Inflation of Environmental – Friendly Machining Parameters on Aluminium 6063 In Its Annealed and Unannealed form

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Abstract**--** **The cost of using coolant in machining industry world-wide is very high. It costs multi-billion Dollars for coolant acquisition and disposition in developed countries. Further the chemicals substances in coolant are very harmful to environment and workers in machine shop. Future trend is inexorably use of dry machining. This project applied the designs of experiments (DOE) approach to optimize parameters of a computer numerical control (CNC) in end milling for Aluminum 6063 alloy and its annealed form under dry machining. The work piece employed was in the form of rectangular block of 100 mm length, 100 mm breadth and 25 mm depth. For various combination of cutting speed, depth of cut and feed rate, the material was milled. The groove difference (i.e., dimensional accuracy of groove width) and the roughness average at the bottom plane of the inside groove (i.e., the plane of end milling) were deliberate. Based on a Taguchi orthogonal array table the Planning of experiments are done. By adapting the method using analysis of variance (ANOVA) to identify the influential factors on the CNC End milling process is formulated. And applying regression analysis a mathematical predictive model for predictions of the groove difference and the roughness average has been developed in terms of cutting speed, feed rate, and depth of cut. Additionally, the annealed form of Aluminum 6063 is machined and optimized in similar way to give better prospective about the project. The feed rate is found to be the most significant factor affecting the groove difference and the roughness average in end milling process for Aluminum 6063.**

Index Term**--** **Environmental– Friendly Machining, DOE, ANOVA and End milling Process.**

1. INTRODUCTION

The increasingly stricter environmental – friendly regulations and their enforcement are eliminating much of the flexibility in the use of cutting fluids. As for now cutting fluid manufacturers are developing new formulations, for e.g. without Pb, or S, elements which improves machinability but detrimental from a health and environmental point of view. It will take a long step before the cutting Fluids can be considered totally harmless and adequate. The costs allied with the employ of cutting fluids is estimated to be several billion $/year. Consequently, elimination on the use of cutting fluids, if feasible, there can be a significant economical inducement. Considering the high cost connected with the utilize of cutting fluids and projected escalating costs when the stricter environmental laws are obligatory, the choice seems noticeable. In such a scenario, dry machining provides a solution. However, to pursue dry machining, one has to balance for the several beneficial effects of the cutting fluids without actually using them. A formidable dispute is one that can perhaps be approached step by step. It may even be essential for industry to lower their expectations by cutting back on speeds or removal rates (if the tool materials cannot withstand the stringent conditions of dry machining) when forced to limit or not use cutting fluids. An approach towards dry machining is to advance the properties of the tool material by making them more refractory, or generate less heat during machining (reduce both friction and shear energies), and/or take away the heat generated hurriedly in dry machining by some other means. There has been a constant development of tool materials over this century starting with ceramics, high-speed steels, cast cobalt alloys, cemented tungsten carbide, cast cobalt alloys, coated HSS and coated carbides, diamond and cubic boron nitride. However, the need to machine increasingly more and more difficult-to-machine materials and at increasingly higher and higher cutting speeds, is constantly imposing pressure for the development of new tool materials.

Machining Aluminum alloys with conventional tools is not carried out without any difficulties. These materials tend to adhere to the tool surface and burrs are formed inside the holes. The tool damage is mainly caused by the formation of an adhesion layer and a built-up edge (BUE) entailing a reduction of the tool life. Thus, cutting fluids have an important role in machining process, because they contribute to the reduction of friction in the tool–work piece contact.

- The chip removal from the tool rake face.
- The drop in temperature at the contact zone.
- The constraint of the chemical species diffusion from the tool towards the chip and vice versa.

Eyup Bagci et al.[2005] [1]., In this work, effects of drilling parameters (feed rate, drilling depth and spindle speed) on the drill bit temperature and thrust force in the dry drilling of Al 7075-T651 material were experimentally investigated. At some stage in dry drilling experiments, thrust forces and drill bit temperature were measured. Drill temperatures were deliberate by inserting standard thermocouples through the coolant (oil) hole of TiN/TiAlN- coated carbide drills. The settings of drill parameters were determined by using the Taguchi experimental method. An orthogonal array, the signal to noise ratio(S/N), and the analysis of variance (ANOVA) are employed to analyze the effect of drilling parameters. The intention was to establish a model using multiple regression analysis between spindle speed, feed rate, drilling depth, and drilling method with the drill bit temperature and thrust force in a Al 7075-T651 alloy material. The study shows that the Taguchi design method is suitable to solve the problems with a minimum number of trials as compared with a full factorial design. Ay Mustafa et al [2011] [2], Aluminum and aluminum alloys are vital to the aerospace production. They are of great significance to other areas of transportation and building in which strength, durability and light weight are required. In this study, an experimental examination on surface roughness, cutting forces and cutting temperature in turning of aluminum 7075 alloy using diamond like carbon (DLC) coated cutting tools was presented. The effects of the feed rate, cutting speed and depth of cut on cutting temperature, surface roughness and cutting force were examined. In order to inflate the experimental results, Taguchi optimization design method was utilized. The effect of each constraint on the obtained results was determined by the use of analysis of variance (ANOVA). The relationship between dependent and independent parameters was modeled with regression analysis. The finest machinability of Al 7075 alloy with DLC coated insert was successfully determined in this study. Chorng-JyhTzeng [2008] [3], this study investigated the optimization of CNC turning operation parameters for SKD11 (JIS) using the Grey relational analysis method. 9 experimental runs based on an orthogonal array of Taguchi design method are performed. The surface properties of roughness average and roughness maximum as well as the roundness were selected as the quality targets. An optimal parameter mixture of the turning operation was obtained via Grey relational analysis. The degree of influence for each controllable process factor onto individual quality targets can be found, by analyzing the Grey relational grade matrix. The depth of cut was identified to be the most influence on the roughness average and the cutting speed is the most influential factor to the roughness maximum and the roundness. Additionally, the analysis of variance (ANOVA) is also applied to identify the most significant factor; the depth of cut is the most significant controlled factors for the turning operations. Raviraj Shetty et al. [2008] [4], discusses the use of Taguchi and response surface methodologies for minimizing the surface roughness in turning of discontinuously reinforced aluminum composites (DRACs) having aluminum alloy 6061 as the matrix and containing 15 vol. % of silicon carbide particles of mean diameter 25 µm under pressured steam jet approach. The calculated results were then collected and analyzed with the help of the commercial software package MINITAB15. The experiments are been conducted using Taguchi's experimental design technique.

2. NEED FOR STUDY

This study intends to prove that milling without cutting fluid is feasible with optimized cutting conditions. Several experiments under various cutting conditions are conducted with the help of design of experiment. In general usage, design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is available, whether under the full control of the experimenter or not. On the other hand, the data's of these terms are usually used for controlled experiments. Proper planned experimentation is often used in evaluating chemical formulations, physical objects, components, structures and materials. In the design of experiments (DOE), the experimenter is often interested in the effect of some process or intervention (the "treatment") on some objects (the "experimental units"), which may be people, groups of people, plants, parts of people, animals, etc. Design of experiments (DOE) is a discipline that has very broad application across all the natural and social sciences and engineering.

3. EXPERIMENTAL TESTING

3.1. Material

This alloy is named as the 6063 Aluminium alloy. Al–Mg–Si alloy is also known as decorative alloy and architectural, because of its distinctly superior finishing quality; easy extrude ability property and strength. It has a good surface finish, high corrosion resistance which is readily suited to welding and can be easily anodized. The applications for Aluminium alloy 6063 used in Architectural, extrusions, shop fittings, doors, windows frames, irrigation tubing.

3.2. Chemical Composition

A scrap piece of Aluminum 6063 was given for testing of chemical composition which provided the following results given in Table 1.

Sample description: Aluminum slab

Table I
Chemical composition of Aluminium 6063

FE%	Si%	Mn%	Cu%	Ni%	Cr%	Ti%
0.341	0.581	0.096	0.026	0.007	0.000	0.041
Sn%	V%	Co%	Zn%	Pb%	Mg%	Al%
0.000	0.007	0.000	0.003	0.019	0.460	98.399

Table II
Physical Properties of Aluminium 6063

Property	Value
Density	2700 kg/m^3
Melting Point	600°C
Modulus of Elasticity	69.5 GPa
Electrical Resistivity	0.035x10^{-6} Ωm
Thermal Conductivity	200 W/m K
Thermal Expansion	23.5 x 10^{-6} /K

3.3. Annealing

Aluminum 6063 slab is prepared for dimension of 100mm x 100mm x25 mm. The slab is kept in furnace for 4 hours at temperature of 350℃and then cooled with controlled temperature of 25℃ per hour till it reached 250℃.Then the slab cooled itself in furnace. The process helped in stress relieving the specimen and hence increasing the ductility and softening the work piece.

Fig. 1. Muffle furnace for annealing

3.4. CNC Vertical Machine Setup

Investigations of dry milling process were carried out at the Vel Tech University, special machine shop. Test was built on the basis of CNC vertical machine, manufacturers of MTAB with a model Sreyas - CNC Drill Tap Center, Maximum transverse (X- Axis) 480mm, Maximum transverse (Y- axis) 360 mm, Maximum transverse (Z- axis) 270 mm with a table base of 600 * 350mm and a spindle bore of A40 and position of accuracy 0.01mm (JIS standard) and repeatability of 0.005mm (JIS standard) and range of spindle speed 100-10000Rpm.

Fig. 2. CNC Vertical Machine Centre

3.5. Schematic Milling Operation

Fig.3. shows the milling machining setup of end milling process. The experiments were carried out on a rigid CNC machine centers (Sreyas - CNC Drill Tap Center), manufactured by MTAB with a capacity of 15kwa and a spindle speed is from 100 – 10000 rpm. The machine tool adapted by this investigation is HSS end mill cutter. The tool used is “12mm diameter tapered shank end mill cutter”.

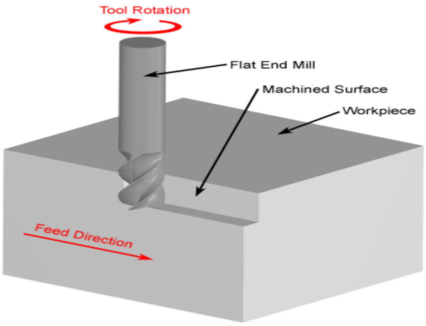

Fig. 3. End milling schematic diagram

3.6 Surface Roughness Tester

The surface roughness instrument using TR200 to find the roughness of any surface having a dimension of standard model TS200 and inductive diamond tip radius 5µ and a bore from diameter 6.00mm, depth 15mm (TS 100). The Ra values were found at three different places on each sample, their mean average value was taken as the final value. Since the surface might be not even at all places. It is checked at three different places.

Fig. 4. Surface roughness measured using TR200

3.7. Brinell Hardness Test and Measurement

The Brinell hardness tests were made by a commercial Vel Tech University Strength laboratory in accordance with ASTM E10-12 using commercial standardizing brinell hardness machine. The value of Brinell Hardness Number is calculated using the formula shown on formula HB=2f /πD(D-(sqrtD^2-d$^{2)}$.The Brinell number in case of our Aluminium6063 unannealed and annealed specimen for 500kgf load and 10 mm diameter is 70 and 58 respectively.

3.8. Experimental Design

The product qualities of machining are always affected by the process parameters such as the cutting speed, the feed rate, and the axial depth of cut, etc. In this study, further processing procedure for dry machining of Aluminium6063 is experimented using the end milling.

For the process to be implemented coding was done in the CNC milling machine and programmed in such a way that helps to obtain various parameters combination for machining. The input parameters of feed rate, speed and depth of cut are changed while machining with different combinations to get various input data. As a result the output parameters in the form of surface roughness are obtained. The rectangular slab specimens for both annealed and unannealed forms have the dimension of 100mm length, 100 mm breadth and 25 mm width.9 trials were completed during the experiment with various feed rate, speed and depth of cut values which is given in Table III.

Table III
Machining parameters used in milling

TRIALS	CUTTING SPEED(mm/sec)	FEED RATE(mm/rev)	DEPTH OF CUT(mm)
1	300	0.05	1.0
2	600	0.05	1.0
3	900	0.05	1.0
4	300	0.10	0.5
5	600	0.10	1.0
6	900	0.10	1.5
7	300	0.05	0.5
8	600	0.10	0.5
9	900	0.15	0.5

3.9. Machining Operation

The specimen is machined in CNC Vertical milling Centre with HSS tool at various machining feed rate, cutting speed and depth of cut combinations. While machining for unannealed specimen, the milling was smooth and observation on surface indicates it, shown in Fig.5 & Fig.6. For annealed specimen the tool showed vibration while cutting for increase in feed rate with other parameters remaining constant. Also for increase in depth of cut adhesion layers were formed on specimen due to heat. Hence very uneven surface is formed in that part of specimen. It clearly indicates that the machinability character has reduced for annealed specimen. It can be seen in Fig.7 & Fig.8.The surface roughness test is performed using TR200 surface roughness meter at three points and the average roughness coefficient is tabulated in table 4 and table 5 for annealed Aluminium 6063 unannealed Aluminium respectively.

Fig .5. Machined Unannealed Aluminium 6063 side 1.

Fig.6. Machined Unannealed Aluminium 6063 side 2.

Fig. 7. Machined annealed Aluminium 6063 side 1

Fig. 8. Machined annealed Aluminium 6063 side 2

Table IV
Surface roughness coefficient for annealed Aluminium 6063

Trials	Feed rate (mm/ rev.)	Cutting speed (mm/ sec)	Depth of cut (mm)	Surface roughness (Ra x 10^{-6})			
				1	2	3	mean
1	0.05	300	1.0	2.652	2.753	2.965	2.832
2	0.05	600	1.0	1.645	1.743	1.821	1.753
3	0.05	900	1.0	1.655	1.824	2.003	1.888
4	0.10	600	1.5	2.146	2.268	2.365	2.238
5	0.10	600	1.5	2.435	2.589	2.754	2.625
6	0.10	600	1.5	2.883	2.995	3.103	3.004
7	0.05	900	0.5	1.754	1.869	1.921	1.886
8	0.10	900	0.5	2.355	2.562	2.694	2.564
9	0.15	900	0.5	2.542	2.599	2.793	2.634

Table V
Surface roughness coefficient for unannealed Aluminium

Trials	Feed Rate (mm/ rev)	Cutting Speed (mm/ sec)	Depth of Cut (mm)	Surface Roughness (Ra x 10^{-6})			
				1	2	3	Mean
1	0.05	300	1.0	0.721	0.831	0.934	0.841
2	0.05	600	1.0	0.890	0.965	1.103	0.952
3	0.05	900	1.0	1.124	1.156	1.780	1.159
4	0.10	600	0.5	1.034	1.244	1.446	1.301
5	0.10	600	1.0	2.012	2.084	2.123	2.062
6	0.10	600	1.5	0.965	0.974	1.002	0.983
7	0.05	900	0.5	1.324	1.550	1.703	1.552
8	0.10	900	0.5	1.903	1.954	2.032	1.967
9	0.15	900	0.5	2.112	2.245	2.346	2.244

4. RESULT AND DISCUSSION

4.1. Experimental Design Approach

The procedure involved in finding the optimum parameters of surface roughness of Aluminium 6063 is with the help of Design of experiments. The parameter design is the key step in the Taguchi method in achieving high quality without increasing the costs. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. A loss function is then distinct to calculate the deviation between the experimental value and the desired value. Taguchi recommends the employ of the loss function to measure the performance characteristic deviating from the desired value. The value of the loss function is transformed into a signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the higher the better, the nominal-the-better and the lower-the-better. The S/Ratio for each level of process parameters is computed based on the S/N analysis. Despite of the category of the performance characteristic, the better performance characteristic to the larger S/N ratio corresponds. Therefore, the most favorable level of the process parameters is the level with the highest S/N ratio. In addition, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. With S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. In conclusion, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design and the observed data. These S/N ratios are expressed on a decibel scale. Factor levels that maximize the appropriate S/N ratio are optimal. The ambition of this research was to produce minimum surface roughness (Ra) in a milling operation. Smaller Ra values symbolize better or improved surface roughness. Therefore, if the quality characteristics are smaller-the-better was implemented. The Taguchi method, which is a dominant tool in the design of an experiment, is used to optimize the turning parameters for effective machining of Aluminium 6063 in annealed and unannealed state. This design is sufficient to investigate three main effects and the influence of their interactions on the surface roughness. With S/N ratio analysis, the optimal combination of the testing parameters could be found. The control parameters were cutting speed (V), feed rate (f), depth of cut (d). Three levels were specified for reach of the factors. The orthogonal array chosen was L9.The main purpose of the ANOVA is to investigate the design parameters and to indicate which parameters significantly affect the quality characteristic. This analysis helps to find out the relative contribution of machining parameter in controlling the response of milling operation. The optimal parametric setting value will directly influence the objective function for determining the surface roughness.

4.2. Taguchi Method

This paper uses Taguchi method which is commonly used in improving industrial product quality due to the proven success and with the Taguchi method; it is possible to considerably reduce the number of experiments. The Taguchi method is an advantageous technique for high and an experimental design technique. This method is powerful DOE tool, which provide a simple, efficient and systematic approach to determine optimal machining parameters. Taguchi method is based on performing evaluation or experiments to test the sensitivity of a set of response variables to a set of control parameters. The system is to design (or independent variables) by considering experiments in an "orthogonal array" with an aim to attain the optimum setting of the control parameters. Orthogonal arrays provide a best set of well balanced (minimum) experiments The Taguchi technique includes the following steps:

- determine the control factors, determine the levels belonging to each control factor and select the appropriate orthogonal array,
- assigning the control factors to the selected orthogonal matrix and conduct the experiments
- analyzing data and determine the optimal levels of control factors,
- Performing the confirmation experiments and obtain the confidence interval.

4.2.1. Selection of control factors

The most appropriate milling parameters is selected and these are: Cutting speed (*V*) , depth of cut (D)and feed rate (*f*) .The parameters and their levels are shown on the table 6. The three levels given to them are in increasing order of their values.

Table VI
Control Factor and Their Level

Item	Control Factor	Level 1	Level 2	Level 3
A	Cutting speed(mm/sec)	300	600	900
B	Feed rate(mm/rev)	0.05	0.10	0.15
C	Depth of cut(mm)	0.5	1.0	1.5

4.2.2 Orthogonal Array

In the Taguchi method, orthogonal array can provide an effective experimental performance with a minimum number of experimental trials. Thus 9 experiments are conducted on both annealed and unannealed Aluminium 6063 alloy. The orthogonal array is formed and various levels and parameters are provided as combination while machining .Thus, three levels and three parameters help in forming L9 orthogonal array for Taguchi design of experiments given in table VII.

Table VII
L9 Orthogonal Array

Experiment No.	A	B	C
1	1	1	2
2	2	1	2
3	3	1	2
4	2	2	1
5	2	2	2
6	2	2	3
7	3	1	1
8	3	2	1
9	3	3	1

4.2.3. Analysis of the Signal-to- Noise(S/N) ratio

In the Taguchi method, the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value (SD) for the output characteristic. The ratio of the mean to the SD is the S/N ratio. The Taguchi method uses S/N ratio to measure the variations of the experimental design. The equation of "smaller is the better" was selected for the calculation of S/N ratio since the lowest values of surface roughness were the desired results in terms of good product quality. Hence the surface roughness and S/N ratio values are tabulated with mini tab software for the two specimen used in Table 8.The formula used for calculating S/N ratio is given below:

$$\text{S/N ratio (S/N)} = -10 \log_{10} \sum_{i=1}^{n} (y^{2})$$

Where n=no. of factors and y= no. of response value.Thus S/N ratio is calculated and tabulated in Table VIII.

Table VIII
Surface roughness and S/N ratio values for specimen

Expt no.	**Coded values**			**Actual values**			**s/n for unannealed aluminium**	**s/n for Annealed Aluminium**
	A	**B**	**C**	**A**	**B**	**C**		
1	1	1	2	300	0.05	1.0	1.58316	-9.00330
2	2	1	2	600	0.05	1.0	-0.461619	-5.06739
3	3	1	2	900	0.05	1.0	-3.87749	-5.7466
4	2	2	1	600	0.10	0.5	-2.99516	-7.26242
5	2	2	2	600	0.10	1.0	-4.74630	-8.02547
6	2	2	3	600	0.10	1.5	0.17143	-9.51309
7	3	1	1	900	0.05	0.5	-2.12635	-4.98384
8	3	2	1	900	0.10	0.5	-6.41103	-7.94192
9	3	3	1	900	0.15	0.5	-6.99094	-8.39607
	Mean=						-2.8726	-7.3266

From the given Fig.9. Level 1 of A and level 3 of B and level 3 of C gives the maximum effect of improving Surface roughness. Hence, A1, B3 and C3 are the best combination i.e. cutting speed of 300 rpm and feed rate of 0.15 mm/rev and depth of cut of 1.5 mm provides the minimum surface roughness for annealed Aluminium6063.

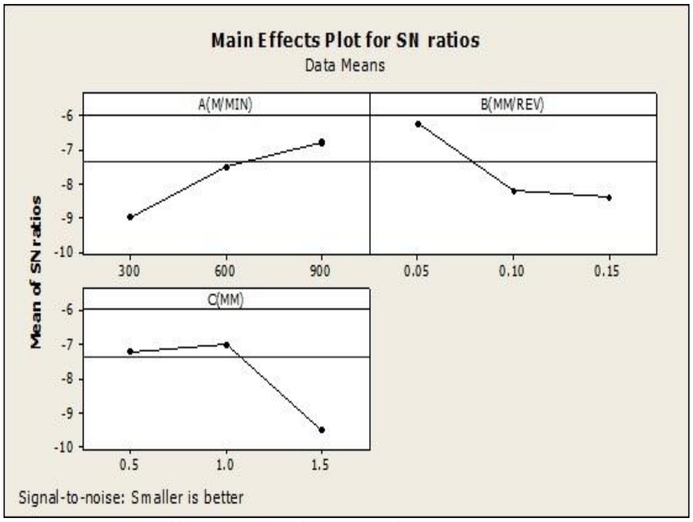

Fig. 9. Factor Effect diagram of S/N ratio for annealed Aluminium specimen

Table.9. Shows response table of S/N ratio of the surface roughness for each level of the factors of Aluminium 6063. The difference of SNR between level 1 and 3 indicates that feed rate (B) contributes the highest effect (Δmax-min= 2.396) on the surface roughness followed by cutting speed (Δmax-min= 2.236) and depth of cut (Δmax-min= 1.552).

Table 9
Response Table for S/N ratio in annealed Aluminium

Level	A(m/min)	B(mm/rev)	C(mm)
1	-9.003	-6.200	-7.146
2	-7.467	-8.186	-6.961
3	-6.767	-8.596	-8.513
Delta	2.236	2.396	1.552
Rank	2	1	3

The graph shown on Fig.10. Shows the main effect of all the three factors on the mean of means of surface roughness.

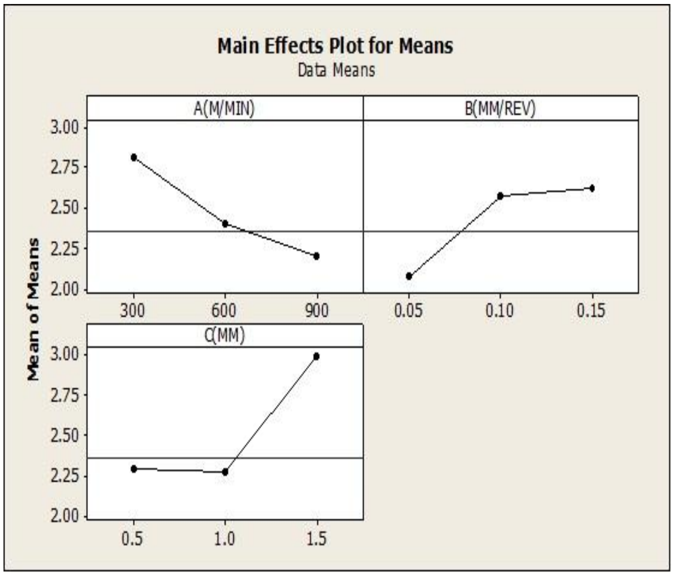

Fig. 10. Mean of Surface roughness means against factors for annealed Aluminium

From the given Fig.11, Level 3 of A and level 3 of B and level 1 of C gives the maximum effect of improving Surface roughness. Hence, A3, B3 and C1 are the best combination i.e. cutting speed of 900 rpm and feed rate of 0.01 mm/rev and depth of cut of 0.5 mm will provide the minimum surface roughness for unannealed Aluminium 6063. Using S/N ratio, factor affecting maximum is determined shown in below Fig.11.

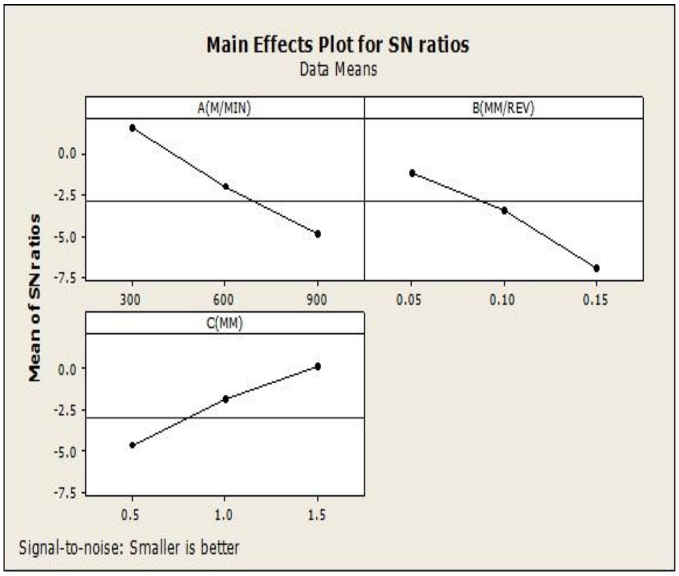

Fig. 11. Factor Effect diagram of S/N ratio for unannealed Aluminium specimen

Table X
Response Table for S/N ratio of unannealed Aluminium 6063

level	a(m/min)	b(mm/rev)	c(mm)
1	1.5814	-0.2210	-4.6309
2	-2.0079	-3.4953	-1.8760
3	-3.8515	-6.9909	0.1714
delta	5.4328	5.7699	4.8023
rank	2	1	3

Table X shows response table of SNR of the surface roughness for each level of the factors of Aluminium 6063. The difference of SNR between level 1 and 3 indicates that feed rate (B) contributes the highest effect (Δmax-min= 5.7699) on the surface roughness followed by cutting speed (Δmax-min= 5.4328) and depth of cut (Δmax-min= 4.8023).The graph shown on Fig.12. Shows the main effect of all the three factors on the mean of means of surface roughness.

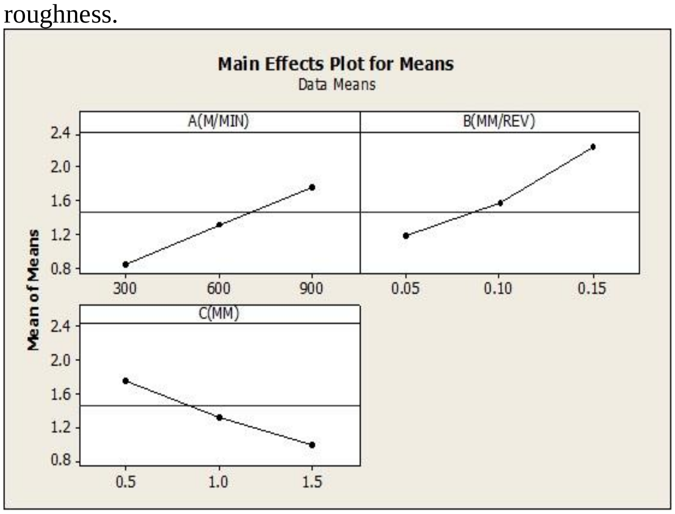

Fig. 12. Mean of Surface roughness means against factors for annealed Aluminium

4.3. Regression Analysis

Multiple regression analysis is performed to indicate the fitness of experimental measurements as presented with statistical software, named as MINITAB. The null hypothesis is that all groups are simply random samples of the same population, in the typical application of ANOVA. This suggests that all treatments have the same effect (perhaps none). Rejecting the null hypothesis suggests that different treatments result in altered effects ANOVA and the Equations of Surface Roughness. The regression analysis is done with surface roughness against the factor with influence on surface roughness. First, a linear polynomial model is developed to control whether the surface roughness data represents a fitness characteristic as below:

Surface Roughness (μ) = $b_o+b_1A+b_2C+b_3C$, where b_1 and b_2 are estimates of the process parameters. The empirical equation is then derived to describe a functional relationship between the surface roughness (T) and process parameters including (A – (spindle speed), B – (feed rate) and C-(depth of cut)) as below for Al 6063 material.

The regression equation for annealed Aluminium is:

Ra = 1.93 - 0.000916 A (M/MIN) + 9.38 B (MM/REV) + 0.372 C(MM)

In multiple regression analysis, R^2, which is called R-sq, is the correlation coefficient and should be between (0.8) and 1. In this study, R2 is found as 0.877 of the value which is greater than (0.8). As seen from this, the multiple regression model for surface roughness match the experimental data. The regression equation for unannealed Aluminium is:

Ra = 0.562 + 0.000768 A (M/MIN) + 8.22 B(MM/REV)+ 0.372 C(MM)

In this study, R^2 is found as 0.975 of the value which is greater than (0.8). As seen from this, the multiple regression models for the surface roughness in unannealed aluminium matches very well with the experimental data.

4.4. ANOVA Analysis

Analysis of Variance (ANOVA is a statistical model tool, used as decision-making tool for detecting any differences in the average performance of groups of items tested. ANOVA helps in properly 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. A statistical hypothesis test is a method of making decisions using data. A test result (calculated from the null hypothesis and the sample) is called statistically significant if it is deemed unlikely to have occurred by chance, supercilious the truth of the null hypothesis. A statistically significant result (when a probability (p-value) is less than a threshold (significance level)) justifies the rejection of the null hypothesis ANOVA results are illustrated in Table. Statistically, there is a tool called an F test to see which design parameters have a significant effect on the quality characteristic. In the analysis, F-ratio is a ratio of mean square error to residual, and is traditionally used to determine the significance of a factor. An F ratio corresponding 95% confidence level in calculation of process parameters accurately is 0.05. The P value reports the significance level (suitable and unsuitable). Percent (%) is defined as the significance rate of process parameters on Surface roughness.

The analysis of variance (ANOVA) was used to investigate which design parameters significantly affect the surface quality. Examination of the calculated values of variance ratio (F), which is the variance of the factor divided by the error variance for all control factors showed a much higher influence of factor feed rate on the surface roughness of the both Aluminium specimens The F value of each design parameters was calculated. A “Model F-Value” is calculated from a model mean square divided by a residual mean square. A test is comparing a residual variance with a model variance. If the variances values are close to the same, the relation will be close to one and it is less likely that any of the factors have a significant effect on the response. In addition, if the “Model P-Value” is (less than 0.05) very small subsequently the terms in the model have a significant effect on the response. Similarly, an “F-Value” on any individual factor terms is calculated from a term mean square divided by a residual mean square. A test is comparing a residual variance with a term variance. If the variances are close to the same, the relation will be close to one and it is less likely that the term has a significant effect on the response. Furthermore, if a “P-Value” of any model terms is (less than 0.05) very small, the individual terms in the model have a significant effect on the response. If a model is adequate the distribution of residuals should be normally distributed. For the normality test, the hypotheses are listed as follows:

1. Null hypothesis: data follow a normal distribution.
2. Alternative hypothesis: data do not follow a normal distribution.

The vertical axis has a probability scale and the horizontal axis with a data scale. A least-squares line is then fit to the plotted points. The line forms an approximation of the cumulative distribution function for the population from which data are drawn. As a “P-Value” that is smaller than 0.05, it will be classified as “significant”, and so the null hypothesis has to be rejected.

The percent numbers depicts that spindle speed and feed rate have significant effects on surface roughness. It can be observed from Table 11 that cutting speed, feed rate and depth of cut affect surface roughness by 17.07%, 37.67% and 26.87% for the Al 6063 annealed material, consecutively. Thus it is clear that the surface roughness have major effect from feed rate followed by cutting speed and then depth of cut. “Model F-Value” of 1.75 with 0.252 of “Model P-Value” suggests that the selected model term “B” is significant.

Table XI
ANOVA Table for annealed Aluminium

variables	Sum of squares	DOF	Mean square	Contribution (%)	F	P
A(m/min)	0.282	2	0.141	17.07	0.62	0.570
B(mm/rev)	0.609	2	0.304	36.87	1.75	0.252
C(mm)	0.444	2	0.222	26.87	1.10	0.391
ERROR	0.316	2	0.158	19.19		
TOTAL	1.651	8				

Fig.13. shows the effect of feed rate on surface roughness at its 3 values for annealed aluminium. Similarly Fig.14. The individual point of fed rate against Ra, hence give idea about various surface roughness for a single value of feed rate. Fig.15. gives residual plots against several parameters such as frequency, percentage, etc. Thus impacts of feed rate on various points are plotted in these graphs.

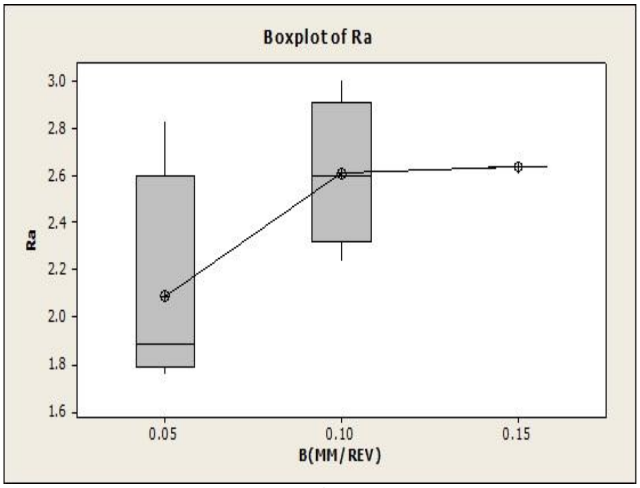

Fig. 13. Box plot graph for annealed Aluminium

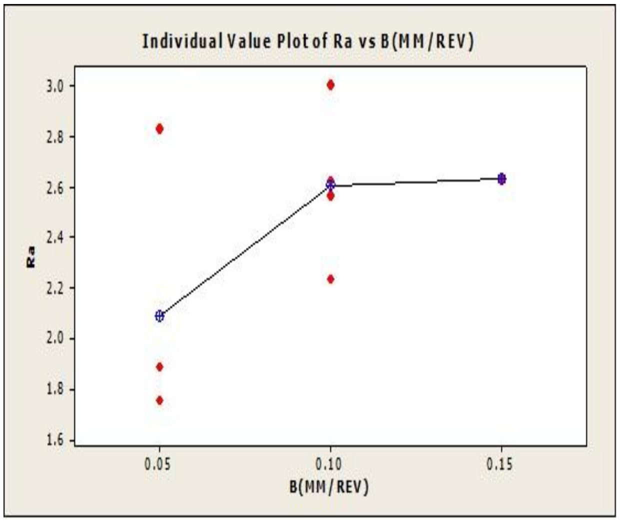

Fig. 14. Individual value Plot of Ra vs feed rate

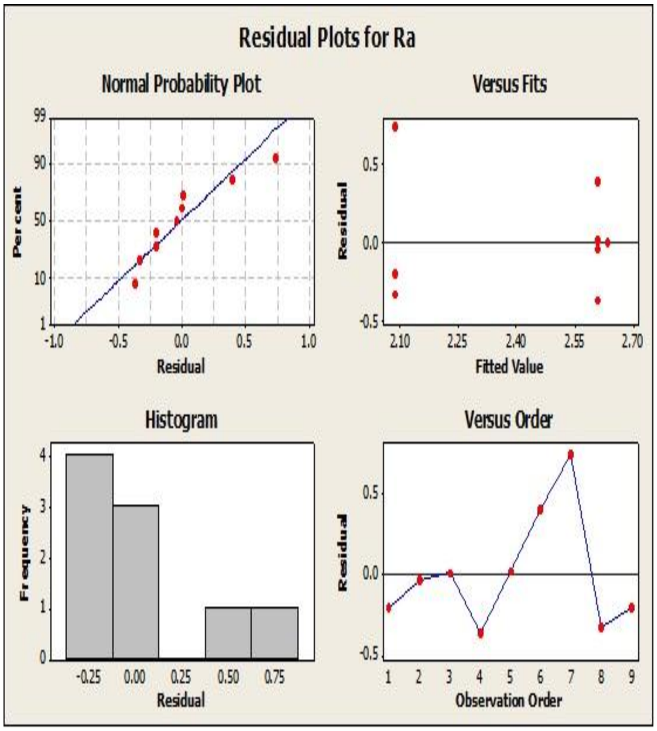

Fig. 15. Residual graph with various parameters for annealed Aluminium

It can be observed from Table 12 that cutting speed, feed rate and depth of cut affect surface roughness by 33.39%, 48.64% and 9.4% for the Aluminium 6063 unannealed material. Thus it is clear that the surface roughness have major effect from feed rate followed by cutting speed and then depth of cut. “Model F-Value” of 2.84 with “Model P-Value” of 0.135 implies that the in selected model “B” is significant.

Table XII
ANOVA Table for unannealed Aluminium

variables	Sum of squares	DOF	Mean square	Contribution (%)	F value	P value
A(m/min)	0.758	2	0.379	33.39	1.5	0.296
B(mm/rev)	1.104	2	0.552	48.64	2.84	0.135
C(mm)	0.213	2	0.364	9.4	0.6774	0.632
Error	0.1946	2	0.097	8.57	-	-
Total	2.270	8	-	100	-	-

Similarly, various graphs are plotted for surface roughness for unannealed aluminium with most significant parameter is feed rate in Fig.16 & Fig.17.Also given is graphs for residual against parameters in graph 4.10.

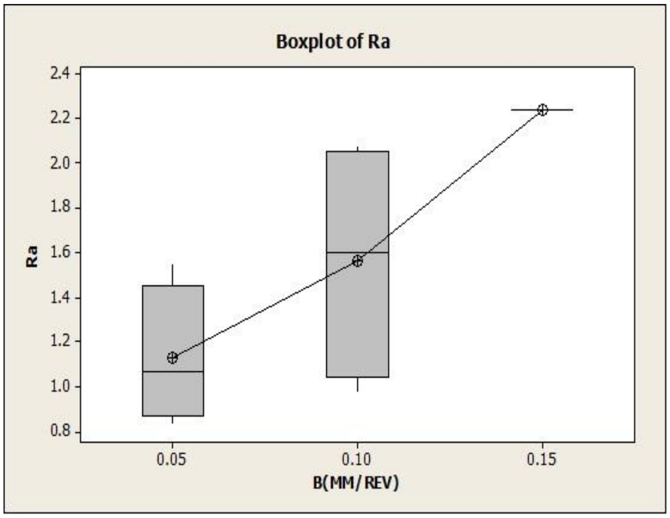

Fig. 16. Box plot graph for unannealed Aluminium

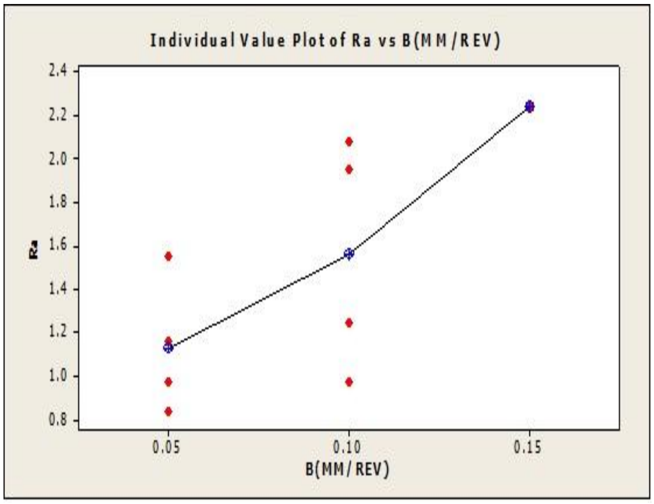

Fig. 17. Individual value Plot of Ra Vs feed rate

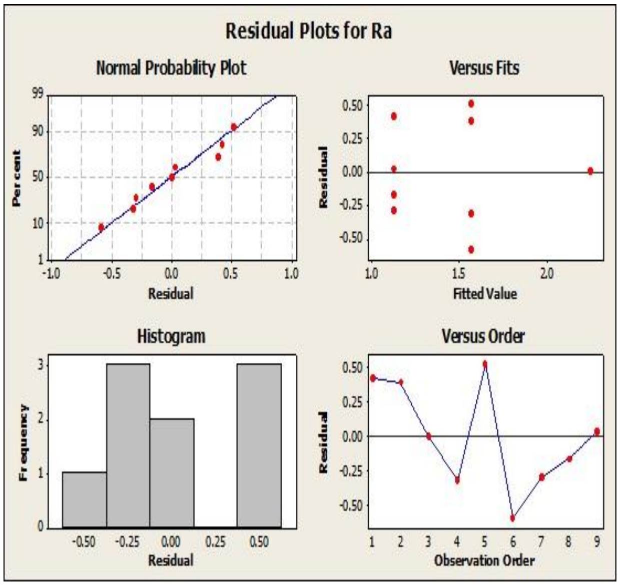

Fig. 18. Residual graph with various parameters for unannealed Aluminium

5. CONCLUSION

This study of the machinability of Al 6063 alloy material with HSS tool inserts has produced some useful results. The criteria for the machinability are surface roughness, 3 control factors which were considered to be effective in creating the most suitable conditions for the criteria (feed, cutting speed and depth of cut) were chosen at three different levels and applied in the experimental study. This paper has discussed an application of the Taguchi method and ANOVA method for investigating the effects of milling parameters on the surface roughness in the dry milling of Al 6063 material. In the drilling processes, cutting conditions have different Cutting speed, depth of cut, and feed rate values. As shown in this study, the Taguchi method provides a systematic and efficient methodology for the design optimization of the cutting parameters with far less effect than would be required for most optimization techniques. The level of importance of the milling parameters on the surface roughness is determined by using ANOVA. Multiple regression analysis is performed to indicate the fitness of experimental measurements. Normality tests on the residuals of the regression models ensure that the models have extracted all applicable information from the experimental data, and these tests also validate the adequacy of the models. The following results are concluded from it:

1. Statistically designed experiments based on Taguchi methods were performed using L9 orthogonal arrays to analyze the metal removal rate as a response variable. Conceptual S/N ratio and the ANOVA approaches for data analysis drew similar conclusions.
2. Statistical results (at a 95% confidence level) show that the speed(A), feed rate (B), and depth of cut (C) affects the surface roughness by 17.07%, 38.09% and 27.507% in the end machining of annealed Aluminium respectively.
3. Similarly, Statistical results (at a 95% confidence level) show that the speed(A), feed rate (B), and depth of cut (C) affects the surface roughness by

33.39%,48.09%and 9.83%in the end machining of non-annealed Aluminium respectively.

4. In this study, the analysis of the confirmation experiment surface roughness has shown that Taguchi parameter design can successfully verify the optimum cutting parameters (A1B3C3), which are cutting speed=300 rpm, feed rate = 0.15 mm/rev and depth of cut=1.5 mm. for annealed Aluminium 6063
5. The analysis of the confirmation experiment surface roughness has shown that Taguchi parameter design can successfully verify the optimum cutting parameters (A3B1C1), which are cutting speed=900 rpm, feed rate = 0.05 mm/rev and depth of cut=0.5 mm. for non-annealed Aluminium 6063.
6. The experiments clearly show the machinability characters decreases for annealed Aluminium 6063 in comparison to its non-annealed counterpart. Both forms surface roughness are highly impacted by feed rate followed by depth of cut for annealed Aluminium 6063, while non-annealed Aluminium has second highest factor impact of cutting speed.

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