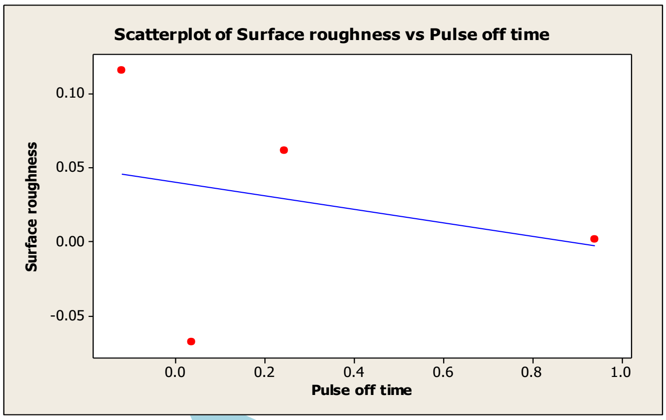

Fig 6.2.1 Scatter plot of surface roughness vs pulse on time

Surface roughness vs pulse off time

S.no of experiment	Pulse on time (T_{on}) (µs)	Pulse off time (T_{off}) (µs)	Peak current (A)	Work piece material	MRR (g/min)	Surface roughness (R_a)
1	119	54	200	AL6351	0.5203	3.313
2	120	55	190	AL6351	0.5030	3.172
3	121	56	180	AL6351	0.4908	1.782
4	122	57	170	AL6351	0.4869	3.515
5	123	58	160	AL6351	0.4466	3.384
6	124	59	150	AL6351	0.4377	3.314
7	125	55	80	AL6351	0.5249	2.893
8	125	60	140	AL6351	0.4388	3.259
9	126	61	130	AL6351	0.4280	3.025
10	127	62	120	AL6351	0.4090	3.281
11	128	63	110	AL6351	0.4395	3.320
12	131	63	100	AL6351	0.3864	3.215

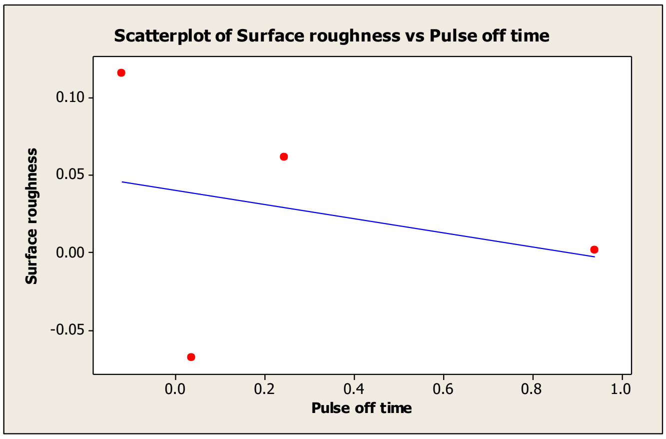

Fig 6.2.3Scatter plot of surface roughness vs pulse off time

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Surface roughness vs peak current

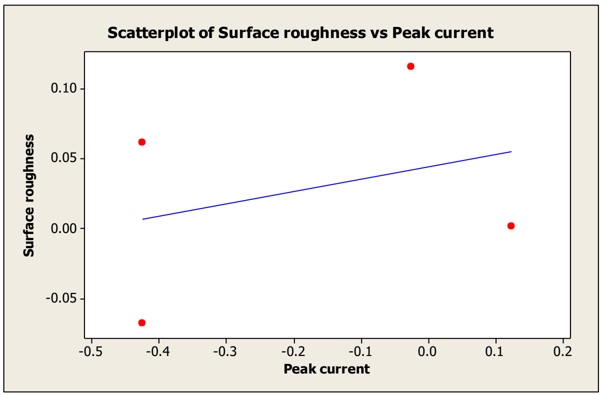

Fig 6.2.4 Scatter plot of surface roughness vs peak current

6.3 Analysis of Variance

The use of S/N ratio is to measure responses to develop products and processes insensitive to noise factor (Cochran and Cox 1992)[12].The results for MRR were analyzed using ANOVA for identifying the significant factors affecting the performance measures. The Analysis of Variance (ANOVA) for the mean MRR at 99% confidence interval is given in table 4.2. F-test was performed on the variance data for each factor to find significance of each. The principle of the F test is that the larger the F value for a particular parameter, the greater the effect on the performance characteristic due to the change in that process parameter. ANOVA table 4.1 for means of MRR shows that as larger value of F is of peak current factor which is 1.0 greater than F value of other factors like pulse on time and pulse of time both coincide with F(0.11).Its clearly evident from F-test value which is greater will influence the MRR more than the smaller values.Thus upon increasing pulse on time while decreasing pulse on time and pilse off time the more material removed by peak current increase only. The main effect plot shows that as the pulse on time is increased,while pulse off time is increased and peak current is decreased the MRR also decreases mainly due to peak current.Other two parameters have a insignificant effect on MRR as compared to peak current.As per the ANOVA for means of MRR table which shows that peak current is the major and pulse on time, pulse off time are the minor factors.

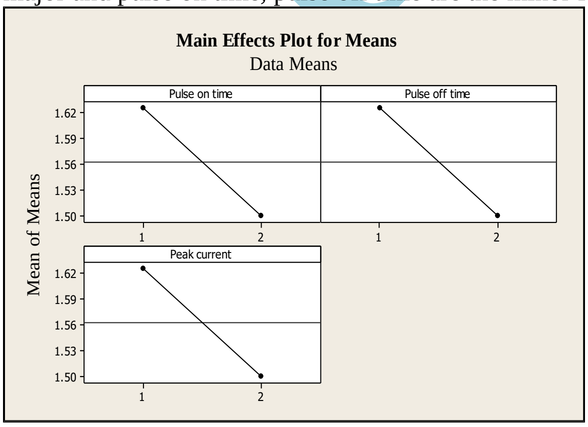

Fig 6.3.1Main effect plot of MRR for means

Main effect plot showing effect of pulse on time.peakcurrent,pulse off time on MRR.

Table 5.3.1 ANOVA for means of MRR

Level	Pulse on time	Pulse off time	Peak current
1	200.00	200.00	200.00
2	190.00	190.00	135.00
3	180.00	180.00	180.00
4	170.00	170.00	170.00
5	160.00	160.00	160.00
6	150.00	150.00	150.00
7	80.00	110.00	140.00
8	140.00	130.00	130.00
9	130.00	120.00	120.00
10	120.00	110.00	105.00
11	110.00	100.00	
12	100.00		
Delta	120.00	100.00	95.00
Rank	1	2	3

Table 5.3.2 Response for Signal to Noise Ratios (Larger is better)

Source	DF	Seq SS	Adj MS	F	P
Pulse on time	1	0.03125	0.03125	0.11	0.795
Pulse off time	1	0.03125	0.03125	0.11	0.795
Peak current	1	0.03125	0.03125	1.0	0.795
Residual error	1	0.28125	0.28125		
Total	4	0.321			

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Table 5.3.4. Response for Means for MRR

Level	Pulse on time	Pulse off time	Peak current
1	46.02	46.02	46.02
2	45.58	45.58	41.82
3	45.11	45.11	45.11
4	44.61	44.61	44.61
5	44.08	44.08	44.08
6	43.52	43.52	43.52
7	38.06	40.49	42.92
8	42.92	42.28	42.28
9	42.28	41.58	41.58
10	41.58	40.83	40.41
11	40.83	40.00	
12	40.00		
Delta	7.96	6.02	5.61
Rank	1	2	3

VI. CONCLUSIONS

After conducting various experiments by changing the process parameters, different results are obtained for MRR and for surface finish. Also the levels of importance have been calculated by ANOVA on the Taguchi's design view. In the previous chapters the design of experiment has been made and from technique of Taguchi's the result response table are obtained which suggests that some parameters are very important in this work like peak current and then the minor parameters which also affect the MRR but not to the great extent. The important analysis of results has been discussed below as:

- The different process parameters have been set for the pilot experiment to analyse their effect on MRR, surface roughness and surface finish.
- It's concluded that by F-test the important parameter for MRR is peak current and then pulse on time and pulse off time.
- Out of factors like pulse on time, pulse off time, peak current the most important factor highlighted by applying ANOVA is peak current which frequently changes the machining time and MRR is found to be increased when peak current is allowed to increase from its previous value.
- It's observed that upon increasing the pulse on time the surface roughness value gradually increases which suggests that surface is getting more rough, while increasing pulse off time the surface roughness decreases which suggests that surface is getting more smooth so this is the major parameter in this work while in case of peak current the surface roughness increases abruptly.

6.1 Future scope

- As the AL 6351 machined under this project parameters which are quite reasonable to predict the material properties which can also be utilized for reaching to good surface finish.
- Machining of AL 6351 predicts that it is easy to machined but under certain parameters it can also not show the expected results and these are like low pulse on time which can further be investigated with proper conditions.

REFERENCES:

[1]. J.Kapoor, S. Singh and J.Khamba, 2010, "Recent Developments in Wire Electrodes for High Performance WEDM", Proceedings of the World Congress on Engineering, Vol.2, pp.1-4.

[2]. S.Kalpakjian and S.Schmid, 2009, "Manufacturing process for engineering materials",Pearson education, South Asia.

[3]. S. Kim (2005), "Determination of Wall Thickness and Height Limits When Cutting VariousMaterialswithWireElectricDischargeMachining", BrighamYoungUniversity,Utah.http://contentdm.hb.byu.edu/ETD/iniage/etd757.pdf.

[4]. R. Agarwal (2010), "Optimization of Process Parameters of Micro Wire EDM", Department of Mechanical Engineering, National Institute of Technology, Rourkela.

[5]. Rabindra Behera1, S. Das[1], D. Chatterjee[2], G. Sutradhar[3]*Forge ability and Machinability of Stir Cast Aluminum Alloy Metal Matrix CompositesJournal of Minerals & Materials Characterization & Engineering, Vol. 10, No.10, pp.923-939, 2011

[6]. Manish Vishwakarma*, Vishal Parashar**, V.K.Khare*** ,Advancement in Electric Discharge Machining on metal matrix composite materials in recent: A Review,International Journal of Scientific and Research Publications, Volume 2, Issue 3, March 2012,ISSN 2250-3153

[7]. R. Arokiadass[1], K. Palaniradja[2], N. Alagumoorthi[3] , Surface roughness prediction model in end milling of Al/SiCp MMC by carbide toolsInternational Journal of Engineering, Science and Technology Vol. 3, No. 6, 2011, pp. 78-87.

[8]. S V Subrahmanyam*, M. M. M. Sarcar** International Journal of Scientific and Research Publications, Volume 3, Issue 3, March 2013 1 ISSN 2250-3153.

[9]. Pujarisrinivasarao[1],Dr.Koonaramji[2],Prof.Beelastyanarayana[3]PujarisrinivasaRao et al. / International Journal of Engineering Science and Technology Vol. 2 (12), 2010, 7729-7739.

[10]. [10] Phadke, M.S, 1989. Quality Engineering Using Robust Design. 1st edition. Prentice Hall: New Jersey.

[11]. [12] William G. Cochran, Gertrude M. Cox, 1992. Experimental Designs, 2nd Edition, Wiley.

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