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Optimazation Of Cutting Parameters For Turning Aluminium Alloys Using Taguchi Method

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Abstract

The manufacturing cost can be minimized by reducing the machining cost through optimization of machining environment by optimizing the machining parameters like cutting speed, feed and depth of cut, etc. and proper setting of various parameter during machining since machining operation is one of the major cost centres for manufacturing the product, the production cost can also be reduced by reducing the lead time and proper selection of machine tools, cutting tools material, tool geometry and cutting parameters. These variables govern the economics of machining operations. Therefore, the attempt has been made to carry out an experimental investigation by using Taguchi technique mainly to find and correlate the technological factors to the economics of machining process. The Taguchi method is systematic application of design and analysis for experiments. It is an effective approach to produce high quality products at relatively low cost. Therefore Taguchi method is used to investigate the multiple performance characteristic in the turning operation.

The paper work deals with experimental investigations carried out to optimize mach-inability of commercial Al – 7050(Aluminium) and to obtain optimum process parameters. The experiments will be carried out taking Al -7050 as the work piece material with carbide tool of various nose radius in the turning operation on CNC lathe machine. Levels of cutting speeds, depth of cuts, feed rates and nose radius will be selected as the most important parameters which affect machinability according to the Taguchi's Method. The Taguchi's orthogonal arrays will be employed to achieve the objective

The Taguchi's Orthogonal array based on DOE (Design of Experiments) is one of the important techniques, which is used for optimization of process parameters of CNC. The L9 orthogonal array has been used to conduct the experiment for the material considered in this study. The response variables measured for the analysis were the Surface finish, Material removal rate, and machining time.

At last confirmation made is considerable effort to simplify the methods of application of the technique and analysis of the results. However, some of the advanced concepts proposed by this require careful scrutiny.
Therefore theme of our project is:-

"Things should be as simple aspossible, but no simpler."

- Albert Einstein

1. Introduction

Many types of tool materials, ranging from high carbon steel to ceramics and diamonds, are used as cutting tools in today's metal working industry. It is important to be aware that differences do exist among tool materials, what these differences are, and the correct application for each type of material. The various tool manufacturers assign many names and numbers to their products. While many of these names and numbers may appear to be similar, the applications of these tool materials may be entirely different. In most cases the tool manufacturers will provide tools made of the proper material for each given application. In some particular applications, a premium or higher priced material will be justified. This does not mean that the most expensive tool is always the best tool. Cutting tool users cannot afford to ignore the constant changes and advancements that are being made in the field of tool material technology. When a tool change is needed or anticipated, a performance comparison (Up to date review) should be made before selecting the tool for the job. The optimum tool is not necessarily the least expensive or the most expensive, and it is not always the same tool that was used for the job last time. The best tool is the one that has been carefully chosen to get the job done quickly, efficiently and economically.

The ideal requirements of a satisfactory cutting tool can easily be defined, but it is more difficult to specify a tool material that meets all these requirements over a wide range of cutting conditions. The physical and metallurgical requirements of a good cutting tool material include

- ✓ High yield strength at cutting temperature;
- ✓ High fracture toughness;
- ✓ High wear resistance;
- ✓ High fatigue resistance;
- ✓ High thermal capacity and thermal conductivity;
- ✓ Low solubility in the work-piece material;
- ✓ High thermal shock resistance; and
- ✓ Good oxidation resistance.

Aluminum alloys are classified under two classes: cast alloys and wrought alloys.Furthermore, they can be classified according to the specification of the alloying elementsinvolved, such as strain-hardening alloys and heat-treatable alloys. Most wroughtaluminum alloys have excellent machinability. While cast alloys containing copper,magnesium or zinc as the main alloying elements can cause some machining difficulties, theuse of small tool rake angles can however improve machinability. Alloys having silicon asthe main alloying element involve larger tool rake angles, lower speeds and feeds, makingthem more cost-effective to machine. Aluminum alloys, which are not sensitive to heattreatments, can be hardened by cold work that can improve their machinability when sharptools are used. Traditionally, the machinability of materials involve tool life,cutting forces, productivity or chip form, with less attention paid to particle emission.

2. OBJECTIVE OF THE PROJECT

The objective of the work is to study and discuss the various methods of Taguchi technique and strategies that are adopted in order to find the following parameters by both experimentally and Taguchi's techniques

- ➢ The use of arrays to study the effect of machining parameters influence on surface roughness.
- ➢ To develop relationships between the control parameters and response parameters during machining.
- ➢ To study the effect of nose radius on the machinability response i.e., surface finish, material removal and machining time.
- ➢ To optimize turning operations parameters for surface roughness, material removal and machining time.
- ➢ To optimize unit production cost to establish on the basis for actual machining time, set up time, tool reuse time, tool life and tool changing time.

3. WHY ALUMINIUM?

The main properties which make aluminium a valuable material are is lightweight, strength, recyclability, corrosion resistance, durability, ductility, formability and conductivity. Due to this unique combination of properties, the variety of applications of aluminium continues to increase. It is essential in our daily lives. We cannot fly; go by high performance car or fast ferry without it. We cannot get heat and light into our homes and office without it. We depend on it to preserve our food, our medicine and t provide electronic components for our computers.

Physically, chemically and mechanically aluminium is a metal like steel, brass, copper, zinc, lead or titanium. It can be melted, cast, formed and machined much like these metal and it conducts electric current. In fact often the equipment and fabrication methods are used for steel.

4. TAGUCHI METHOD OF ROBUST DESIGN

The objective of engineering design, a major part of research and development (R & D), is to produce drawings, specifications, and other relevant information needed to manufacture products that meet customer requirements. Knowledge of scientific phenomena and past engineering experience with similar product designs and manufacturing processes from the basis of the engineering design and manufacturing processes from the basis of the engineering design activity. However, a number of new decisions related to the particular product design must be made regarding product must be made regarding product architecture, parameter of the product design, the process architecture, and parameter of the manufacturing process. A large amount of engineering effort is consumed in conducting the experiment to generate the information needed to guide these decisions. Efficiency in generating such information is the key to meeting marketing windows, keeping development and manufacturing cost low, and having high-quality products. Robust design is an engineering methodology for improving productivity during research and development so that high-quality products can be produced quickly and at low cost.

5. STEPS IN ROBUST DESIGN Optimizing a product or process design means determining the best architecture, levels of control factors, and tolerance. Robust Design is a methodology for finding the optimum settings of the control factors to make the product or process insensitive to noise factors. It involves eight steps that can be grouped into three major categories of planning experiments, conducting them, and analyzing and verifying the result.

6. TAGUCHI METHOD DESIGN OF EXPERIMENTS

1. Define the process objective, or more specifically, a target value for a performance measure of the process.
2. Determine the design parameters affecting the process.
3. Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment.
4. Conduct the experiments indicated in the completed array to collect data on the effect on the performance measure.
5. Complete data analysis to determine the effect of the different parameters on the performance measure.

7. CONSTRUCTION OF ORTHOGONAL ARRAY

This section describes the techniques for constructing orthogonal array that suit a particular case study. The process of fitting an orthogonal array to a specific project has been made particularly easy by a graphical tool, called linear graphs, developed by Taguchi to represent interactions between pairs of columns in an orthogonal array. This section shows the use of linear graphs and a set of standard orthogonal arrays for constructing orthogonal arrays to fit a specific project.

Before constructing an orthogonal array, the following requirements must be defined:

- Number of factors to be studied
- Number of levels for each factor
- Specific 2-factor interactions to be estimated

Special difficulties that would be encountered in running the experiments. Special difficulties that would be encountered in running the experiments.

- Counting Degrees Of Freedom
- Selecting A Standard Orthogonal Array
- To Design The Matrix Experiment And To Define The Data Analysis Procedure
-

8. EXPERIMENTAL SETUP

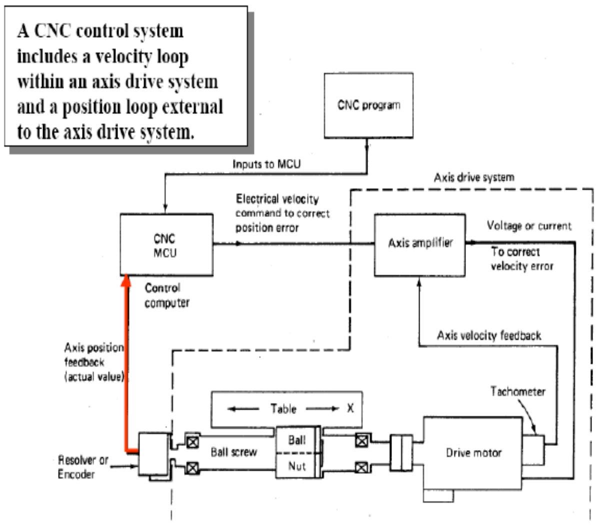
INTRODUCTION TO CNC SYSTEM ELEMENTS

DEFINITION

In CNC (Computer Numerical Control), the instructions are stored as a program in a micro-computer attached to the machine. The computer will also handle much of the control logic of the machine, making it more adaptable than earlier hard-wired controllers.

A typical CNC system consists of the following six elements

1. Part program
2. Program input device
3. Machine control unit
4. Drive system
5. Machine tool
6. Feedback system



9. MATERIAL REMOVAL RATE AND MACHINING TIME

Material removal rate and machining time is calculated using formulas.

- ➢ RR = Π x D x d x f x N
  Where D is Initial diameter of the work piece
  dis depth of cut
  f is feed rate
  N is speed
- ➢ achining time = L / f x N
  Where L is total length of the work piece
  f is feed rate N is speed

10. RESULTS

OBSERVATION AND YEILD MATRICES

OBSERVATION AND YEILD MATRIX FOR 2 FACTORS & 3 LEVELS

SL. No.	Cutting Speed (rpm)	Feed (mm/rev)	Surface Roughness (µm)	Material Removal Rate (mm3/rev)	Machining Time (min)
1	500	0.010	1.2235	1178.09	9.600
2	500	0.045	2.8397	5301.43	2.133
3	500	0.090	0.8480	10602.87	1.066
4	1000	0.010	3.5370	2356.19	4.800
5	1000	0.090	0.4937	21205.75	0.533
6	1000	0.045	3.1400	10602.87	1.066
7	2000	0.090	0.5380	42411.50	0.266
8	2000	0.010	8.1800	4712.38	2.400
9	2000	0.045	0.5905	21205.75	0.533

- ❖ **EFFECT OF CUTTING PARAMETER ON SURFACE ROUGHNESS**

MAIN EFFECT OF CUTTING PARAMETERS ON SURFACE ROUGHNESS OF ALUMINIUM 7050 AFTER TURNING IN CNC LATHE USING L9 ORTHOGONAL ARRAY

The effect of cutting parameters are nose radius, feed rate, cutting speed, depth of cut on surface roughness of aluminum 7050 after turning in CNC LT-16 Lathe using L9 orthogonal array are investigated.

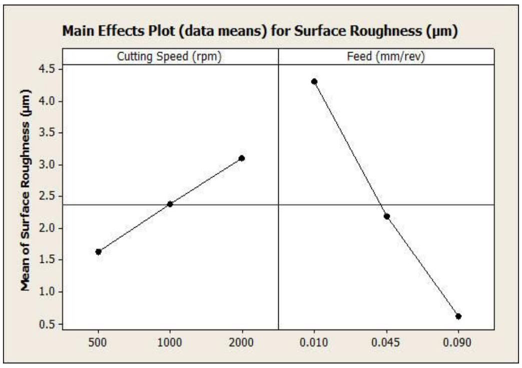


Figure 6.1

It can be seen from Fig that within the scope of this investigation as speed of the cutting tool increases there is decrease in the surface roughness. For variation in the speed of cutting tool from 500rpm to 2000rpm the average surface roughness varies from 1.6 micrometer to 3.25 micrometer respectively, surface roughness of the work material decreases by 2.18 times.

It can be seen from Fig that within the scope of this investigation as feed of the cutting tool increases there is increase in the surface roughness. For variation in the feed rate of cutting tool from 0.010mm/rev to 0.090mm/rev the average surface roughness varies from 4.3 micrometer to 0.7 micrometer respectively, surface roughness of the work material decreases by 6.14 times.

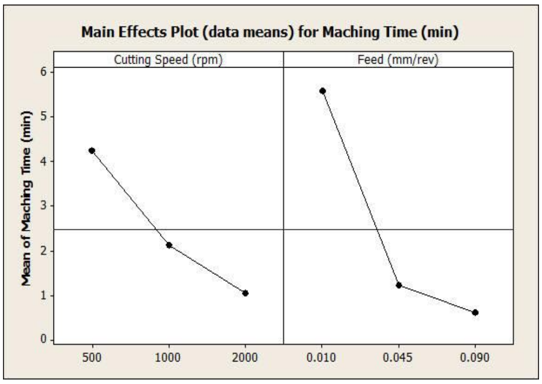
Optimized parameters for Al-7050 alloy to obtain better surface finish

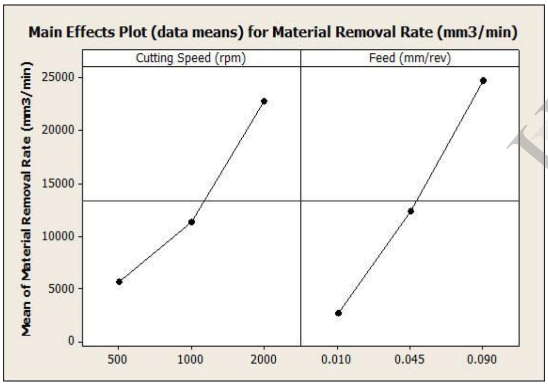
Control Factors		Optimum level	Unit
1	Cutting Speed	2000	rpm
2	Feed	0.010	mm/rev

- ❖ **EFFECT OF CUTTING PARAMETER ON MATERIAL REMOVAL RATE**

MAIN EFFECT OF CUTTING PARAMETERS ON MATERIAL REMOVAL RATE OF ALUMINIUM 7050 AFTER TURNING IN CNC LATHE USING L9 ORTHOGONAL ARRAY

The effect of cutting parameters are nose radius, feed rate, cutting speed, depth of cut on surface roughness of aluminium 7050 after turning in CNC LT-16 Lathe using L9 orthogonal array are investigated





It can be seen from Fig that within the scope of this investigation as speed of the cutting tool increases there is an increase in the material removal rate. For variation in the speed of cutting tool from 500rpm to 2000rpm the average material rate varies from 6000mm^3/min to 23000mm^3/min respectively, material removal rate of the work material improves by 3.833 times.

It can be seen from Fig that within the scope of this investigation as feed rate of the cutting tool increases there is an increase in the material removal rate. For variation in the feed rate of cutting tool from 0.01mm/rev to 0.09 mm/rev the average material rate varies from 2500 mm^3/min to 25000mm^3/min respectively, material removal rate of the work material improves by 10 times.

Optimized parameters for Al-7050 alloy to obtain better material removal rate

Control Factors		Optimum level	Unit
1	Cutting Speed	2000	rpm
2	Feed	0.090	mm/rev

- ❖ **EFFECT OF CUTTING PARAMETER ON MACHINING TIME**

MAIN EFFECT OF CUTTING PARAMETERS ON MACHINING TIME OF ALUMINIUM 7050 AFTER TURNING IN CNC LATHE USING L9 ORTHOGONAL ARRAY

The effect of cutting parameters are nose radius, feed rate, cutting speed, depth of cut on surface roughness of aluminium 7050 after turning in CNC LT-16 Lathe using L9 orthogonal array are investigated.

It can be seen from Fig that within the scope of this investigation as speed of the cutting tool increases there is decrease in the machining time. For variation in the speed of cutting tool from 500rpm to 2000rpm the average machining time varies from 1min to 4.3min respectively, machining time of the work material improves by 4.3 times.

It can be seen from Fig that within the scope of this investigation as feed rate of the cutting tool increases there is decrease in the machining time. For variation in the feed rate of cutting tool from 0.010mm/rev to 0.090mm/rev the average machining time varies from 5.7min to 0.7min respectively, machining time of the work material improves by 8.14 times.

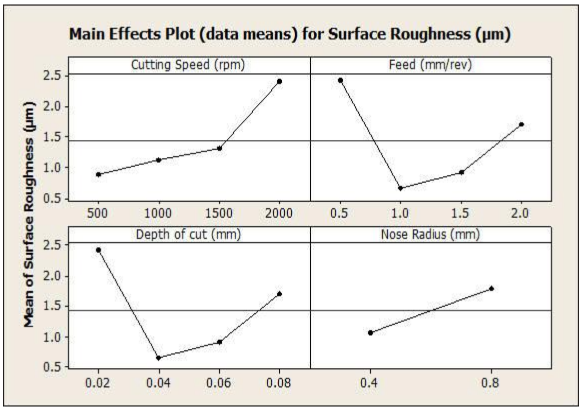
Optimized parameters for Al-7050 alloy to obtain better machining time

Control Factors		Optimum level	Unit
1	Cutting Speed	500	rpm
2	Feed	0.010	mm/rev

❖ **EFFECT OF CUTTING PARAMETER ON SURFACE ROUGHNESS**

MAIN EFFECT OF CUTTING PARAMETERS ON SURFACE ROUGHNESS OF ALUMINIUM 7050 AFTER TURNING IN CNC LATHE USING L16 ORTHOGONAL ARRAY

The effect of cutting parameters are nose radius, feed rate, cutting speed, depth of cut on surface roughness of aluminium 7050 after turning in CNC LT-16 Lathe using L9 orthogonal array are investigated.



It can be seen from Fig that within the scope of this investigation as speed of the cutting tool increases there is decrease in the surface roughness. For variation in the speed of cutting tool from 500rpm to 2000rpm the average surface roughness varies from 0.8 micrometer to 2.4 micrometer respectively, surface roughness of the work material increases by 0.33 times.

It can be seen from the fig.----- that within the scope of this investigation as feed rate increases the surface roughness deteriorates and then improves after a feed rate of 1.0 mm/rev. feed rate of 1.0 mm/rev gives the lowest surface roughness and hence gives better surface finish.

It can be seen from the fig.----- that within the scope of this investigation as depth of cut decreases the surface roughness increases For variation in the depth of cutting tool from 0.02 to 0.08 mm the average surface roughness varies from 2.4 to 1.7 micrometer respectively, surface roughness of the work material decreases by 1.411 times.

It can be seen from the fig.----- that within the scope of this investigation as nose radius varies from 0.4 to 0.8mm the average surface roughness varies from 1.2 to 1.7 micrometer respectively, surface roughness of the work material decreases by 0.70588 times.

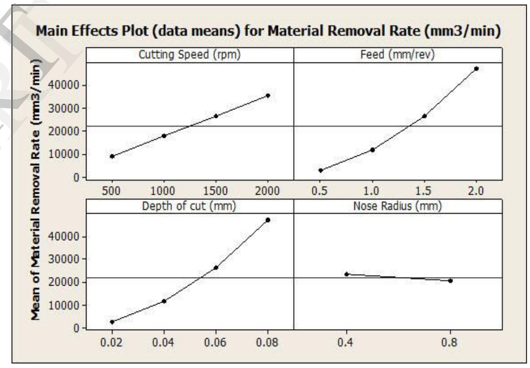
Table 6.4 Optimized parameters for Al-7050 alloy to obtain better surface finish

Control Factors		Optimum level	Unit
1	Cutting Speed	2000	rpm
2	Feed	0.5	mm/rev
3	Depth of cut	0.02	mm
4	Nose Radius	0.8	mm

❖ EFFECT OF CUTTING PARAMETER ON MATERIAL REMOVAL RATE

MAIN EFFECT OF CUTTING PARAMETERS ON MATERIAL REMOVAL RATE OF ALUMINIUM 7050 AFTER TURNING IN CNC LATHE USING L16 ORTHOGONAL ARRAY

The effect of cutting parameters are nose radius, feed rate, cutting speed, depth of cut on surface roughness of aluminium 7050 after turning in CNC LT-16 Lathe using L16 orthogonal array are investigated



It can be seen from Fig that within the scope of this investigation as speed of the cutting tool increases there is decrease in the material removal rate. For variation in the speed of cutting tool from 500rpm to 2000rpm the average material removal rate varies from 9000mm^3/min to 35000 mm^3/min respectively, material removal rate of the work material improves by 2.571 times.

It can be seen from Fig that within the scope of this investigation as feed of the cutting tool increases there is an increase in the material removal rate. For variation in the feed rate of cutting tool from 0.5mm/rev to 2.0mm/rev the average material removal rate varies from 3000mm^3/min to 48000mm^3/min respectively, material removal rate of the work material improves by 16 times.

It can be seen from Fig that within the scope of this investigation as depth of the cutting tool increases there is an increase in the material removal rate. For variation in the depth of cut of cutting tool from 0.02mm to 0.08mm the average material removal rate varies from 2000mm^3/min to 49000mm^3/min respectively, material removal rate of the work material improves by 24.5 times.

It can be seen from Fig that within the scope of this investigation as nose radius of the cutting tool increases there is an decrease in the material removal rate. For variation in the nose radius of cutting tool from 0.4mm to 0.8mm the average material removal rate varies from 21000mm^3/min to 19000mm^3/min respectively, material removal rate of the work material decreases by 0.904 times.

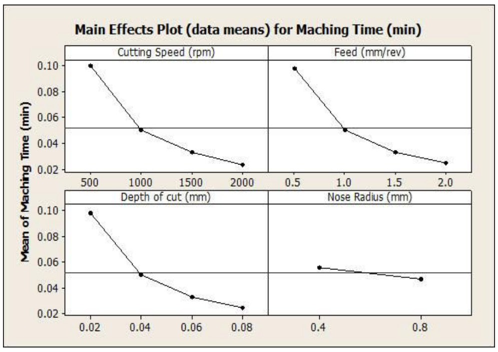
Optimized parameters for Al-7050 alloy to obtain better material removal rate

Control Factors		Optimum level	Unit
1	Cutting Speed	2000	rpm
2	Feed	2.0	mm/rev
3	Depth of cut	0.08	mm
4	Nose Radius	0.4	mm

❖ EFFECT OF CUTTING PARAMETER ON MACHINING TIME

MAIN EFFECT OF CUTTING PARAMETERS ON MACHINING TIME OF ALUMINIUM 7050 AFTER TURNING IN CNC LATHE USING L16 ORTHOGONAL ARRAY

The effect of cutting parameters are nose radius, feed rate, cutting speed, depth of cut on surface roughness of aluminium 7050 after turning in CNC LT-16 Lathe using L16 orthogonal array are investigated.



It can be seen from Fig that within the scope of this investigation as speed of the cutting tool increases there is decrease in the machining time. For variation in the speed of cutting tool from 500rpm to 2000rpm the average machining time varies from 0.022min to 0.10min respectively, machining time of the work material improves by 4.54 times.

It can be seen from Fig that within the scope of this investigation as feed rate of the cutting tool increases there is decrease in the machining time. For variation in the feed rate of cutting tool from 0.5mm/rev to 2mm/rev the average machining time varies from 0.10min to 0.023min respectively, machining time of the work material improves by 4.34 times.

It can be seen from Fig that with in the scope of this investigation as depth of cut of the cutting tool increases there is no decrease in the machining time. For variation in the feed rate of cutting tool from 0.02mm to 0.08mm the average machining time varies from 0.022min to 0.09min respectively, machining time of the work material improves by 4.09 times.

It can be seen from Fig that within the scope of this investigation as nose radius of the cutting tool increases there is no increase in the machining time. For variation in the nose radius of cutting tool from 0.4mm to 0.8mm the average machining time varies from 0.055min to 0.045min respectively, machining time of the work material improves by 1.2min times.

Optimized parameters for Al-7050 alloy to obtain better machining time

Control Factors		Optimum level	Unit
1	Cutting Speed	500	rpm
2	Feed	0.5	mm/rev
3	Depth of cut	0.02	mm
4	Nose Radius	0.4	mm

11. CONCLUSIONS

1) Desired parameter for surface finish has been achieved

The main parameters that affects surface roughness have been identified analyzed under different conditions and finally optimized. The main parameters being cutting speed, feed rate, depth of cut the nose radius.

2) Trial and error has been avoided

Thanks to TAGUCHI'S technique of design of experiments, utilizing orthogonal arrays the number of tests involved generally i.e., by trial and error has been reduced considerably.

3) Various options to select surface roughness

By this project we can conclude that there are several options through which the surface roughness can be obtained that is through cutting speed, feed rate, depth of cut, and nose radius.

4) Innovative method to optimize machinability by statistical method

By utilizing TAGUCHI'S technique we have invented an innovative method to optimize machinability and cutting tool parameters in turning operation.

- The analysis of the experimental observations highlights that MRR in CNC turning process is greatly influenced by depth of cut.
- It is found that if speed increases then MRR would increase.

11. SCOPE FOR FUTURE WORK

The machining was done on Al-7050 to study the effect of the independent process parameters on process output parameters. Performance evaluation was done on surface roughness, material removal rate and machining time. Performance characteristic was analyzed using Taguchi's Technique.

- ❖ There is scope for extending the study with various work materials like brass, magnesium, nickel, steel, thermoset plastic, titanium and zinc.
- ❖ The material of cutting tool used in the present project was carbide. The experiment can be performed with different cutting tools including Tungsten carbide electrode to asses the machining performance of CNC machine.
- ❖ The present project work was carried out by considering Al-7050 as work material of 25mm diameter & 75mm length and carbide tools of 0.4mm and 0.8mm nose radius as tool material. Further this project can be extended for different diameter and length of work materials and by varying tool nose radius and the much more harder tool material like ceramic, cubic boron nitride etc of suitable nose radius.
- ❖ The project work can be extended by considering the other parameters like Spindle speed, axial depth of cut, radial depth of cut etc.
- ❖ The project can also be extended by considering the noise factors.

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