A Project Report on

"Optimization of Surface Roughness of Al-7075 T651 in CNC End Milling"

Submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Engineering

In

Mechanical Engineering

Under the Guidance of

Professor Rizwan S. Shaikh

By:

Saif Hanif Pawaskar	13ME134
Bilal Ahmed Firfiray	13ME129
Abdul Raquib Imran Ali Khan	11ME029
Yusuf Hafiz	12ME015

Anjuman-I-Islam's

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KALSEKAR TECHNICAL CAMPUSNEW PANVEL

(Approvedby AICTE, recg. By Maharashtra Govt. DTE,

Affiliated to Mumbai University)

PLOT #2&3, SECTOR 16, NEAR THANA NAKA, KHANDAGAON, NEW PANVEL,NAVI MUMBAI-410206,
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CERTIFICATE

This is to certify that the project entitled

"Optimization of Surface Roughness of Al-7075 T6 in CNC End Milling"

Submitted by

SAIF HANIF PAWASKAR[1]

BILAL AHMED FIRFIRAY[2]

ABDUL RAQUIB IMRAN ALI KHAN[3]

YUSUF HAFIZ[4]

To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University of Mumbai**, is approved.

Internal Examiner	**External Examiner**
(Prof. Rizwan Shaikh)	(Prof. _______________)
Headof Department	**Principal**
(Prof. Zakir Ansari)	(Dr_______________)

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APPROVAL OF DISSERTATION

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(Internal Examiner) **(External Examiner)**

____________________ ____________________

Date: ___________

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ABSTRACT

The demand for high strength and low weight material in aerospace industries is found to be increasing in fabrication of structures and equipment's of aircraft and space satellites. Aluminium alloys possesses the characteristics of lightweight and high strength. The identification of the optimum values of input parameters to achieve better surface finish as response parameters is the prime objective of the project. The Aluminium 7075 T651 is worked on the End milling process on the HAAS CNC machine. Different parameters of Cutting Speed, Feed, and Depth of Cut in the Orthogonal Array method using Taguchi method. The results are to be worked on the DOE method on software MINITAB.

The material can further be worked upon different input parameters on various machines and for different response parameters. For carrying out the above-mentioned process various papers were referred for guidance and knowledge in the same field of previously carried experiments and results. Various technical concepts and tools like The Taguchi, Orthogonal Array, DOE, ANNOVA, Fuzzy Logic, and Response Parameters etc. were learned from the Published papers and it helped extensively in gaining knowledge required for the experiments to be performed on our project.

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NOMENCLATURE

	Meaning
C.S.	Cutting Speed
F.R.	Feed
DOC	Depth of Cut
Ra	Surface Roughness
ANNOVA	Analysis of Variance
Al	Aluminium
S/N	Signal to Noise Ratio
DOF	Degree of Freedom
F	Statistic Value.
Adj MS	Adjusted Mean Square
Adj SS	Adjusted Sum of Square
Seq SS	Sequential Sum of Square
P	Probability

Chapter 1

Introduction

Surface roughness is an important measure of product quality, since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has an impact on the mechanical properties like fatigue behaviour, corrosion resistance, etc. and functional attributes like friction, wear, light reflection, heat transmission and electrical conductivity, etc. There have been many research developments in modelling surface roughness and optimization of the controlling parameters to obtain a surface finish of desired level, since only the proper selection of cutting parameters can produce a better surface finish. In the manufacturing industries, various machining processes are adopted for removing the material from the work piece for a better product.

Out of these, end milling process is one of the most vital and common metal cutting operations used for machining parts because of its ability to remove materials faster with a reasonably good surface quality. In recent times, Computer Numerically Controlled (CNC) machine tools have been implemented to utilize full automation in milling, since they provide greater improvements in productivity, increase the quality of the machined parts and require less operator input.

- End mill - A rotating cutting tool having a cylindrical shank with the teeth at the end, used for machining sides of metal piece and other object.

Applications

- Used to cut mazy profiles, slots, grooves etc in industrial.
- Production of cavities in metal working dies

1.1. Objective

The demand for high strength and low weight material in aerospace industry is found to be increasing in fabrication of structure and equipment of aircraft.Aluminium alloy possesses characteristics of lightweight and high strength. The 7000 Series Aluminium is the highest strength series for aircraft applications.But the problem faced by this material is that is has moderate corrosion and fatigue resistance. This problem can be solved largely by minimizing the surface roughness.

1.2. Literature review

Various papers are studied and discussion on some papers are presented in this section.

Thakur Paramjit Mahesh, R.Rajesh [1] described the application of the fuzzy logic integrated with Taguchi method for minimizing the surface roughness and maximizing the material removal rate simultaneously. In CNC End Milling of Al 7075 T6 Aerospace alloy. The Input parameters taken are SPEED, FEED, DOF and NOSE RADIUS. Al 7075 T6 is one of the highest strength alloy in 7000 series family. In Taguchi method, L27 Orthogonal Array with 4 factors and 3 Levels are chosen and S/N ratio is calculated. S/N Ratio of roughness and MRR are fed as inputs to Fuzzy Logic system and output received is Multi response performance index (MRPI) with application of ANOVA, Nose radius and DOC are identified as most signified parameters contributing about 31% of Variance. There was a significant improvement in MRPI of Optimal process parameters as compared to MRPI of initial process parameters Optimization process parameters would solve problems of corrosion and fatigue by material by minimizing roughness. same time it will increase productivity by maximizing MRR.

Following parameters setting was been identified as to yield the best combination of parameters - A3B1C3D2. Significant improvement in surface roughness and MRR. Most important factor affecting response have been nose radius and depth of cut.

J.S. Pang, M.N.M. Ansari, Omar S. Zaroog, Moaz H. Ali, S.M. Sapuan [2] used the Taguchi design optimization of machining parameters on the CNC end milling process of halloysite nanotube with aluminium reinforced epoxy matrix (HNT/Al/Ep) hybrid composite. The Taguchi method was performed to select the optimal cutting parameters from varying combinations of cutting parameters for end-milling operations on the HNT-Al/epoxy hybrid composite material.A basic L27(33) orthogonal array was selected with 27 experimental runs which included the three main factors each at three levels and this proved that the Taguchi parameter design is an efficient way to determine the optimal combination of cutting parameters for lowest surface finish and cutting force.

The Taguchi method was performed to select the optimal cutting parameters from varying combinations of cutting parameters for end-milling operations on the HNT-Al/epoxy hybrid composite material.

A. Arun Premnath, T. Alwarsamy, T. Abhinav, C. Adithya, Krishnakant [3] the Response Surface Model (RSM) has been developed to predict the surface roughness during face milling of Hybrid composites. Experiments carried out with tungsten carbide insert at various cutting Speed, Feed, and Weight fraction of Alumina. Material used are Al 6061-reinforced with Al2O3 of size 45 micron and Graphite of 60 microns, which are produced by stir casting route, Central composite face centered second order response surface methodology was employed to create a mathematical model and the adequacy of model was verified using analysis of variance. And Concluded that – i) From RSM model, predicted and measured values are quite close, which indicates that the developed model can be effectively used to predict the surface roughness. Using this model, a noticeable saving in time and cost has been obtained to select the level of milling. ii) Speed is major factor, which has more influence on surface roughness, followed by feed rate and weight fraction of Al2O3 Among the interaction, cutter speed and feed rate has a greater influence compared with other interaction on surface roughness on milling of Al Hybrid MMC composites

Lohithaksha M Maiyara, Dr.R.Ramanujamb, K.Venkatesanc, Dr.J.Jeraldd [4] investigated the parameter optimization of end milling operation for Inconel 718 super alloy with multi-response criteria based on the taguchi orthogonal array with the grey relational analysis. Nine experimental runs based on an L9 orthogonal array of Taguchi method were performed. Cutting speed, feed rate and depth of cut are optimized with considerations of multiple performance characteristics namely surface roughness and material removal rate. A grey relational grade obtained from the grey relational analysis is used to solve the end milling process with the multiple performance characteristics. Additionally, the analysis of variance (ANOVA) is also applied to identify the most significant factor. Finally, confirmation tests were performed to make a comparison between the experimental results and developed model. Experimental results have shown that machining performance in the end milling process can be improved effectively through this approach.

Lakshmipathi Tammineni1 and Hari Prasada Reddy Yedula [5]deals with the effect of three selective parameters viz. cutting speed, feed and depth of cut on the surface roughness of Aluminium 1050 during milling operation. The main objective of this work is to investigate the influence of the above-mentioned parameters on the surface roughness and flatness to obtain the optimum surface texture using Response Surface Methodology and to recommend the best parameters that contribute to obtain the optimum surface roughness value. The values of said three parameters taken for the study are: cutting speed range - 500 to 1500 rpm, feed range - 50 to 70 mm/rev and depth of cut range - 0.5 to 1.5mm, and given as input to the Mini Tab software. As a result, 15 number of design of experiments with various combinations of the three parameters under consideration have been generated. Experiments have been conducted in the run order on CNC Milling Machine by using manual coding method, and the surface roughness has been tested using TR-200 surface roughness tester, and the flatness has been tested by using Coordinate Measuring Machine (CMM). The obtained surface roughness and flatness values are analysed through graphs generated by using Response Surface Methodology (RSM) of Minitab Software.

1.3. Summary And Gap Of Literature Review

- Different tools like Taguchi, ANOVA, Fuzzy Logic, Regression, Orthogonal Array, D.O.E. etc. were used to carry out experiments for Optimization of Surface Roughness.

i. Surface roughness increases rapidly with increase in feed rate

ii. Surface Roughness decrease with increase in cutting speed.

iii. An increase in either the feed rate or axial depth of cut increases the surface roughness, while an increase in the spindle speed decreases the surface roughness

No research and analysis is carried out on Aluminium of Grade 7075 T651 for response parameter of Surface Roughness

1.4. Problem Definition

To optimize the level of the Surface Roughness of Aluminium **Alloy 7075 T651** in the HAAS CNC mill with End Milling Operation. Considering input parameters like SPEED, FEED, DEPTH OF CUT, With SURFACE ROUGHNESS as Response Parameters. Using Three Level Orthogonal Array (L9) with validation on MINITAB software.

1.5. Flowchart

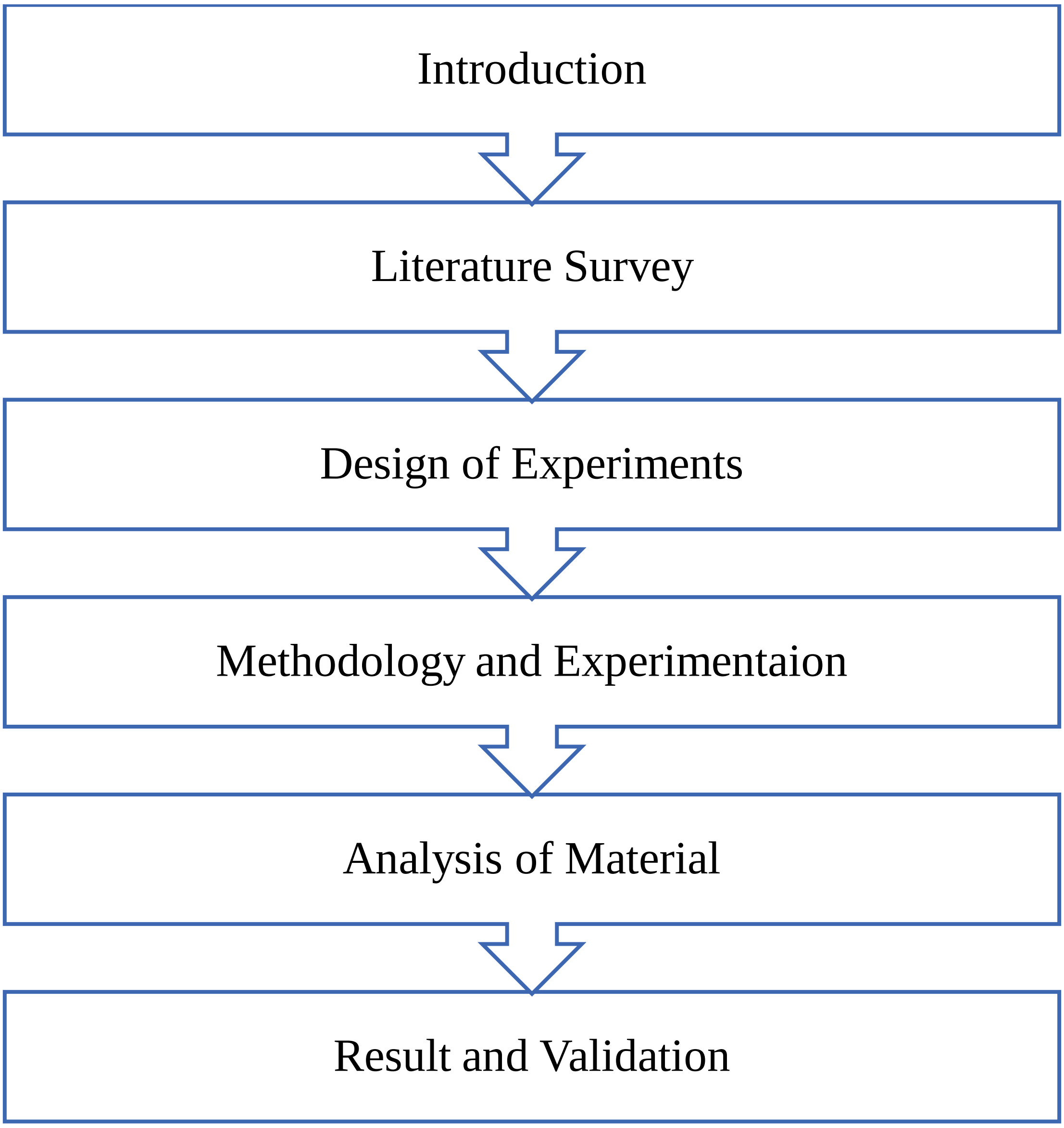

Figure 1.1 Flow Chart of the Project

Chapter 2

Methodology of the Project

2.1 Design of Experiments (DOE)

Design of experiments (DOE) is a systematic method to determine the relationship between factors affecting a process and the output of that process. In other words, it is used to find cause-and-effect relationships. This information is needed to manage process inputs in order to optimize the output.

Design of Experiments (DOE) usingthe Taguchi Approach is astandardized form of experimentaldesign technique (referred asclassical DOE) introduced by R. A.Fisher in England in the early1920’s. As a researcher inJapanese Electronic ControlLaboratory, in the late 1940’s, Dr.Genichi Taguchi devoted much ofhis quality improvement effort onsimplifying and standardizing theapplication of the DOE technique.

Common areas of application of the technique are:

- Optimize Designs using analytical simulation studies

- Select better alternative in Development and Testing

- Optimize Manufacturing Process Designs

- Determine the best Assembly Method

- Solve manufacturing and production Problems

Design techniques, you couldimprove the performances of yourproduct and process designs in thefollowing ways:

- Improve consistency ofperformance and save cost
- Build insensitivity(Robustness) towards theuncontrollable factors

A designed experiment is a test or series of tests in which purposeful changes are made to the input variables of a process or system so that we may observe and identify the reasons for changes in the output response. For example, *Figure 5.4.3* depicts a process or system under study. The process parameters x_1, x_2, x_3, …, x_p are controllable, whereas other variables z_1, z_2, z_3, …,z_q are uncontrollable. The term y refers to the output variable. The objectives of the experiment are stated as:

• Determining which variables are most influential on the response, y.

• Determining where to set the influential x's so that y is almost always near the desired nominal value.

• Determining where to set the influential x's so that variability in y is small.

• Determining where to set the influential x's so that the effects of the uncontrollable z_1, z_2 …z_q are minimized.

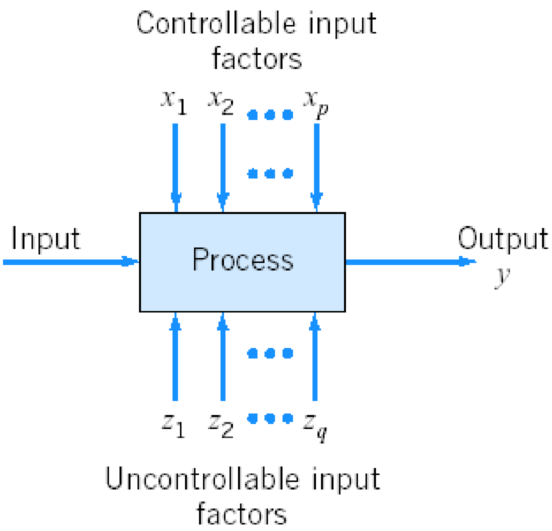

Figure 2.1 Design of Experiment

Experimental design is used as an important tool in numerous applications. For instance, it is used as a vital tool in improving the performance of a manufacturing process and in the engineering design activities. The use of the experimental design in these areas results in products those are easier to manufacture, products that have enhanced field performance and reliability, lower product cost, and short product design and development time.

Guidelines for designing experiments

- Recognition and statement of the problem.
- Choice of factors and levels.
- Selection of the response variable.
- Choice of experimental design.
- Performing the experiment.
- Data analysis.
- Conclusions and recommendations.

i. Taguchi Method

Taguchi designs are used for robust parameter design, in which the primary goal is to find factor settings that minimize response variation, while adjusting (or keeping) the process on target. Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions.

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 (or independent variables) by considering experiments in "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. An array name indicates the number of rows and columns it has, and also the number of levels in each of the columns. For example, array L4 (23) has four rows and three "2 level" columns. Similarly, the array L18 (2137) has 18 rows; one "2 level" column; and seven "3 level" columns. Thus, there are eight columns in the array L18. The number of rows of an orthogonal array represents the requisite number of experiments. The number of rows must be at least equal to the degrees of the freedom associated with the factors i.e. the control variables. In general, the number of degrees of freedom associated with a factor (control variable) is equal to the number of levels for that factor minus one. For example, a case study has one factor (A) with "2 levels" (A), and five factors (B, C, D, E, F) each with "3 level". Table 5.4.2 depicts the degrees of freedom calculated for this case. The number of columns of an array represents the maximum number of factors that can be studied using that array.

Taguchi's techniques have been used widely in engineering design (Ross 1996 & Phadke 1989). TheTaguchi method contains system design, parameter design, and tolerance design procedures toachieve a robust process and result for the best product quality (Taguchi 1987 & 1993). The main trustof Taguchi's techniques is the use of parameter design (Ealey Lance A.1994), which is an engineeringmethod for product or process design that focuses on determining the parameter (factor) settingsproducing the best levels of a quality characteristic (performance measure) with minimum variation.Taguchi designs provide a powerful and efficient method for designing processes that operateconsistently and optimally over a variety of conditions. To determine the best design, it requires theuse of a strategically designed experiment, which exposes the process to various levels of designparameters.

Experimental design methods were developed in the early years of 20th century and have beenextensively studied by statisticians since then, but they were not easy to use by practitioners (Phadke1989). Taguchi's approach to design of experiments is easy to be adopted and applied for users withlimited knowledge of statistics; hence it has gained a wide popularity in the engineering andscientific community. Taguchi specified three situations:

- Larger the better (for example, agricultural yield);
- Smaller the better (for example, carbon dioxide emissions); and
- On-target, minimum-variation (for example, a mating part in an assembly).

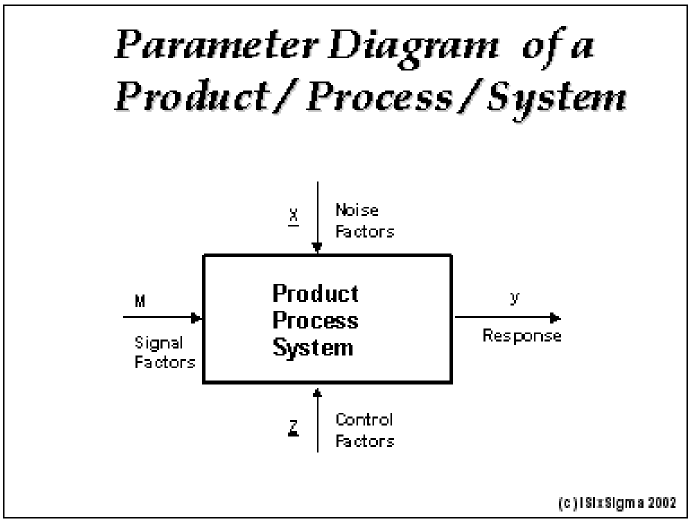

Figure 2.2 Signal to Noise Ratio

Eight-Steps in Taguchi Methodology:

Step-1: Identify the main function, side effects, and failure mode

Step-2: Identify the noise factors, testing conditions, and quality characteristics

Step-3: Identify the objective function to be optimized

Step-4: Identify the control factors and their levels

Step-5: Select the orthogonal array matrix experiment

Step-6: Conduct the matrix experiment

Step-7: Analyse the data, predict the optimum levels and performance

Step-8: Perform the verification experiment and plan the future action

Methodology Used: Taguchi Techniques

Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions is based on "ORTHOGONALARRAY" experiments which gives much reduced "variance" for the experiment with "optimumsettings "of control parameters. Thus the marriage of Design of Experiments with optimization ofcontrol parameters to obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays"(OA) provide a set of well balanced (minimum)experiments & desired output, serve as objectivefunctions for optimization, help in data analysis and prediction of optimum results.

Mathematical modelling:

"ORTHOGONAL ARRAYS "(OAs) experimentsUsing OAs significantly reduces the number of experimental configurations to be studiedMontgomery, (1991). The effect of many different parameters on the performance characteristic in aprocess can be examined by using the orthogonal array experimental design proposed by Taguchi.Once the parameters affecting a process that can be controlled have been determined, the levels atwhich these parameters should be varied must be determined. Determining what levels of a variableto test requires an in-depth understanding of the process, including the minimum, maximum, and current value of the parameter. If the difference between the minimum and maximum value of aparameter is large, the values being tested can be further apart or more values can be tested. If therange of a parameter is small, then less value can be tested or the values tested can be closer together.

Array Selector

	Number of Parameters (P)																													
Number of Levels	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16	L16	L16	L16	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32
3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27	L27	L36	L36	L36	L36	L36	L36	L36	L36	L36	L36								
4	L'16	L'16	L'16	L'16	L'32	L'32	L'32	L'32	L'32																					
5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50																			

Figure 2.3 Orthogonal Array

The Taguchi method is a powerful tool for designing high quality systems. To increase the experimental efficiency, the L18 mixed orthogonal table in the Taguchi quality design. Ross (1988) is used to determine the significant machining factors. In the experiments, we select six influential machining parameters, such as cutting tools of different materials, depth of cut, cutting speed, feed rate, working temperature and ultrasonic power, each of which has three different levels (high, medium and low levels).

Experiment	P1	P2	P3	P4	P5	P6	P7	P8
1	1	1	1	1	1	1	1	1
2	1	1	2	2	2	2	2	2
3	1	1	3	3	3	3	3	3
4	1	2	1	1	2	2	3	3
5	1	2	2	2	3	3	1	1
6	1	2	3	3	1	1	2	2
7	1	3	1	2	1	3	2	3
8	1	3	2	3	2	1	3	1
9	1	3	3	1	3	2	1	2
10	2	1	1	3	3	2	2	1
11	2	1	2	1	1	3	3	2
12	2	1	3	2	2	1	1	3
13	2	2	1	2	3	1	3	2
14	2	2	2	3	1	2	1	3
15	2	2	3	1	2	3	2	1
16	2	3	1	3	2	3	1	2
17	2	3	2	1	3	1	2	3
18	2	3	3	2	1	2	3	1

Figure 2.4 Orthogonal Array Experimentation

Design of Experiment (DOE's) Requires Planning

1. Design and Communicate the Objective:
2. Define the Process:
3. Select a Response and Measurement System:
4. Ensure that the Measurement System is Adequate:
5. Select Factors to be studied:
6. Select the Experimental Design:
7. Set Factor Levels:
8. Final Design Considerations:

ii. Signal to Noise (S/N) Ratio

There are three forms of signal to noise (S/N) ratio that are of common interest for optimization of static problems.

[1] Smaller-the-better

This is expressed as

n=-10Log10[mean of sum of squares of measured data]

This is usually the chosen S/N ratio for all the undesirable characteristics like “defects” for which the ideal value is zero. When an ideal value is finite and its maximum or minimum value is defined (like the maximum purity is 100% or the maximum temperature is 92 K or the minimum time for making a telephone connection is 1 sec) then the difference between the measured data and the ideal value is expected to be as small as possible. Thus, the generic form of S/N ratio becomes,

n=-10Log10 [mean of sum of squares of {measured-ideal}]

[2] Larger-the-better

This is expressed as

n=-10Log10 [datameasuredofreciprocalofsquaresofsumofmean]

This is often converted to smaller-the-better by taking the reciprocal of the measured data and next, taking the S/N ratio as in the smaller-the-better case.

[3] Nominal-the-best

This is expressed as

n=-10Log10 [square of mean/variance]

This case arises when a specified value is the most desired, meaning that neither a smaller nor a larger value is desired.

iii. Orthogonal Array

Orthogonal Arrays (often referred to Taguchi Methods) are often employedin industrial experiments to study the effect of several control factors.

Popularized by G. Taguchi. Other Taguchi contributions include:

- Model of the Engineering Design Process
- Robust Design Principle
- Efforts to push quality upstream into the engineering design process

An orthogonal array is a type of experiment where the columns for theindependent variables are "orthogonal" to one another.

Benefits:

1. Conclusions valid over the entire region spanned by the control factorsand their settings
2. Large saving in the experimental effort
3. Analysis is easy

To define an orthogonal array, one must identify:

1. Number of factors to be studied
2. Levels for each factor
3. The specific 2-factor interactions to be estimated
4. The special difficulties that would be encountered in running theexperiment

We know that with two-level full factorial experiments, we can estimatevariable interactions. When two-level fractional factorial designs are used,we begin to confound our interactions, and often lose the ability to obtainunconfused estimates of main and interaction effects. We have also seenthat if the generators are chosen carefully then knowledge of lower orderinteractions can be obtained under that assumption that higher orderinteractions are negligible.

Orthogonal arrays are highly fractionated factorial designs. Theinformation they provide is a function of two things

• The nature of confounding

•Assumptions about the physical system.

Selection of proper Orthogonal array depends on the computation of total degree of freedom. The number of comparison made between the levels to know which is better is called Degree of Freedom. For example, a three level process parameters can be compared with two other levels, hence the degree of freedom is two.

Table 2.1 Orthogonal Array selected for Experiment

Experiment No	**SPEED**	**FEED**	**DEPTH OF CUT**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

iv. Analysis of Variance (ANNOVA)

ANOVA (Analysis of Variance)

ANOVA is a statistical method that stands for analysis of variance. ANOVA was developed by Ronald Fisher in 1918 and is the extension of the t and the z test. Before the use of ANOVA, the t-test and z-test were commonly used. But the problem with the T-test is that it cannot be applied for more than two groups. In 1918, Ronald Fisher developed a test called the analysis of variance. This test is also called the Fisher analysis of variance, which is used to do the analysis of variance between and within the groups whenever the groups are more than two. If you set the Type one error to be .05, and you had several groups, each time you tested a mean against another there would be a .05 probability of having a type one error rate. This would mean that with six T-tests you would have a 0.30 (.05×6) probability of having a type one-error rate. This is much higher than the desired .05.

ANOVA creates a way to test several null hypotheses at the same time.

The logic behind this procedure has to do with how much variance there is in the population. It is likely he researcher will not know the actual variance in the population but they can estimate this by sampling and calculating the variance in the sample. You compare the differences in the samples to see if they are the same or statistically different while still accounting for sampling error.

General Purpose of ANOVA:

These days, researchers are using ANOVA in many ways. The use of ANOVA depends on the research design. Commonly, researchers are using ANOVA in three ways: one-way ANOVA, two-way ANOVA, and N-way Multivariate ANOVA.

One-Way: When we compare more than two groups, based on one factor (independent variable), this is called one-way ANOVA. For example, it is used if a manufacturing company wants to compare the productivity of three or more employees based on working hours. This is called one-way ANOVA.

Two-Way:When a company wants to compare the employee productivity based on two factors (2 independent variables), then it said to be two way (Factorial) ANOVA. For example, based on the working hours and working conditions, if a company wants to compare employee productivity, it can do that through two-way ANOVA. Two-way ANOVA’s can be used to see the effect of one of the factors after controlling for the other, or it can be used to see the INTERACTION between the two factors. This is a great way to control for extraneous variables, as you are able to add them to the design of the study.

Factorial ANOVA can be balanced or unbalanced. This is to say, you can have the same number of subjects in each group (balanced) or not (unbalanced). This can come about, depending on the study, as just a reflection of the population, or an unwanted event such as participants not returning to the study. Not having equal sizes groups can make it appear that there is an effect when this may not be the case. There are several procedures a researcher can do in order to solve this problem:

Discard cases (undesirable): Conduct a special kind of ANOVA, which can deal with the unbalanced design

There are three types of ANOVA's that can candle an unbalanced design. These are the Classical Experimental design (Type 2 analysis), the Hierarchical Approach (Type 1 analysis), and the Full regression approach (Type 3 analysis). Which approach to use depends on whether the unbalanced data occurred on purpose.

-If the data is unbalanced because this is a reflection of the population and it was intended, use the Full Regression approach (Type 3).

-If the data was not intended to be unbalanced but you can argue some type of hierarchy between the factors, use the Hierarchical approach (Type 1).

-If the data was not intended to be unbalanced and you cannot find any hierarchy, use the classical experimental approach (Type 2).

N-Way:When the factor comparison is taken, then it said to be n-way ANOVA. For example, in productivity measurement if a company takes all the factors for productivity measurement, then it is said to be n-way ANOVA.

ANOVA is used very commonly in business, medicine or in psychology research. In business, ANOVA can be used to compare the sales of different designs based on different factors. A psychology researcher can use ANOVA to compare the different attitude or behaviour in people and whether or not they are the same depending on certain factors. In medical research, ANOVA is used to test the effectiveness of a drug.

2.2 Methodology of the Dissertation

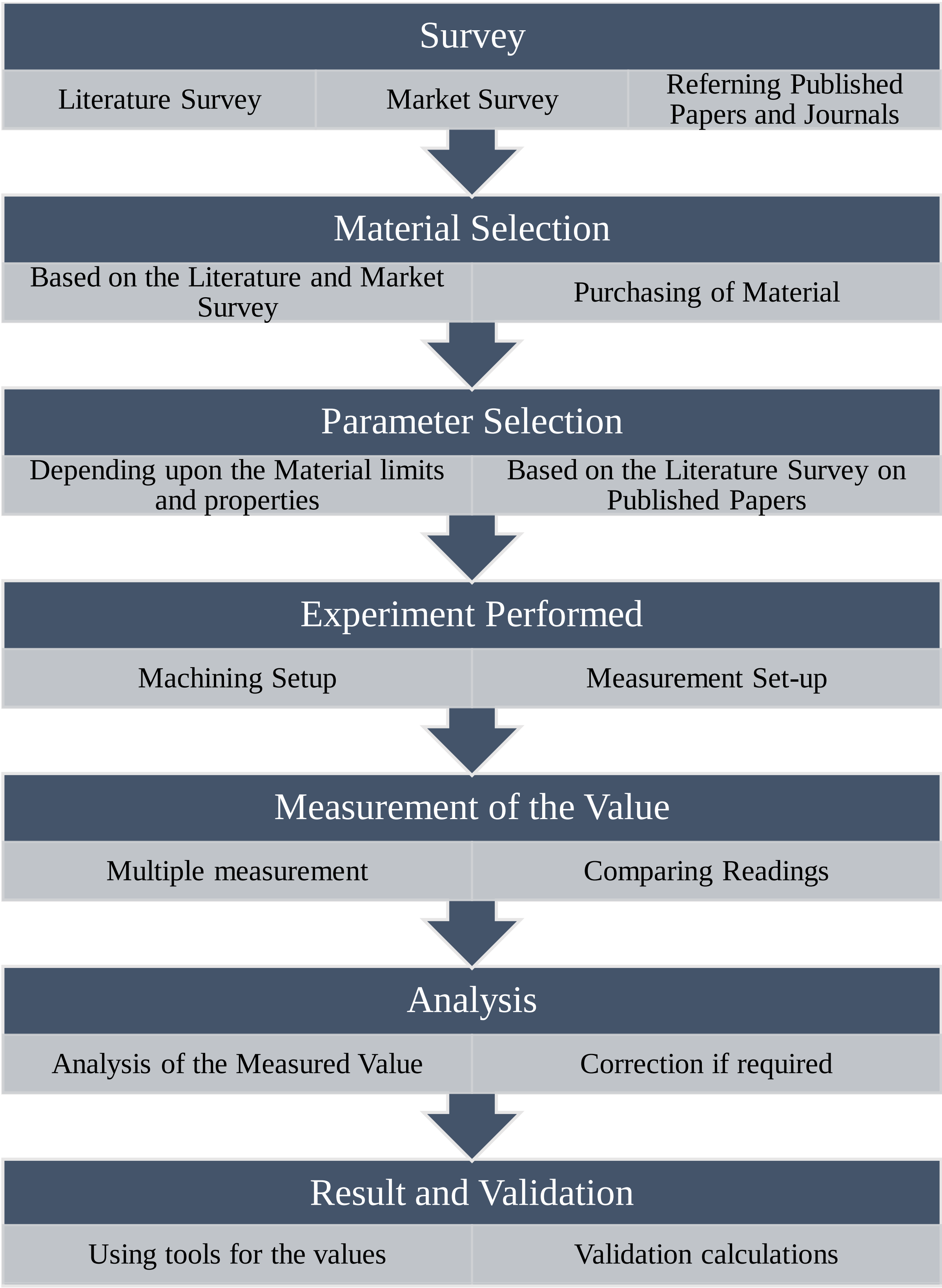

Figure 2.5 Flow Chart of Methodology

Formation of Levels

Table 2.2Formation of Levels for experimentation

Parameters	Level 1	Level 2	Level 3
Cutting Speed (rpm)	2000	4000	6000
Feed Rate (mm/min)	160	640	1440
Depth of Cut (mm)	0.2	0.4	0.6

Orthogonal Array formed

Selection of Orthogonal Array: To select an appropriate orthogonal array for experiments, the total degrees of freedom need to be computed. In thisstudy each three level parameter has 2 degree of freedom(DOF = Number of level–1), the total DOF required forthree parameters each at three levels is 8. Once thedegrees of freedom required are known, the next step is toselect an appropriate orthogonal array to fit the specifictask. The degrees of freedom for the orthogonalarray should be greater than or at least equal to those forthe process parameters. In this study, an L9 Orthogonalarray (a standard 3-level OA) having 8 degree of freedomwas selected from the Taguchi's special set of predefinedarrays.

Table 2.3 Orthogonal Array used in Experimentation

SR. No.	Cutting Speed	Feed Rate	Depth of cut
1	2000	160	0.2
2	2000	640	0.4
3	2000	1440	0.6
4	4000	160	0.4
5	4000	640	0.6
6	4000	1440	0.2
7	6000	160	0.6
8	6000	640	0.2
9	6000	1440	0.4

Chapter 3

Experimentation

3.1. Material Survey

Commonly available materials in the market are:

1. Normal Aluminium

2. Commercial Aluminium

Table 3.1 Material Cost

Grade	Applications	Price per kg
Aluminium 2024	Air Craft, Hydraulic piston etc.	Rs.725
Aluminium 5083	Ship Building	Rs.2500
Aluminium 7075 T651	Air Craft, Hydraulic piston etc.	Rs.2500

i. MATERIAL SELECTED

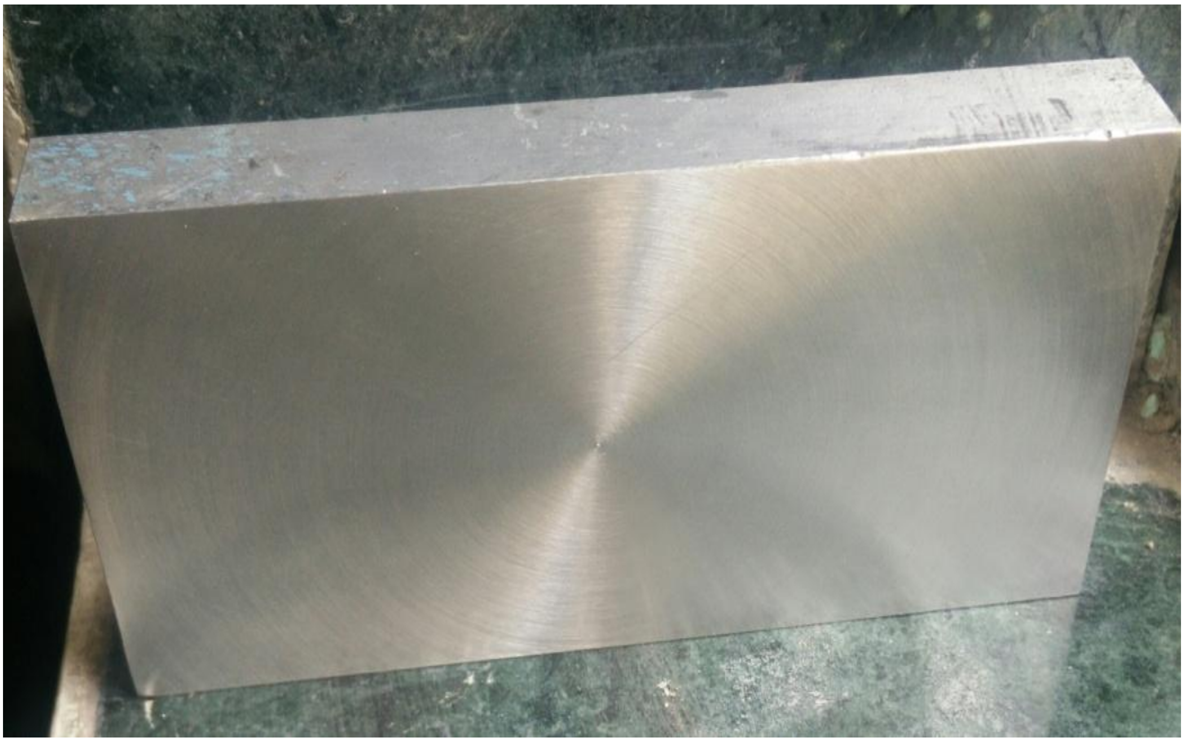

Figure 3.1 Aluminium 7075 T651

Aluminium: **7075-T651**

Subcategory: 7000 Series Aluminium Alloy; Aluminium Alloy; Metal; Nonferrous Metal

Material Notes: General 7075 characteristics and uses (from Alcoa): Very high strength material used for highly stressed structural parts. The T7351 temper offers improved stress-corrosion cracking resistance.

Applications: Aircraft fittings, gears and shafts, fuse parts, meter shafts and gears, missile parts, regulating valve parts, worm gears, keys, aircraft, aerospace and defence applications; bike frames, all-terrain vehicle (ATV) sprockets.

Composition Notes: A Zr + Ti limit of 0.25 percent maximum may be used with this alloy designation for extruded and forged products only, but only when the supplier or producer and the purchaser have mutually so agreed. Agreement may be indicated, for example, by reference to a standard, by letter, by order note, or other means, which allow the Zr + Ti limit.

Table 3.2 Material Properties

Component	Wt. %	Component	Wt. %	Component	Wt. %
Al	87.1 - 91.4	Mg	2.1 - 2.9	Si	Max 0.4
Cr	0.18 - 0.28	Mn	Max 0.3	Ti	Max 0.2
Cu	1.2 - 2	Other, each	Max 0.05	Zn	5.1 - 6.1
Fe	Max 0.5	Other, total	Max 0.15		

3.2. Machine and Apparatus

Figure 3.2HAAS Mini CNC Mill

The Computer Numerical Controlled Machines are widely used in the industries, fully controlled with minimum human interference to increase the productivity and to improve the quality of machined part.

The HAAS Mini CNC Mill is used for the End-Milling operation of the Aluminium Alloy.

Machine Specifications:

Table 3.3 Specification of the Machine

Travels Mini Mill Super Mini Mill	**X -** 406 mm 406 mm Y - 305 mm 305 mm Z - 254 mm 254 mm
Table	Length (total) - 914 mm 914 mm Length (work surface) - 730 mm 730 mm Width - 305 mm 305 mm Max Weight on Table - 227 kg 227 kg
T-Slots	T-Slot Width - 16 mm Number of T-Slots 3 Centre Distance - 110 mm
Spindle	Taper Size CT or BT 40 CT or BT 40 Speed 6000 rpm Drive System Belt-Drive Max 45 Nm @ 1 200 rpm / 23 Nm @ 4 600 rpm Max Rating 7.5 hp 15 hp/5.6 kW 11.2 kW
Brushless Axis Motors	Max Thrust Rating - 8 896 N
Feed rates	Max Rapids - 15.2 m/min 30.5 m/min Max Cutting -12.7 m/min 21.2 m/min
Tool Changer	Capacity - 10 Max Tool Diameter - 89 mmMax Tool Weight - 5.4 kg Tool to Tool 4.2 sec 2.8 secChip to Chip 5.0 sec 3.8 sec
General	Machine Weight - 1 542 kg 1 542 kg Air Required - 113 Lpm @ 6.9 bar 113 Lpm @ 6.9 bar

Measuring Device:

Figure 3.3MGW Surface Roughness Tester (SRT-1)

Measurement - MGW Surface Roughness Tester (SRT-1)

MGW PRECISION TOOLS SURFACE ROUGHNESS TESTER SRT-1

- Use DSP chip control and data processing, high speed, low power consumption LCD digital display with backlight function (Do not need to buy another battery)
- Can be measured in several parts of the surface roughness: Planar, curved surface, small hole, slot of the irregular surface.
- Design of electromechanical integration, small volume, lightweight, convenient with measuring value storage function and data storage query
- Can communicate with PC computer for statistics and printing by the optional cable and the software for RS232C interface.
- Optional surface sensor, deep groove sensor, measuring platform, connected with a long rod and other accessories.
- Multi parameter measurement: Ra, Rz, Rq, Rt.

3.3. Experimental Set Up:

Figure 3.4 Setup of Experiment

Program for Machining:

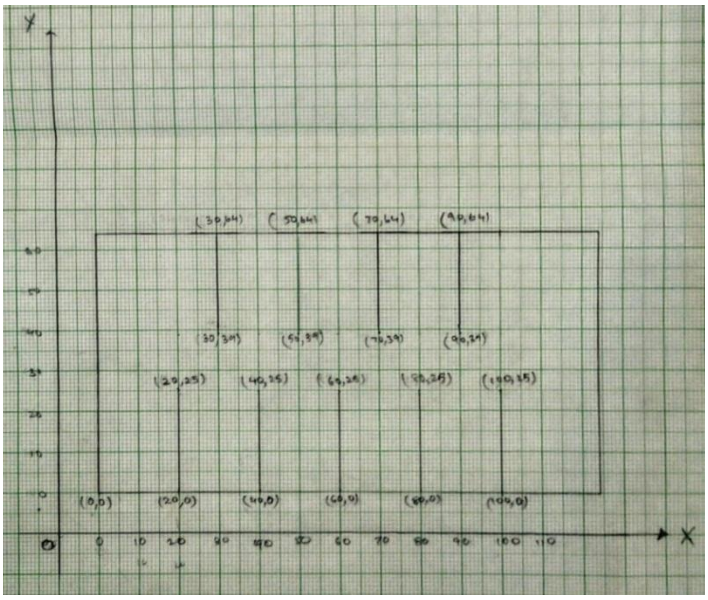

Figure 3.5 Program Graph

Table 3.4 CNC Machine Program

Sr. No	G/M Codes	X Co-ordinate / Speed	Y Co-ordinate/ Feed	Z Co-ordinate
1	G00	X00	Y00	Z00
2	M03	S2000	F160	
3	G00	X20	Y00	
4	G01			Z-0.2
5	G01	X20	Y25	
6	G00			Z5
7	M03	S2000	F640	
8	G00	X40	Y00	
9	G01			Z-0.4
10	G01	X40	Y25	
11	G00			Z5
12	M03	S2000	F1440	
13	G00	X60	Y00	
14	G01			Z-0.6
15	G01	X60	Y25	
16	G00			Z5
17	M03	S4000	F160	
18	G00	X80	Y00	
19	G01			Z-0.4
20	G01	X80	Y25	
21	G00			Z5
22	M03	S4000	F640	
23	G00	X100	Y00	
24	G01			Z-0.6
25	G01	X100	Y25	
26	G00			Z5
27	M03	S4000	F1440	
28	G00	X90	Y39	
29	G01			Z-0.2
30	G01	X90	Y64	

31	G00			Z5
32	M03	S6000	F160	
33	G00	X70	Y39	
34	G01			Z-0.6
35	G01	X70	Y64	
36	G00			Z5
37	M03	S6000	F640	
38	G00	X50	Y39	
39	G01			Z-0.2
40	G01	X50	Y64	
41	G00			Z5
42	M03	S6000	F1440	
43	G00	X30	Y39	
44	G01			Z-0.4
45	G01	X30	Y64	
46	G00			Z5
47	G28			
48	M05			
49	M30			

Figure 3.6 Operating of Machine

Figure 3.7 Completion of Machining

3.4. Software Used for experiment

Minitab Inc. is one of the world's leading developers of statistical and process improvement software. Minitab Statistical Software has been used in virtually every major Six Sigma initiative around the world, and is used to teach statistics in over 4,000 colleges and universities. Quality Companion is used worldwide to plan and execute Six Sigma projects. Minitab products are backed by outstanding services, including training, e-learning opportunities, and free technical support.

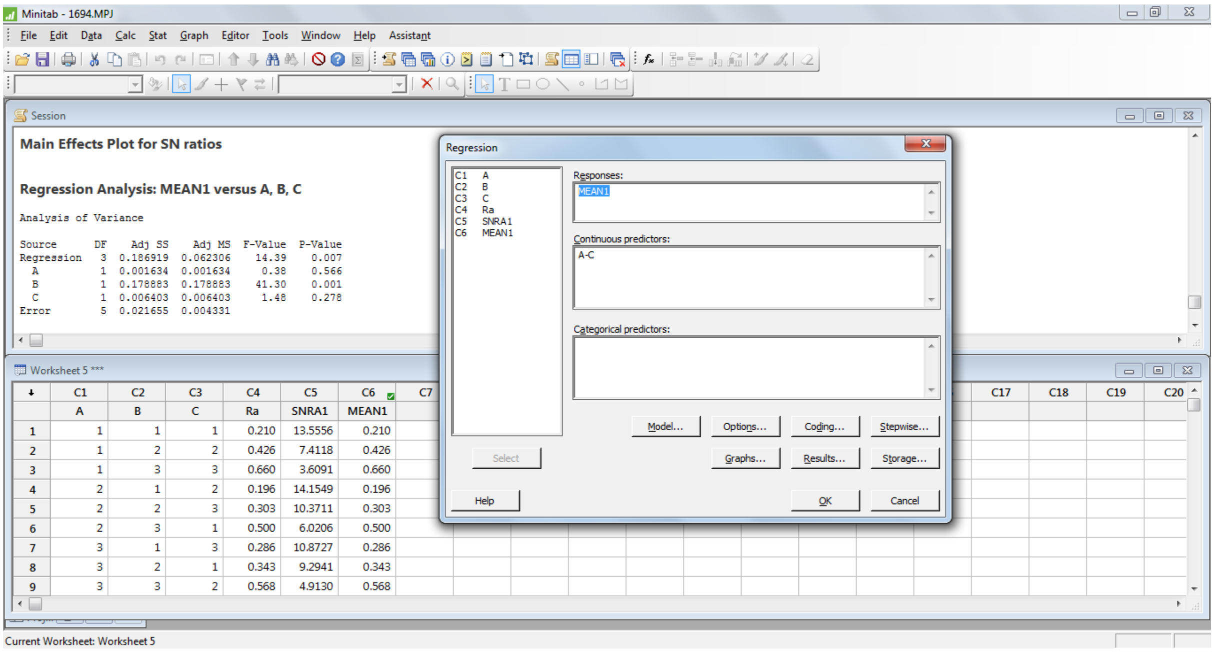

Figure 3.8 Software work on Regression Analysis

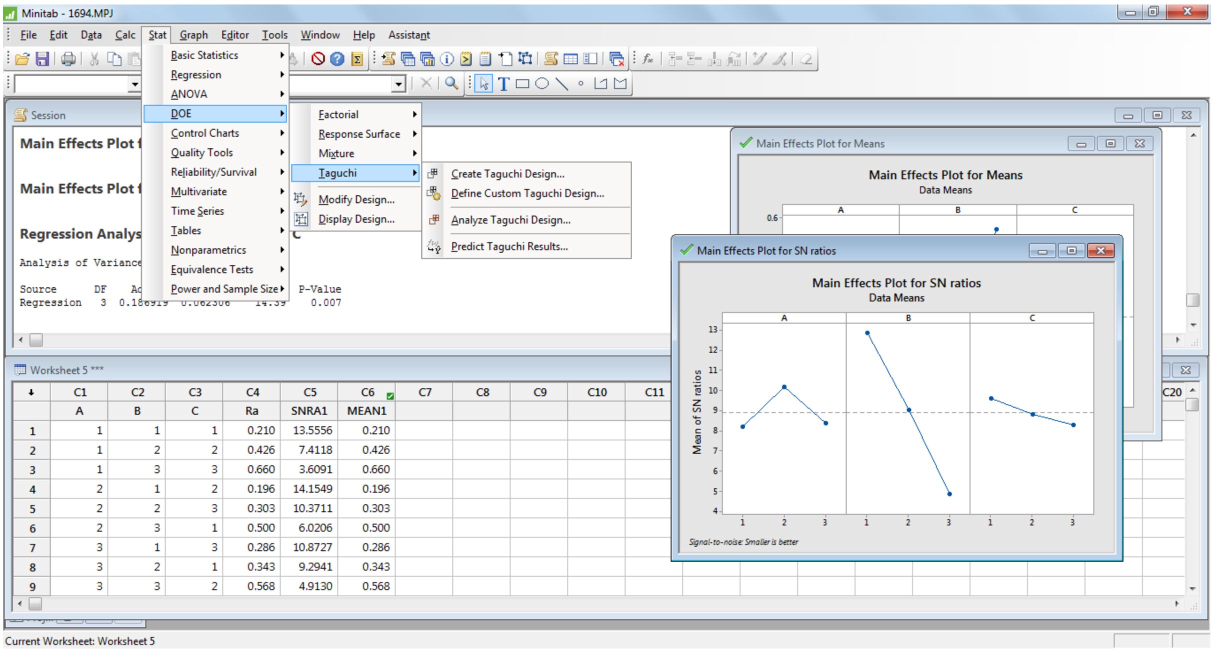

Figure 3.9 Software work on S/N Ratio and Mean

Chapter 4

Reading, Calculation and Analysis

4.1. End Milling Readings

Figure 4.1 Measurement of Ra Values on Surface Roughness tester

Readings and Calculations:

Table 4.1 Surface Roughness Reading measurement and Values of Mean and S/N Ratio

SR.NO.	Cutting Speed 'r.p.m'	Feed Rate 'mm/min	Depth of cut 'mm'	Surface Roughness (Ra) 'µm'			S/N Ratio	S/N Ratio By formula	Mean
1	2000	160	0.2	0.211	0.209	0.210	13.5556	13.55	0.210
2	2000	640	0.4	0.426	0.427	0.425	7.4118	7.41	0.426
3	2000	1440	0.6	0.660	0.661	0.659	3.6091	3.61	0.660
4	4000	160	0.4	0.196	0.197	0.195	14.1549	14.15	0.196
5	4000	640	0.6	0.304	0.302	0.303	10.3711	10.37	0.303
6	4000	1440	0.2	0.498	0.503	0.499	6.0206	6.02	0.500
7	6000	160	0.6	0.285	0.288	0.286	10.8727	10.87	0.286
8	6000	640	0.2	0.343	0.340	0.345	9.2941	9.29	0.343
9	6000	1440	0.4	0.567	0.568	0.570	4.9130	4.91	0.568

Calculation Of S/N Ratio (Smaller Is Better) By Formula

Formula for Smaller is better

$$S/N\ Ratio = -10*\log(\sum y^2/n)$$

1. S/N Ratio = -10*log(0.210^2/1)=13.55

2. S/N Ratio = -10*log(0.426^2/1)=7.41

3. S/N Ratio = -10*log(0.660^2/1)=3.61

4. S/N Ratio = -10*log(0.196^2/1)=14.15

5.S/N Ratio = -10*log(0.303^2/1)=10.37

6. S/N Ratio = -10*log(0.500^2/1)=6.02

7. S/N Ratio = -10*log(0.286^2/1)=10.87

8. S/N Ratio = -10*log(0.343^2/1)=9.29

9. S/N Ratio = -10*log(0.568^2/1)=4.91

Calculation for Mean

Formula for Mean

$$R_a=(R_{a1}+R_{a2}+R_{a3})/3$$

1. Ra=(0.211+0.209+0.210)/3 =0.210

2. Ra=(0.426+0.427+0.425)/3 = 0.426

3. Ra=(0.660+0.661+0.659)/3 = 0.660

4. Ra=(0.196+0.197+0.195)/3 = 0.196

5. Ra=(0.304+0.302+0.303)/3= 0.303

6. Ra=(0.498+0.503+0.499)/3 =0.500

7. Ra=(0.285+0.288+0.286)/3 =0.286

8. Ra=(0.343+0.340+0.345)/3 =0.343

9. Ra=(0.567+0.568+0.570)/3 =0.568

4.1.1. Analysingof S/N Ratio

What is S/N ratio?

In Taguchi designs, a measure of robustness used to identify control factors that reduce variability in a product or process by minimizing the effects of uncontrollable factors (noise factors). Control factors are those design and process parameters that can be controlled. Noise factors cannot be controlled during production or product use, but can be controlled during experimentation. In a Taguchi designed experiment, you manipulate noise factors to force variability to occur and from the results, identify optimal control factor settings that make the process or product robust, or resistant to variation from the noise factors. Higher values of the signal-to-noise ratio (S/N) indicate control factor settings that minimize the effects of the noise factors.

The signal-to-noise (S/N) ratio measures how the response varies relative to the nominal or target value under different noise conditions. For optimization the selected S/N ratios is:

Signal-to-noise ratio	**Use when the goal is to:**	**And your data are**
Smaller is better	Minimize the response	Non-negative with a target value of zero

Response Table for Signal to Noise Ratios

Smaller is better

Table 4.2Response Table for S/N Ratio

Level	Cutting speed	Feed rate	Depth of cut
1	8.192	12.861	9.623
2	10.182	9.026	8.827
3	8.360	4.848	8284
Delta	1.990	8.013	1.339
Rank	**2**	**1**	**3**

The response table shows the average of each response characteristic (S/N ratios, means) for each level of each factor. Above Table include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values; rank 1 to the highest Delta value, rank 2 to the second highest, and so on. Feed rate has more important significance on surface roughness followed by cutting speed and depth of cut has minimum significance on surface roughness.

Main Effect Plot for S/N Ratios:

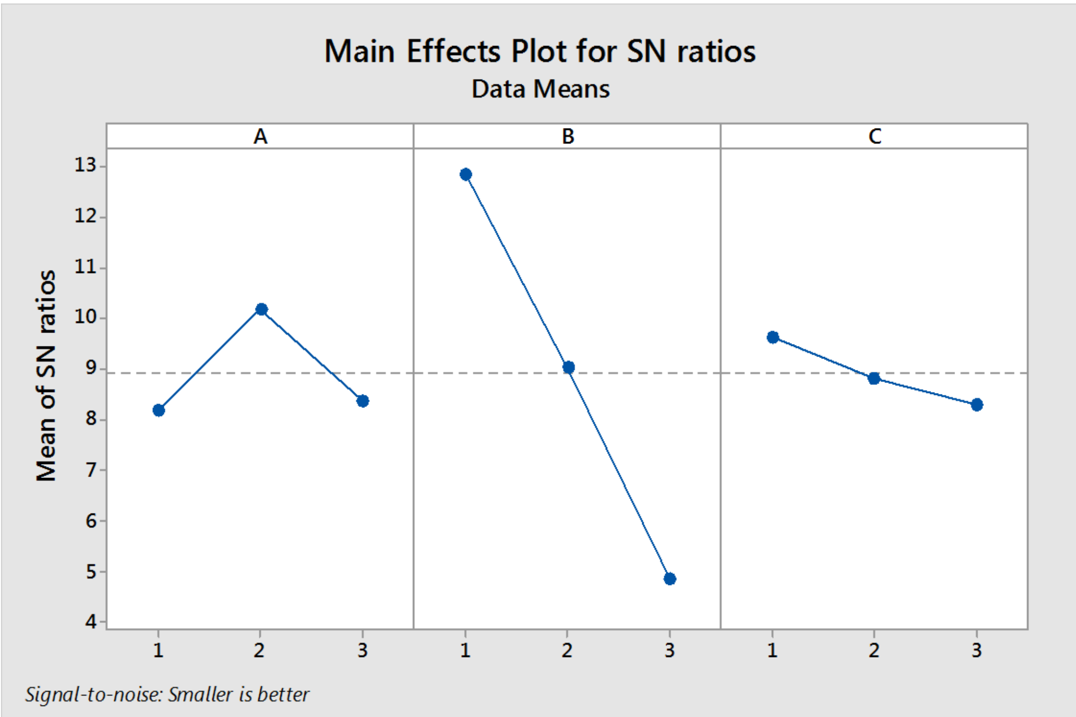

Figure 4.2Main effect plot for S/N ratio

From Fig.4.2, it can be seen that the surface roughness first increases with the cutting speed up to the optimum level i.e. 4000 rpm and after that it decreases whereas in case of feed rate surface roughness is maximum up to the optimum level i.e.160mm/min decreases with increases in its value. But in case of depth of cut, surface roughness increases up to the optimum level i.e. 0.2 mm and after that it decreases gradually.

Optimum Values for Each Factor

Table 4.3 Optimum Values for Each Factor

Cutting Speed	Level 2	4000 rpm	10.182
Feed Rate	Level 1	160 mm/min	12.861
Depth of cut	Level 1	0.2 mm	9.623

4.1.2. Analysis of Variance for S/N ratios

Table 4.4. ANOVA for S/N Ratio

Source	Degree of Freedom	Sequential Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F-statistic	P-value
C.S.	2	7.309	7.309	3.655	2.10	0.323
F. R.	2	96.382	96.382	48.191	27.70	0.035
D.O.C	2	2.722	2.722	1.361	0.78	0.561
Residual Error	2	3.480	3.480	1.740	-	-
Total	8	109.893	-	-	-	-

The analysis of variance was carried out at 95%confidence level. The purpose of ANOVA is to investigate which cutting parameters significantly affect the surface roughness. This is accomplished by separating the total variability of the S/N Ratios, which is measured by the sum of squared deviations from the total mean of the S/N ratio, into contributions by each cutting process parameter and the error (Table 4.4). In the experimentation work, for S/N ratios, feed rate ($p = 0.035$) has the significant effect on surface finish at an α-level of 0.05, other parameters cutting speed ($p = 0.323$) and depth of cut ($p = 0.561$) are non-significant.

4.1.3. Analysis of Mean

<u>What Is Mean?</u>

It is the average value of the roughness measured in each Experiment.

<u>Response Table for Means</u>

Table 4.5. Response Table for Mean

Level	C.S	F. R.	D.O.C
1	0.4320	0.2307	0.3510
2	0.3330	0.3573	0.3967
3	0.3990	0.5760	0.4163
Delta	0.0990	0.3453	0.0653
Rank	**2**	**1**	**3**

From the above response table 4.5. shows the average of each response characteristic (S/N ratios, means) for each level of each factor. Above table also include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values; rank 1 to the highest Delta value, rank 2 to the second highest, and so on. Feed rate has more important significance on surface roughness followed by cutting speed and depth of cut has minimum significance on surface roughness.

Main Effect Plot for Mean

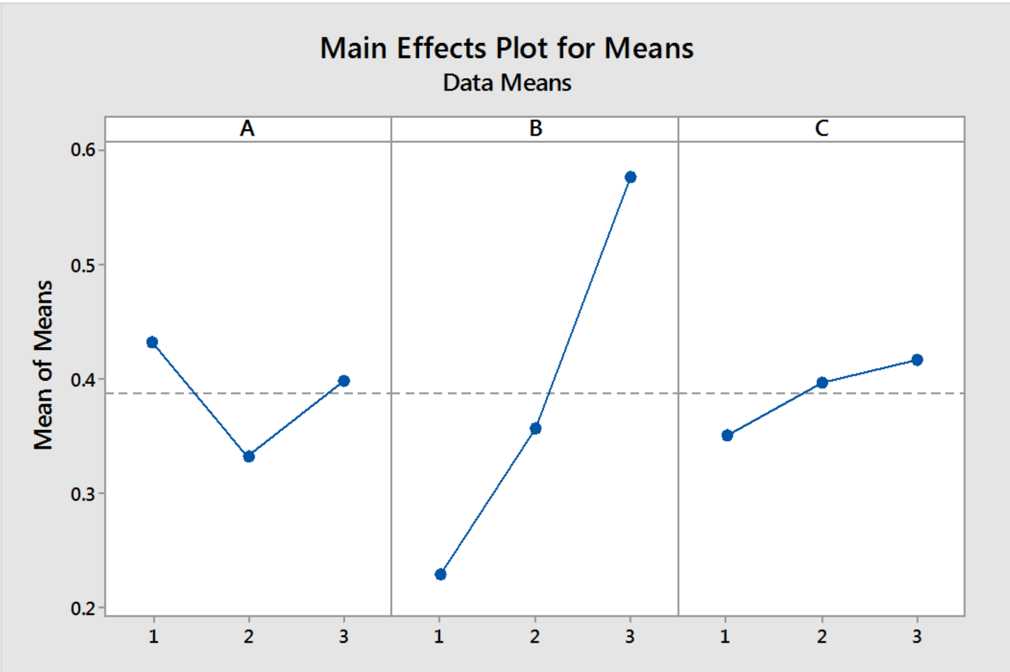

Figure 4.3. Main effect plot for Mean

From Fig.4.3, it can be seen that the surface roughness decreases with increases in cutting speed up to the optimum level i.e. 4000 rpm whereas in case of feed rate surface roughness is low to the optimum level i.e.160mm/min and increases with increases in its value. But in case of depth of cut, surface roughness increases up to the optimum level i.e. 0.2 mm and after that it increases gradually.

Optimum Values for Each Factor

Table 4.6. Optimum Values for Each Factor

Cutting Speed	Level 2	4000 rpm	0.3330
Feed Rate	Level 1	160 mm/min	0.2307
Depth of cut	Level 1	0.2 mm	0.3510

Analysis of Variance for Mean

Table 4.7. Analysis of Variance for Mean

Source	Degree of Freedom	Sequential Sum of Square	Adjusted Sum of Square	Adjusted Mean of Square	F- statistic	P-value
C.S	2	0.015246	0.015246	0.007623	4.39	0.186
F.R	2	0.183115	0.183115	0.091557	52.73	0.019
D.O.C	2	0.006741	0.006741	0.003370	1.94	0.340
Residual Error	2	0.003473	0.003473	0.001736	-	-
Total	8	0.208574	-	-	-	-

The analysis of variance was carried out at 95%confidence level. The purpose of ANOVA is to investigate which cutting parameters significantly affect the surface roughness. This is accomplished by separating the total variability of the S/N Ratios, which is measured by the sum of squared deviations from the total mean of the S/N ratio, into contributions by each cutting process parameter and the error (Table 4.7). In the experimentation work, for S/N ratios, feed rate ($p = 0.019$) has the significant effect on surface finish at an α-level of 0.05, other parameters cutting speed ($p = 0.186$) and depth of cut ($p = 0.340$) are non-significant.

4.1.4. Regression Analysis

Regression results indicate the direction, size, and statistical significance of the relationship between a predictor and response.

- Sign of each coefficient indicates the direction of the relationship.
- Coefficients represent the mean change in the response for one unit of change in the predictor while holding other predictors in the model constant.
- P-value for each coefficient tests the null hypothesis that the coefficient is equal to zero (no effect). Therefore, low p-values suggest the predictor is a meaningful addition to your model.
- The equation predicts new observations given specified predictor values.

By use of Minitab 17 regression analysis equation for the work was found shown as below:

Ra = 0.0103 - 0.0165 C. S + 0.1727 F. R + 0.0327 D.O.C

Table 4.8 Regression Analysis by Equation

Cutting Speed	Feed rate	Depth of cut	Ra
L2	L1	L1	0.0561
L3	L2	L3	0.0783
L1	L3	L2	0.1162

Chapter 5

5.1. Conclusion

Optimization of the process parameters in End Milling of AL7075 T-651 by Taguchi's experimental design method has been performed. An L9 Orthogonal Array was selected to study the relationships between the surface finish and the three controllable input machining parameters such as cutting speed, feed rate and depth of cut.

The following conclusions can be drawn based on the experimental results of this research work:

1. Taguchi's experimental design method provides a simple, systematic and efficient methodology for the optimization of the Surface finish parameters

2. The optimum values for each factor are shown as below:

Cutting Speed	Level 2	4000 rpm	10.182
Feed Rate	Level 1	160 mm/min	12.861
Depth of cut	Level 1	0.2 mm	9.623

3. Surface Roughness decreases with increase in feed rate. But in case of cutting speed and depth of cut, it increases up to the optimum level and decreases on further increasing these values.
4. Feed rate has an important significant factor for Surface roughness as compared to cutting speed and depth of cut.

5.2. Future Scope

- Different material or different categories of Aluminium Alloy can be used as the experimental material.
- Changed Parameters such as Nose Radius, cutting angles etc. as the input parameters and many other Response parameters like MRR, Chip formation etc.
- Dissimilar Machine instead of CNC can be used with or without Coolant in the experimental Setup.
- Multi Response parameter can be opted as methodology for the experimentation.
- Various other Cutting tools can be used for the End Milling and identifying the Surface Roughness effect of each of them.
- Alternative to DOE approach can be employed for analysis and validation of the project.

Chapter 6

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PUBLICATION

The paper titled "A Review Paper on the Surface Optimization of Aluminium Alloy in Milling" in the "International Journal Science and Research Development" (**IJSRD**) in the Volume 4 Issue 1 in March 2016.


Mini
Mill