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Optimization Of Machining Parameter For Aluminium Material

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Abstract- Machining is an important manufacturing process used to shape metal materials into desired sizes and shapes. Aluminium is widely used in industries because of its light weight, good strength, and corrosion resistance. However, proper selection of machining parameters is necessary to achieve good surface finish, longer tool life, and higher productivity. This project focuses on the optimization of machining parameters such as cutting speed, feed rate, and depth of cut during the machining of aluminium material. Different machining experiments are conducted by changing these parameters to study their effect on surface roughness and material removal rate. The Taguchi method is used as a statistical technique to analyze the results and determine the best combination of parameters. The main objective of this project is to improve machining performance, reduce production cost, and increase efficiency in aluminium machining operations. The optimized parameters obtained from this study can help industries achieve better quality products with minimum machining time and tool wear.

Keywords: Machining parameters, Cutting speed, Feed rate, Depth of cut, Surface roughness, Tool wear, Material Removal Rate (MRR).

I. INTRODUCTION (ALUMINIUM H9 MATERIAL)

1.1 Introduction:

Machining is a subtractive manufacturing process used to remove material in order to achieve desired geometry and surface finish. Among various engineering materials, aluminium is widely used due to its low density, high strength-to-weight ratio, and corrosion resistance.

Aluminium H9 is a strain-hardened material with improved hardness and strength due to cold working. It is commonly used in automotive, aerospace, and structural applications.

However, machining performance depends heavily on process parameters such as: Cutting speed
Feed rate Depth of cut
Improper selection of these parameters leads to:
Poor surface finish Increased tool wear Low productivity
Therefore, optimization of machining parameters is necessary.

II. METHODOLOGY

2.1 Introduction to Experimental Design

In machining operations, the performance of the process is highly influenced by multiple input parameters such as cutting speed, feed rate, and depth of cut. These parameters interact with each other and affect output responses like material removal rate (MRR) and surface roughness (Ra).

Traditional experimental approaches require a large number of trials to study the influence of all parameters and their combinations. This increases:

- Experimental time
- Cost of machining
- Material consumption

To overcome these limitations, a systematic and efficient statistical approach is required. In this project, the Taguchi method is used for designing experiments and optimizing machining parameters.

2.2 Taguchi Method Overview

The Taguchi method is a powerful statistical tool developed by Dr. Genichi Taguchi for improving product quality and process performance. It focuses on making the system robust against variations caused by uncontrollable factors (noise).

The method uses:

- Orthogonal Arrays (OA)
- Signal-to-Noise (S/N) ratio
- Analysis of means

to identify optimal parameter settings.

2.2.1 Objectives of Taguchi Method

The main objectives of using Taguchi method in this study are:

- To reduce number of experiments
- To identify significant machining parameters
- To improve surface finish
- To increase material removal rate
- To minimize variation in results

2.2.2 Advantages of Taguchi Method

- Requires fewer experiments compared to full factorial design
- Simple and systematic approach
- Reduces experimental cost and time
- Provides reliable and accurate results
- Helps in identifying dominant factors

2.3 Steps in Taguchi Method

The following steps were followed in this project:

Step 1: Identification of Problem

The problem identified in this study is:

- Poor surface finish
- Low productivity in machining

Hence, optimization of machining parameters is required.

Step 2: Selection of Control Factors

Control factors are the input parameters that can be controlled during machining. In this study, the selected control factors are:

1. Spindle Speed (RPM)
2. Feed Rate (mm/rev)
3. Depth of Cut (mm)

Step 3: Selection of Levels

Each parameter is assigned four levels to study its variation effect.

Parameter	Level 1	Level 2	Level 3	Level 4
Speed	1790	2387	2785	3300
Feed	0.10	0.15	0.20	0.25
DOC	0.30	0.60	0.90	1.20

Step 4: Selection of Orthogonal Array

An orthogonal array is used to design experiments efficiently. In this project:

- L16 Orthogonal Array is selected
- It allows conducting 16 experiments instead of 64 (full factorial)

This significantly reduces effort while maintaining accuracy.

Step 5: Conducting ExperimentsExperiments were conducted on a CNC lathe machine using Aluminium H9 material.

For each trial:

- Parameters were set according to OA
- Machining was performed
- Output values were recorded

Measured outputs:

- Surface Roughness (Ra)
- Material Removal Rate (MRR)

Step 6: Calculation of S/N Ratio

The Signal-to-Noise ratio is used to measure quality characteristics. It considers:

- Mean performance
- Variation in results

Types of S/N Ratios Used

1. Smaller-the-Better (for Surface Roughness)
Used when lower value is desired

$S/N = -10 \log (\Sigma y^2 / n)$

2. Larger-the-Better (for MRR)
Used when higher value is desired

$S/N = -10 \log (1/n\ \Sigma(1/y^2))$

Higher S/N ratio always indicates better performance.

Step 7: Analysis of Results

After calculating S/N ratios:

- Mean S/N values were computed
- Main effect plots were generated
- Influence of each parameter was studied

This helps to:

- Identify most significant factor
- Determine optimal levels

Step 8: Determination of Optimal Parameters

Optimal parameters are selected based on:

- Highest S/N ratio
- Desired performance (low Ra, high MRR)

Step 9: Confirmation Test

A confirmation experiment is conducted using optimal parameters to verify results. This ensures:

- Accuracy of optimization
- Reliability of results

2.4 CNC Machining Process

The machining process was carried out using CNC turning operation.

2.4.1 CNC Lathe Machine

A CNC lathe is used for:

- Turning cylindrical parts
- Achieving high precision
- Automating machining process

2.4.2 Use of G71 Canned Cycle

The G71 cycle is used for rough turning operations.
Purpose:

- Remove large amount of material
- Reduce programming effort
- Improve machining efficiency

Basic Format:

G71 U(depth of cut) R(retract)
G71 P(start) Q(end) U(finish allowance) W(feed) F(feed rate)

Advantages:

- Automatic multiple cuts
- Uniform material removal
- Reduced cycle time

2.5 Measurement of Responses

2.5.1 Material Removal Rate (MRR)

MRR is defined as the volume of material removed per unit time.

MRR = Volume removed / Machining time Higher MRR indicates:

- Higher productivity
- Faster machining

2.5.2 Surface Roughness (Ra)

Surface roughness indicates the quality of machined surface.

- Measured using surface roughness tester
- Eressed in micrometers (μm)

Lower Ra means:

- Better surface finish

- Higher product quality

2.6 Importance of Optimization

Optimization of machining parameters is essential because:

- Improves surface finish
- Increases production rate
- Reduces tool wear
- Minimizes machining cost
- Enhances product quality

III. EXPERIMENTAL DETAILS

1.1 Selection Of Material:

Aluminium H9 is a type of aluminium material that belongs to the strain-hardened (work-hardened) temper category.The designation H9 indicates that the aluminium has been heavily cold-worked to increase its strength and hardness compared to soft or annealed aluminium.Aluminium is widely used in engineering because it is lightweight, corrosion-resistant, and easy to machine. When aluminium is processed into the H9 temper, it becomes stronger and more durable, making it suitable for applications where higher strength and better wear resistance are required.Aluminium H9 material is commonly used in manufacturing industries for components such as machine parts, structural components, automotive parts, and aerospace components. It also provides good surface finish and dimensional accuracy, which is important in machining and fabrication processes.Due to its high strength-to-weight ratio, good thermal conductivity, and resistance to corrosion, Aluminium H9 is an important material in modern mechanical and industrial applications.

Input Parameters :

1. Cutting speed
2. Feed rate
3. Depth of cut

Output Parameters:

- removal rate
- Surface roughness

Applications Of H9:

1. Automobile parts (pistons, brake drums)
2. Aerospace components
3. Machine parts
4. Structural components
5. Defence equipment

Property	Value
Base Material	HE9 (Aluminium 6063)
Density	2.70 g/cm³
Young's Modulus	68.9 GPa
Tensile Strength	130–230 MPa *(depends on temper, e.g., T5/T6)*
Elongation at Break	8–18%
Poisson's Ratio	0.33
Melting Temperature	~615–655 °C
Thermal Conductivity	200–218 W/(m·K)
Linear Thermal Expansion Coefficient	2.3×10^{-5} /K
Specific Heat Capacity	900 J/(kg·K)

Table 3.1 Al 6063 Mechanical Properties

Elements	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Wt %	0.20–0.60	0.35 max	0.10 max	0.10 max	0.45–0.90	0.10 max	0.10 max	0.10 max	Balance

Table 3.2 Al 6063 Chemical Composition

Fig. 3.3 Al 6063 after machining

3.3 Machine Tool and Setup

The experiments were conducted on a CNC lathe machine, which provides high precision and repeatability in machining operations. The workpiece was properly clamped using a chuck to ensure stability during cutting. A suitable cutting tool was selected based on material compatibility and machining requirements. Proper alignment of the tool and workpiece was maintained to avoid vibration and dimensional errors. Coolant was used during machining to reduce heat generation and improve tool life.

3.4 CNC Turning Process Using G71 Canned Cycle

The machining process was carried out using the G71 canned cycle, which is used for rough turning operations in CNC lathes. This cycle allows automatic removal of material in multiple passes, reducing manual programming effort. It improves machining efficiency by maintaining consistent cutting conditions throughout the operation. The G71 cycle also ensures uniform material removal, which helps in achieving better dimensional accuracy. It is widely used in industry for bulk material removal before finishing operations.

3.5 Process Parameters

Three main machining parameters were selected for this study: spindle speed, feed rate, and depth of cut. Each parameter was varied at four different levels to study its effect on performance characteristics. Spindle speed controls the cutting velocity, while feed rate determines the advancement of tool per revolution. Depth of cut defines the thickness of material removed in a performance.single pass. Proper selection of these parameters is essential for achieving optimal machining

Parameters	level			
	1	2	3	4
Speed, RPM	1790	2387	2785	3300
Feed, mm/rev	0.1	0.15	0.2	0.25
Depth of cut, mm	0.3	0.6	0.9	1.

Table: 3.5 Process Parameters and Their Levels

3.6 Experimental Design (L16 Orthogonal Array)

The experimental design was based on the Taguchi L16 orthogonal array, which allows efficient study of multiple parameters with fewer experiments. Instead of conducting 64 experiments in a full factorial design, only 16 experiments were performed. Each row of the orthogonal array represents a unique combination of parameters. This design ensures balanced comparison of all factors and their levels. It significantly reduces time, cost, and effort while maintaining accuracy in analysis.

SR.NO.	SPEED (S RPM)	FEED (F) mm/ rev	DOC (U) mm
I	**1790**	**0.10**	**0.30**
F	**2387**	**0.10**	**0.60**
C	**2785**	**0.10**	**0.90**
D	**3300**	**0.10**	**1.20**
E	**1790**	**0.15**	**0.60**
B	**2387**	**0.15**	**0.30**
G	**2785**	**0.15**	**1.20**
H	**3300**	**0.15**	**0.90**
A	**1790**	**0.20**	**0.90**
J	**2387**	**0.20**	**1.20**
K	**2785**	**0.20**	**0.30**
L	**3300**	**0.20**	**0.60**
M	**1790**	**0.25**	**1.20**
N	**2387**	**0.25**	**0.90**
O	**2785**	**0.25**	**0.60**
P	**3300**	**0.25**	**0.30**

Table: 3.6 L16 OA Design

3.7 Measurement of Material Removal Rate (MRR)

Material Removal Rate (MRR) is an important performance parameter that indicates machining productivity. It is calculated as the volume of material removed per unit time during machining. In this study, MRR was determined based on machining time and volume of material removed. Higher MRR indicates faster machining and improved production efficiency. However, excessive MRR may affect surface quality and tool life, so optimization is necessary.

3.8 Measurement of Surface Roughness (Ra)

Surface roughness (Ra) is used to evaluate the quality of the machined surface. It represents the average deviation of surface irregularities from the mean line. In this study, Ra values were measured using a surface roughness tester after each machining trial. Lower Ra values indicate smoother surface finish and better product quality. Surface roughness is influenced by feed rate, tool condition, and cutting parameters.

3.9 Data Collection and Recording

All experimental readings were carefully recorded after each trial to ensure accuracy and consistency. The values of MRR and surface roughness were tabulated for further analysis. Proper precautions were taken to minimize measurement errors during data collection. The recorded data was later used for calculating S/N ratios and analyzing parameter effects. Accurate data collection is essential for reliable optimization results.

VI. RESULTS AND CONCLUSION

6.1 Taguchi Analysis:

The experimental results of material removal rate and surface roughness measured were depicted in the table 5.1. The analysis was carried out using MINITAB-17 software. The effect of process parameters on responses were calculated and plotted. Taguchi results for the responses are given in the tables, where the ranks indicate the relative importance of each factor. The main effect plots were drawn to study the variation effects of parameters on the responses with their changes in levels.

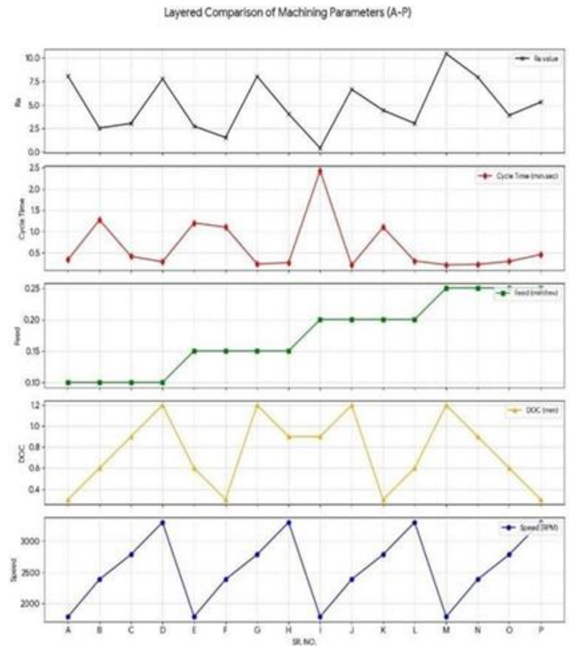

FIG 3.4 Conclusion of Experiment

The present experiment was conducted using the Taguchi L16 orthogonal array to study the effect of machining parameters—spindle speed, feed rate, and depth of cut (DOC)—on Material Removal Rate (MMR) and Surface Roughness (Ra) in a turning operation.

6.11. Effect of Machining Parameters

Feed Rate (Most Influential on Surface Finish)

- Surface roughness (Ra) increases significantly with feed.
- At low feed (0.10 mm/rev), the surface finish is best (Ra ≈ 0.433).
- At higher feed (0.25 mm/rev), roughness increases sharply. Conclusion:

Feed rate is the dominant factor affecting surface quality. Depth of Cut (Most Influential on MRR)

- MRR increases rapidly with increase in DOC.
- Maximum MRR occurs at DOC = 1.20 mm.

- However, higher DOC leads to poor surface finish.

Conclusion:
Depth of cut is the most significant parameter for productivity (MRR). Spindle Speed

- Increasing speed slightly improves MRR.
- Higher speeds tend to increase surface roughness after a limit due to vibration and heat.

Conclusion:
Speed has a moderate effect compared to feed and DOC.

6.2. Optimization Results.

6.21 For Maximum MRR Achieved at:
- Speed = 2387 RPM
- Feed = 0.20 mm/rev
- DOC = 1.20 mm
- Maximum MRR = 9.27×10^{-4} cm^3/sec

High productivity requires high feed and high DOC.

6.22 For Minimum Surface Roughness Achieved at:
- Speed = 1790 RPM
- Feed = 0.10 mm/rev
- DOC = 0.30 mm
- Minimum Ra = 0.433 µm

Best finish requires low feed and low DOC.

6.23 Overall Optimal Condition (Balanced)
- Speed = 2785 RPM
- Feed = 0.15 mm/rev
- DOC = 0.60 mm

Provides:
- Moderate MRR
- Acceptable surface finish
- Stable machining performance

6.3 Taguchi Technique Effectiveness
- Taguchi method successfully reduced the number of experiments using L16 array.
- S/N ratio analysis helped identify:
- Optimal parameter levels
- Influence of each factor
- It provides a systematic and efficient optimization approach.

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