Original Article
ISSN (Online): 2582-7472
ShodhKosh: Journal of Visual and Performing Arts
December 2023 4(2), 1552-1564

EXPERIMENTAL INVESTIGATION AND COMPARATIVE STUDY OF CNC MILLING PROCESS PARAMETER BY FACTORIAL METHODS WITH TAGUCHI METHOD ON ALUMINUM ALLOY

K Nagamani[1] Dr. B Venkatesh[2], N Keerthi[3]

aits.med.knm@gmail.com, aits.med.bv@gmail.com, aits.med.nk@gmail.com

Assistant Professor Department of Mechanical Engineering, Annamacharya University, Rajampet.

DOI

10.29121/shodhkosh.v4.i2.2023.2650

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

This study explores the comparative effectiveness of the One Factor at a Time (OFAT) and Taguchi methods in optimizing CNC milling parameters for aluminum alloy 6061. The primary aim is to enhance the material removal rate (MRR) and minimize surface roughness (Ra) and temperature under both coolant and non-coolant conditions. A systematic approach is employed, involving a series of CNC milling experiments where depth of cut, feed rate, and spindle speed are varied. By utilizing both one factor at a time and Taguchi methods, this research seeks to identify the most influential factors affecting MRR, Ra, and temperature. The Taguchi method is applied for its robust design capabilities, while the one factor at a time method isolates individual parameters to assess their impact. The Percentage of Variation in Ra and temperature, with and without coolant, is analyzed for both methods to determine their efficacy in process optimization. Through nine experimental trials, the study aims to ascertain which method provides superior results in terms of optimizing MRR and reducing Ra and temperature. The findings will offer significant insights into the effectiveness of each method, contributing to the improvement of CNC milling processes. This research not only advances the understanding of process optimization in CNC machining but also provides practical recommendations for selecting the most suitable optimization approach based on specific machining objectives.

Keywords: CNC milling, One Factor at a Time (OFAT), Taguchi method, aluminum alloy 6061, material removal rate (MRR), surface roughness (Ra), temperature, process optimization

Introduction:

The advent of the fourth industrial revolution has brought about significant advancements in manufacturing technologies, among which CNC (Computer Numerical Control) machining stands out as a pivotal innovation. CNC machining is a sophisticated, computerized manufacturing process that utilizes pre-programmed software and code to control the movement of production equipment. This technology has transformed traditional

How to cite this article (APA): Nath, C., and Kumar, S. (2024). From Colonial Servitude to Contemporary Marginalisation: Exploring the Struggles of Assam's Adivasis and Tea Garden Workers. *ShodhKosh: Journal of Visual and Performing Arts, 4*(2), 1552-1564 DOI: 10.29121/shodhkosh.v4.i2.2023.2650

manufacturing by automating processes that were once manual, thereby enhancing production speed, output, and precision. CNC machining encompasses various procedures, including CNC turning, CNC milling, CNC drilling, and CNC grinding, each contributing to the evolution of modern manufacturing practices.

CNC milling machines, in particular, play a crucial role in contemporary manufacturing and prototyping. These machines use computerized controls to precisely cut and shape materials such as metals, composites, wood, and plastics. The primary function of CNC milling is to convert digital designs or CAD (Computer-Aided Design) models into physical prototypes or finished products by removing material from a workpiece according to preset instructions. This capability allows for the creation of complex shapes, patterns, and geometries with high accuracy and repeatability. CNC milling machines are versatile, capable of producing parts with tight tolerances and excellent surface quality.

Aluminum alloys are widely used in manufacturing due to their desirable properties, including lightweight, strength, and corrosion resistance. Among these, the 6061 aluminum alloy is particularly notable for its excellent machinability, making it a popular choice in various industries, including aerospace, automotive, and consumer electronics. The 6061 alloy offers good mechanical properties and can be easily cut, drilled, and shaped, making it suitable for a range of applications from structural components to intricate parts.

Despite the advantages of CNC machining and aluminum alloys, optimizing machining parameters remains a significant challenge. The research problem addressed in this paper is the need for effective methods to optimize CNC milling parameters to enhance material removal rate (MRR), surface finish, and temperature control. Existing studies, such as those by Moshat et al. and Naresh et al., highlight the potential of optimization techniques like the Taguchi method and Principal Component Analysis (PCA) in improving CNC milling processes. However, there is a need for further investigation into the comparative effectiveness of different optimization methods, including the One Factor at a Time (OFAT) approach.

The objective of this research is to compare the OFAT and Taguchi methods in optimizing CNC milling parameters for aluminum alloy 6061. Specifically, this study aims to determine which method more effectively enhances MRR, minimizes surface roughness (Ra), and controls temperature, both with and without coolant. By conducting a series of experiments, the research seeks to identify the most influential factors and provide insights into the optimal approach for CNC milling process optimization.

Methodology

3.1 Selection of Machining Process

The CNC milling machine selection process is structured to meet the project's objectives and specifications. Key factors considered include:

- **Machine Specifications**: Size, spindle speed, horsepower, and number of accessible axes.
- **Equipment Features**: Type of bed, control system, tool changer capacity, and overall rigidity.
- **Project Constraints:** Part geometry, material compatibility, maintenance requirements, and budgetary constraints.

An in-depth evaluation of these factors is performed to acquire a CNC milling machine that offers an optimal balance between performance and cost-effectiveness, ensuring precision and productivity in machining operations.

3.2 Design of Experiments (DOE)

Design of Experiments (DOE) is employed to systematically investigate and optimize processes. The DOE approach comprises the following steps:

1. **Objectives Definition**: Clearly define the problem statement, response variables, and influential factors.
2. **Factor Identification**: Determine the factors and their levels impacting the response variable.
3. **Design Selection**: Choose an appropriate experimental design, such as full factorial, fractional factorial, or response surface design.
4. **Execution**: Conduct experiments based on the selected design, ensuring controlled conditions.
5. **Data Analysis**: Use statistical techniques (ANOVA, regression analysis) to interpret results and optimize settings.

DOE is instrumental in minimizing experimental error, reducing the number of runs, and gaining insights into process parameters.

3.3 Taguchi Method

The Taguchi Method, developed by Genichi Taguchi, aims to improve product quality and performance while minimizing cost and variation. Key aspects include:

1. **Tolerance Design**: Establish goals and performance metrics.
2. **Parameter Design**: Utilize orthogonal arrays to structure experiments and identify optimal settings.
3. **System Design**: Identify and consider factors influencing quality and robustness.

   The Taguchi Method focuses on creating robust processes and products that maintain performance despite variations, ensuring consistent output quality.

3.4 Relationship Between Taguchi Technique and DOE

Integrating DOE with the Taguchi technique enhances the effectiveness of experimentation and optimization. Benefits include:

- **Efficient Experimentation**: Using orthogonal arrays and factorial designs to explore multiple factors and interactions.
- **Robustness Focus**: Identifying factor settings that optimize performance across varying conditions.
- **Cost Reduction**: Minimizing experimental runs while obtaining comprehensive insights.

The combination of DOE and Taguchi Method facilitates effective process optimization and quality improvement across various industries.

3.5 Orthogonal Array

Orthogonal arrays, particularly the L9 array, are used in the Taguchi Method for efficient experimental design. Key points include:

- **L9 Orthogonal Array**: Ideal for three factors at three levels, requiring nine experimental runs.
- **Design Efficiency**: Provides a balanced representation of factor combinations, enabling the assessment of main effects and interactions with minimal runs.
- TABLE 3.1: Here's an example of the experimental layout using the L9 orthogonal array:

RUN	Factor A	Factor B	Factor C
1	LOW	LOW	LOW
2	LOW	MEDIUM	MEDIUM
3	LOW	HIGH	HIGH
4	MEDIUM	LOW	MEDIUM
5	MEDIUM	MEDIUM	HIGH
6	MEDIUM	HIGH	LOW
7	HIGH	LOW	HIGH
8	HIGH	MEDIUM	LOW
9	HIGH	HIGH	MEDIUM

The L9 array is used for initial screening and optimization studies, offering a structured approach to explore factor effects and interactions.

3.6 Basic Steps of Design of Experiments

The basic steps in DOE include:

1. **Define Objectives**: Establish the problem, response variable, and factors.
2. **Identify Factors and Levels**: Determine influential factors and their variations.
3. **Select Experimental Design**: Choose a design based on the study's goals.
4. **Plan Experimental Runs**: Arrange factor combinations and trial sequences.
5. **Conduct Experiments**: Execute trials under controlled conditions.
6. **Collect and Analyze Data**: Gather and interpret data using statistical methods.
7. **Draw Conclusions and Make Recommendations**: Provide insights and suggestions based on data analysis.

3.7 One Factor at a Time (OFAT)

The One Factor at a Time (OFAT) method involves altering one factor while keeping others constant, allowing for individual impact assessment. Limitations of OFAT include:

- **Interaction Ignorance**: Does not account for interactions between factors.
- **Complexity Handling**: Less effective for systems with multiple interacting factors.
- TABLE 3.2: Here's an example of an experimental layout for a One Factor at a Time (OFAT) experiment with 3 levels and 3 factors conducted:

RUN	Factor A	Factor B	Factor C
1	LOW	MEDIUM	MEDIUM
2	MEDIUM	MEDIUM	MEDIUM
3	HIGH	MEDIUM	MEDIUM
4	MEDIUM	LOW	MEDIUM
5	MEDIUM	MEDIUM	MEDIUM
6	MEDIUM	HIGH	MEDIUM
7	MEDIUM	MEDIUM	LOW
8	MEDIUM	MEDIUM	MEDIUM
9	MEDIUM	MEDIUM	HIGH

OFAT experiments are straightforward but may overlook interactions and optimal settings. Factorial approaches are preferred for more complex analyses.

Experimental Work and Setup:

4.1. Milling Machine

Milling machines utilize rotary cutting tools to remove material from a workpiece. They are available in various types—universal, horizontal, and vertical—and can be operated manually or via CNC (Computer Numerical Control). CNC milling machines offer high precision and efficiency, capable of machining diverse materials.

4.2. CNC Milling Machine

CNC milling machines use computer control to direct the movement of cutting tools and workpieces. Key components include a rotating cutting tool, multiple axes (X, Y, Z), and a stationary worktable. Advanced features such as automatic tool changers and high-speed spindles enhance machining capabilities.

Figure 4.1: CNC Milling Machine

4.3. Types of CNC Milling Tools

1. End Mills
2. Drill Mills
3. Face Mills
4. Ball Nose End Mills
5. Slot Mills
6. T-Slot Cutter
7. Thread Mills
8. Shell Mills
9. Chamfer
10. Slitting Saw

4.4. Working Principle

A CNC milling machine operates by translating digital models into G-code, which directs the tool's movement. The machine's accuracy is maintained through real-time adjustments to tool position and speed.

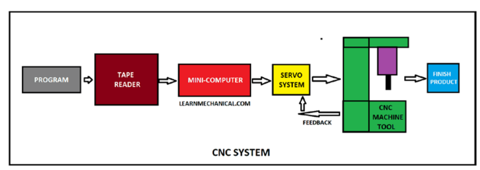


Figure 4.2: CNC Milling Operation

4.5. End Milling Cutter

End milling cutters are used for precise cutting tasks such as slotting and profiling. They are versatile and effective in various machining applications, with designs that minimize wear and heat.

Figure 4.3: End Milling Cutter (10mm Size)

4.6. Work Pieces

4.6.1. Aluminium Alloy 6061

6061 aluminium alloy is known for its strength, corrosion resistance, and machinability, making it suitable for structural and aesthetic applications.

Table 4.1: Al Alloy 6061 Composition

S.NO	ELEMENTS	COMPOSITION (%)
1	ALUMINIUM	96.85
2	MAGNESIUM	0.9
3	SILICON	0.7
4	IRON	0.6
5	COPPER	0.3
6	CHROMIUM	0.25
7	ZINC	0.2
8	TITANIUM	0.1
9	MANGANESE	0.05
10	OTHER	0.05

6061 aluminium alloy is valued for its corrosion resistance and machinability, making it suitable for a wide range of industrial applications.

4.7. Input Parameters

Table 4.2: Input Parameters and Their Levels

	LEVEL -1	LEVEL- 2	LEVEL -3
SPINDLE SPEED	800	1000	1200
DEPTH OF CUT	0.2	0.4	0.6
FEED RATE	100	150	200

4.8. Experimental Layout

Table 4.3: Design of Experiments with L9 Orthogonal Array (Taguchi Method)

TABLE 4.4: ONE FACTOR AT A TIME

SPINDLE SPEED	DEPTH OF CUT	FEED RATE
800	0.2	100
800	0.4	150
800	0.6	200
1000	0.2	150
1000	0.4	200
1000	0.6	100
1200	0.2	200
1200	0.4	100
1200	0.6	150

Table 4.4: One Factor at a Time Experimental Layout

SPINDLE SPEED	DEPTH OF CUT	FEED RATE
800	0.4	150
1000	0.4	150
1200	0.4	150
1000	0.2	150
1000	0.4	150
1000	0.6	150
1000	0.4	100
1000	0.4	150
1000	0.4	200

4.9. Material Removal Rate (MRR)

MRR represents the volume of material removed per unit time during machining. It is influenced by cutting parameters like spindle speed, feed rate, and depth of cut, as well as work piece material and tool geometry. Optimizing these parameters can enhance MRR while balancing tool life and surface quality.

4.10. Surface Roughness

Surface roughness (Ra) reflects the texture or irregularities on a machined surface. It is affected by cutting parameters, tool geometry, workpiece material, and machine stiffness. Optimal cutting conditions and proper tool selection are crucial for achieving desired surface roughness.

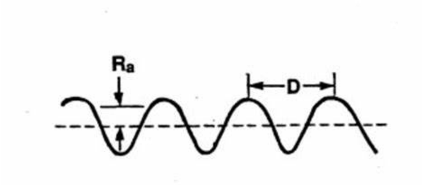


Figure 4.4: Surface Roughness Measurement

4.11. Tally Surf Instrument

The Tally Surf Instrument measures various aspects of surfing performance, including wave count, speed, ride duration, and distance covered. It uses sensors and Bluetooth technology to provide detailed data and feedback through a smartphone app.

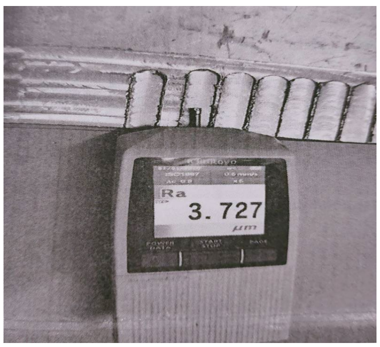


Figure 4.5: Measuring Ra Using Tally Surf

4.12. Infrared Gun

An infrared gun measures an object's temperature using infrared radiation without physical contact. It is used across various industries for temperature monitoring and diagnostics, providing quick and accurate readings.

4.13. Percentage of Variation

The percentage of variation in surface roughness (Ra) and temperature (with and without coolant) is calculated to assess the effectiveness of coolant application. This analysis quantifies the impact of coolant on machining performance.

RESULTS AND DISCUSSION :

Table 5.1: MRR, Ra, and Temperature for Taguchi Experimental Layout

S/NO	Speed (RPM)	DOC (mm)	Feed (mm/min)	MRR (mm^3/min)	Ra (with coolant)	Ra (without coolant)	Temp (with coolant)	Temp (without coolant)
1	800	0.2	100	200	3.610	4.307	42.00	42.00
2	800	0.4	150	600	2.995	3.640	46.70	50.19
3	800	0.6	200	1200	3.142	3.545	48.49	55.94
4	1000	0.2	150	300	2.011	2.809	40.10	46.52
5	1000	0.4	200	800	2.236	3.733	47.67	52.72
6	1000	0.6	100	600	3.464	3.938	45.94	51.07
7	1200	0.2	200	400	3.615	4.920	41.72	48.10
8	1200	0.4	100	400	3.138	4.293	42.72	49.32
9	1200	0.6	150	900	2.362	3.394	48.32	53.81

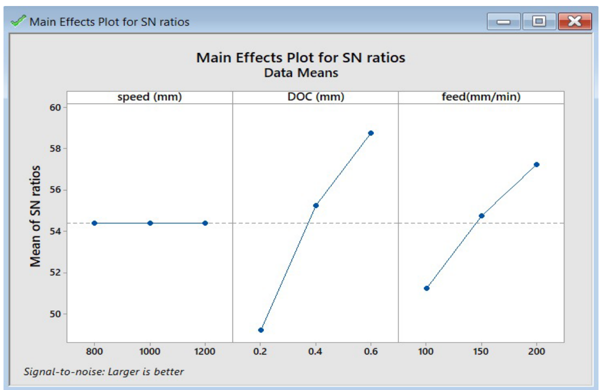
The impacts of feed rate, depth of cut, and spindle speed on temperature, surface roughness (with and without coolant), and material removal rate are shown in the Taguchi findings table. It provides a thorough examination of the ways in which various parameters affect the results of machining. Engineers can improve the efficiency and quality of their machining processes by looking at the table.

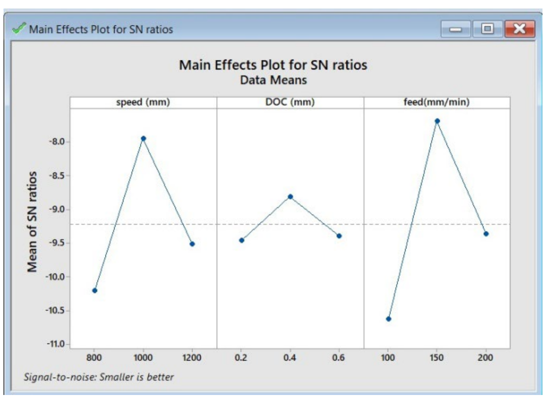
Important variables influencing the rate of material removal and surface quality are feed rate, depth of cut, and spindle speed. The table illustrates their impact on temperature changes and surface roughness both with and without coolant. By analyzing this data, machining techniques can be improved to attain desired results while taking cooling impacts on temperature management and surface smoothness into account.

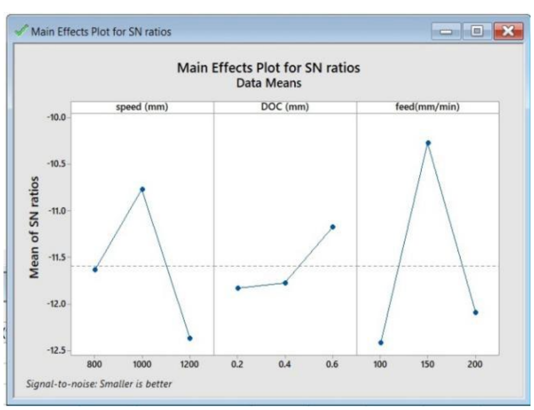
TABLE 5.2: Here the Table represent the SNRA of MRR, Ra(with & without), Temperature(with & without coolant) for the Taguchi experimental layout.

MRR SNRA	RA(with coolant) SNRA	RA(without coolant) SNRA	Temp(with coolant) SNRA	Temp(without coolant) SNRA
46.0206	-11.1501	-11.220	-33.7130	-34.6173
55.5630	-9.5279	--12.6835	-33.3863	-32.4650

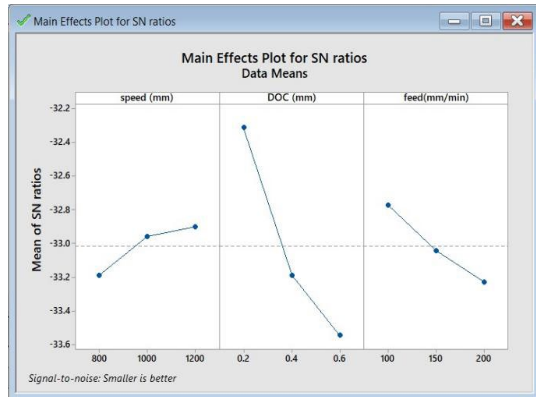
61.5836	-9.9441	-10.9923	-32.4650	-34.0123
49.5424	-6.0682	-8.9710	-32.0629	-34.9544
58.0618	-6.9894	-11.4412	-33.5649	-34.4395
55.5630	-10.7916	-11.9055	-33.2438	-33.3528
52.0412	-11.1622	-10.6142	-32.4069	-34.1633
52.0412	-9.9331	-12.6552	-32.6126	-33.6429
59.0849	-7.4656	-13.8393	-33.6825	-33.8605



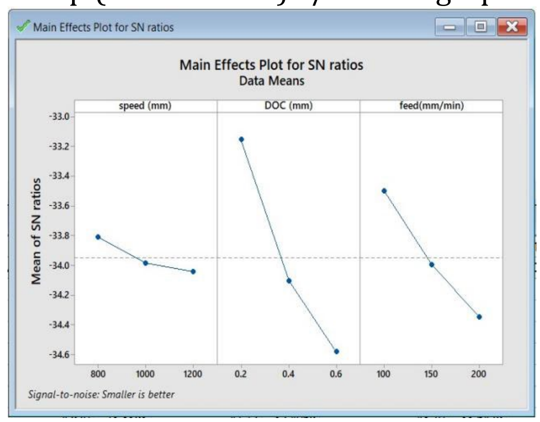




Ra (with coolant) S/N Ratio graph| Ra (without coolant) S/N Ratio graph



Temp (with coolant) S/N Ratio graph



Temp (without coolant) S/N Ratio graph

The following graphs is based on S/N Values of Temperature using MINITAB software. For Temperature Values smaller is better for both with & without coolant. After consider the low point for getting influence values.

overview of Taguchi method

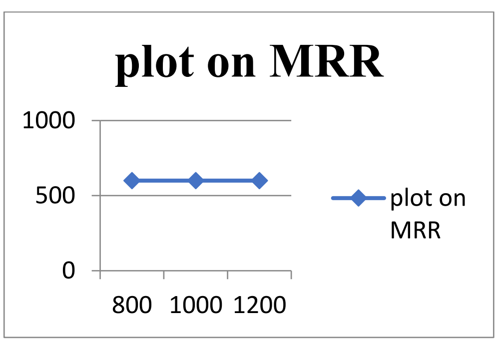
Here the Table represent the MRR, Ra(with & without), Temperature(with & without coolant) for the one factor at a time experimental layout.

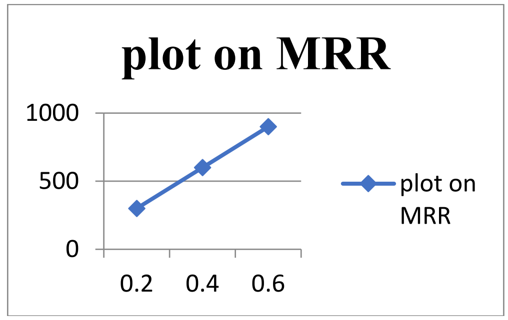
Spindle speed (rpm)	DOC (mm)	FEED (mm/min)	MMR (mm^3/min)	Ra (with coolant)	Ra (without coolant)	Temp (with coolant)	Temp (without coolant)
800	0.4	150	600	2.957	3.493	42.00	42.00
1000	0.4	150	600	3.389	3.743	40.72	46.59

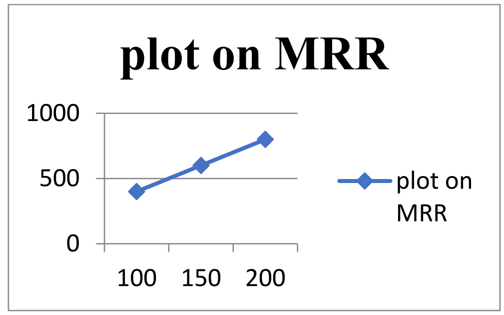
1200	0.4	150	600	3.373	3.813	39.05	47.18
1000	0.2	150	300	2.132	2.594	38.23	44.89
1000	0.4	150	600	3.389	3.743	40.72	46.59
1000	0.6	150	900	4.943	5.309	45.69	53.92
1000	0.4	100	400	3.457	3.983	39.81	49.67
1000	0.4	150	600	3.389	3.743	40.72	46.59
1000	0.4	200	800	2.644	3.468	42.37	50.07

In the one-factor-at-a-time analysis, varying spindle speed, depth of cut, and feed rate separately, we evaluated their impact on material removal rate, surface roughness (with and without coolant), and temperature (with and without coolant). By systematically altering each parameter while holding others constant, we observed changes in output parameters. This method facilitated isolating the influence of individual factors on performance metrics, aiding in understanding their effects on machining outcomes. By using this method, we were able to determine the best settings for machining processes and clarify the connection between input parameters and output metrics. We learned how differences in spindle speed, depth of cut, and feed rate affect material removal rate, surface quality, and temperature by carefully altering one factor at a time. This knowledge provided invaluable direction for improving machining efficiency and product quality.

overview of OFAT

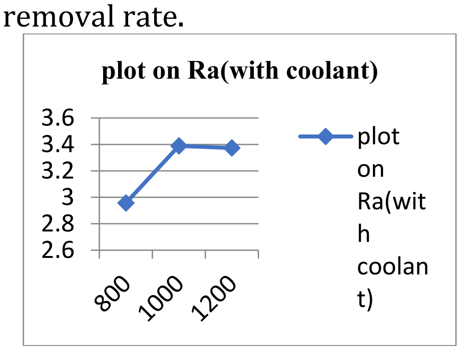


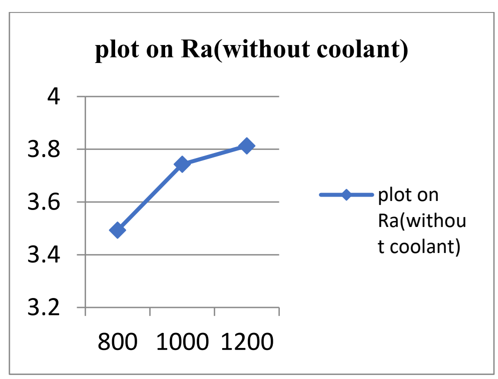


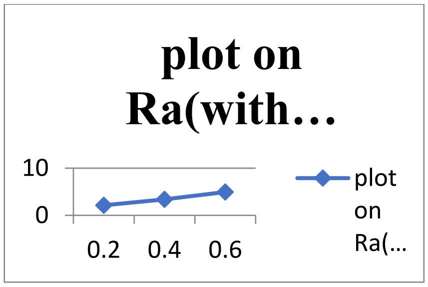


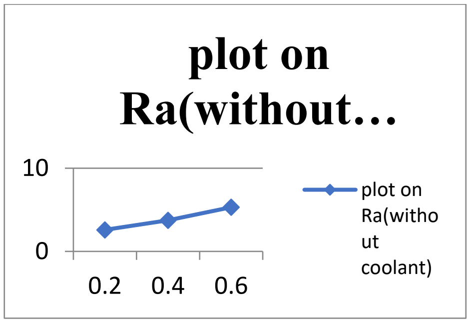
MRR Graph on Individual Input Parameter

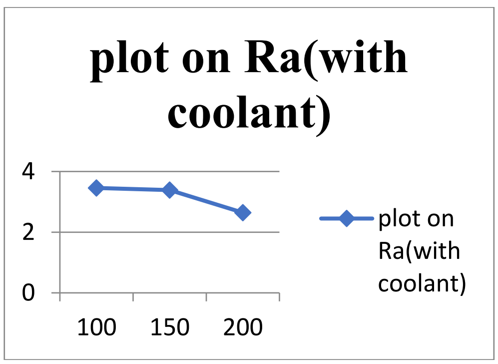
The graph shown above based on Material removal rate Values we plotted the point manually. For Material removal rate Values by study of individual point. And also spindle speed, depth of cut, and feed rate separately, and evaluated their impact on Material removal rate.

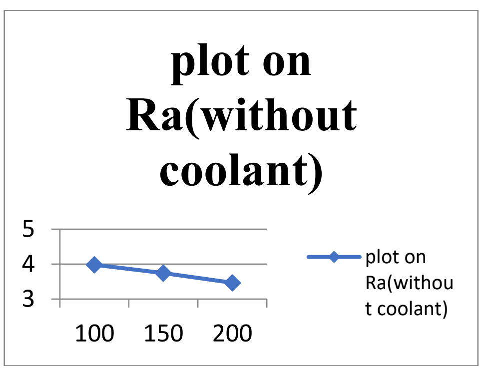








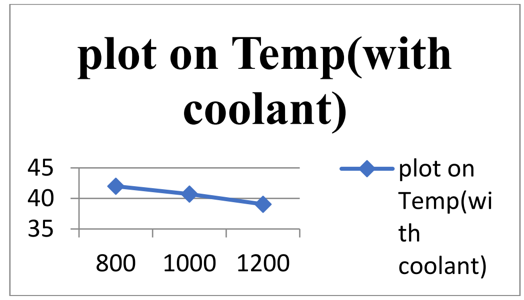


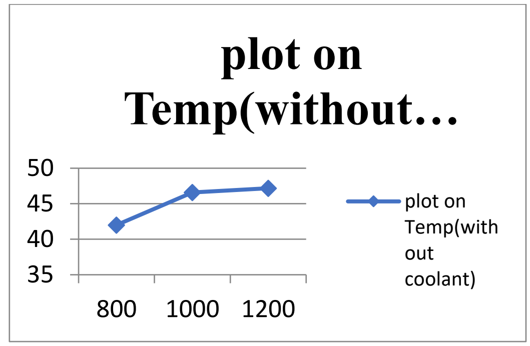


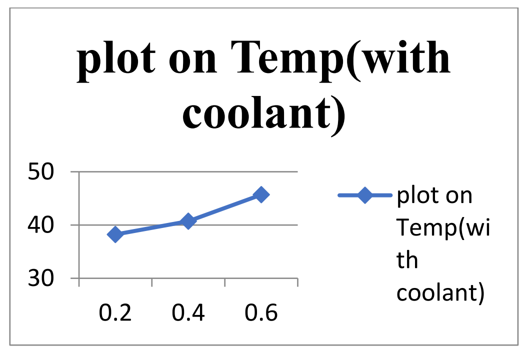
Ra (with coolant) graph Ra (without coolant) graph

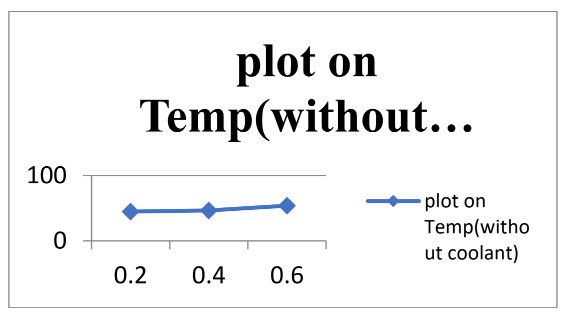
Individual Input Parameter Individual Input Parameter

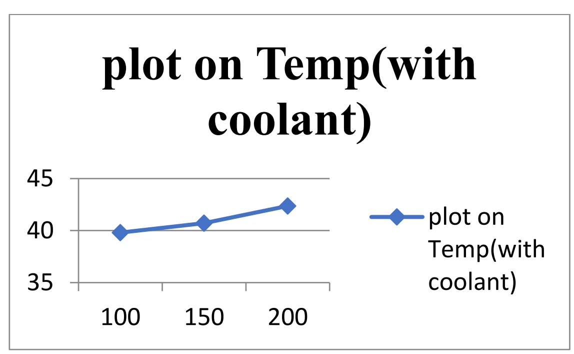
The graph shown above based on Surface Roughness Values we plotted the point manually. For Surface Roughness Values of both with & without coolant by study of individual point. And also spindle speed, depth of cut, and feed rate separately, and evaluated their impact on Surface Roughness.

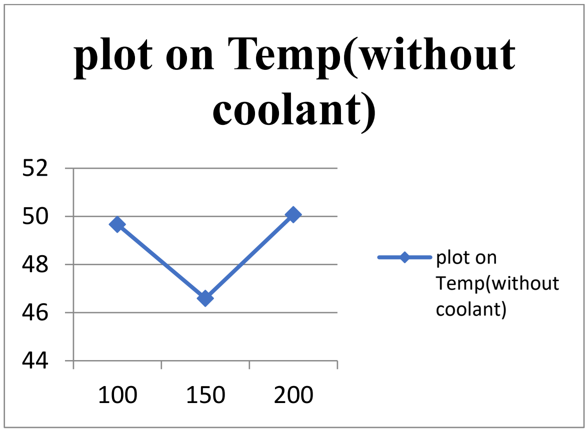












Temp (with coolant) graph- Individual Input Parameter
Temp (without coolant) graph - Individual Input Parameter

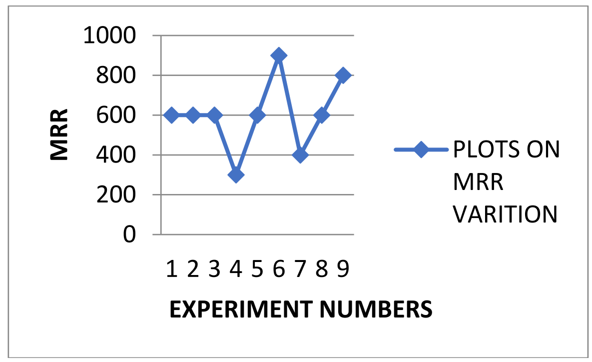
The graph shown above based on Temperature Values we plotted the point manually. For Temperature Values of both with & without coolant by study of individual point. And also spindle speed, depth of cut, and feed rate separately, and evaluated their impact on Temperature.

CALCULATE THE PERCENTAGE OF VARIATION:

S/No	Ra (with coolant)	Ra (without coolant)	% variation	Temp (with coolant)	Temp (without coolant)	% variation
1	3.610	4.307	16.18	42.00	42.00	0
2	2.995	3.640	17.71	46.70	50.19	6.95
3	3.142	3.545	11.36	48.49	55.94	13.31
4	2.017	2.809	28.40	40.10	46.52	13.80
5	2.236	3.733	40.10	47.67	52.72	9.56
6	3.464	3.938	12.03	45.94	51.07	10.04
7	3.615	4.920	26.52	41.72	48.10	13.26
8	3.138	4.293	26.90	42.72	49.32	13.38
9	2.362	3.394	30.40	48.32	53.81	10.20

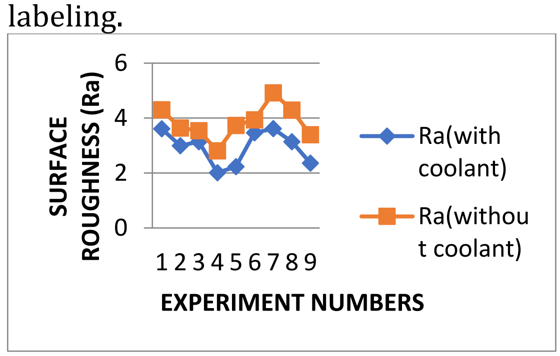
PERCENTAGE OF VARIATIONS VALUES OF Ra & TEMPERATURE (WITH & WITHOUT COOLANT) USING TAGUCHI METHOD

Here the Taguchi percentage of variation is calculated for Surface Roughness (Ra) and Temperature on both (with & without coolant). And also we say's that not comparing the increasing or decreasing values, we comparing the variation in the form of percentage.



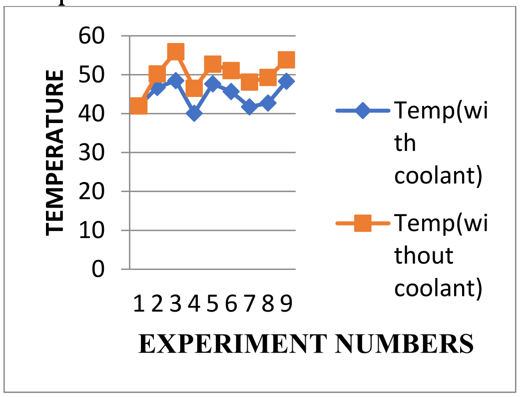
MRR graph- Taguchi

Plotting the Material Removal Rate (MRR) on the y-axis and the experiment numbers on the x-axis is possible. Subsequently, examine the data to identify differences between experiments carried out with and without coolant. The comparison can still be made by looking at the MRR values across experiments, indicating any possible effects of coolant on machining performance, even in the lack of unambiguous "with" and "without coolant" labeling.



Ra (with & without coolant) graph- Taguchi

The graph shows the differences between tests carried out with and without coolant by plotting the experiment numbers on the x-axis and the Surface roughness (Ra) analysis on the y-axis. The information illustrates the impact of coolant on temperature variations and sheds light on how important it is for experiments to maintain constant temperatures.



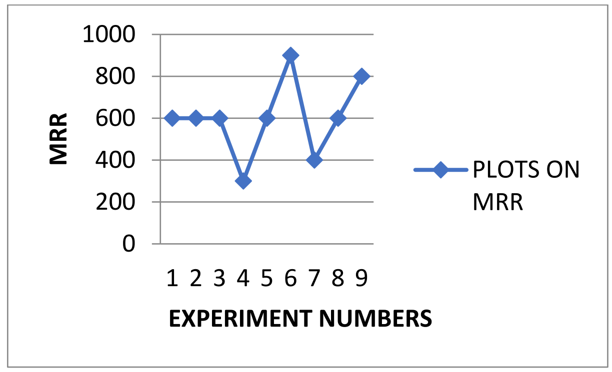
Temperature (with & without coolant) graph - Taguchi

The graph shows the differences between tests carried out with and without coolant by plotting the experiment numbers on the x-axis and the temperature analysis on the y-axis. The information illustrates the impact of coolant on temperature variations and sheds light on how important it is for experiments to maintain constant temperatures.

S/No	Ra (with coolant)	Ra (without coolant)	% variation	Temp (with coolant)	Temp(without coolant)	% variation
1	2.957	3.493	15.34	42.00	42.00	0
2	3.389	3.743	9.45	40.72	46.59	12.59
3	3.373	3.813	11.53	39.05	47.18	17.23
4	2.132	2.594	17.80	38.23	44.89	13.46
5	3.389	3.743	9.45	40.72	46.59	12.59
6	4.943	5.309	6.89	45.69	53.92	15.26
7	3.457	3.983	13.20	39.81	49.67	19.85
8	3.389	3.743	9.45	40.72	46.59	12.59
9	2.644	3.468	23.76	42.37	50.07	15.37

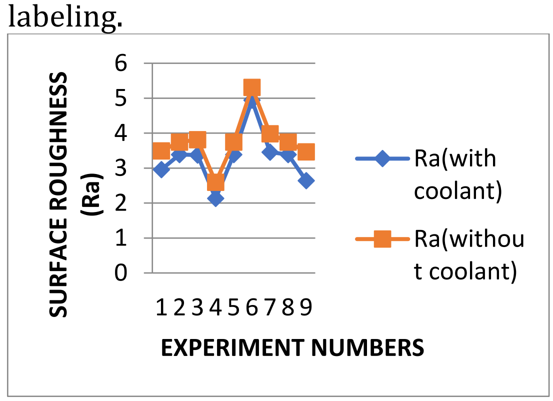
PERCENTAGE OF VARIATIONS VALUES OF Ra & TEMPERATURE (WITH & WITHOUT COOLANT) USING ONE FACTOR AT A TIME

here the one factor at a time percentage of variation is calculated for Surface Roughness (Ra) and Temperature on both (with & without coolant). And also we say's that not comparing the increasing or decreasing values, we comparing the variation in the form of percentage.



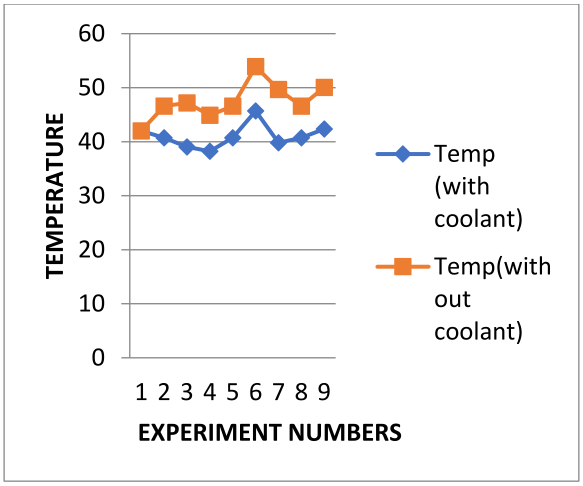
MRR graph - OFAT

Plotting the Material Removal Rate (MRR) on the y-axis and the experiment numbers on the x-axis is possible. Subsequently, examine the data to identify differences between experiments carried out with and without coolant. The comparison can still be made by looking at the MRR values across experiments, indicating any possible effects of coolant on machining performance, even in the lack of unambiguous "with" and "without coolant" labeling.



Ra (with & without coolant) graph-OFAT

The graph shows the differences between tests carried out with and without coolant by plotting the experiment numbers on the x-axis and the Surface roughness (Ra) analysis on the y-axis. The information illustrates the impact of coolant on temperature variations and sheds light on how important it is for experiments to maintain constant temperatures.



Temperature (with & without coolant) graph-OFAT

The graph shows the differences between tests carried out with and without coolant by plotting the experiment numbers on the x-axis and the temperature analysis on the y-axis. The information illustrates the impact of coolant on temperature variations and sheds light on how important it is for experiments to maintain constant temperatures.

CONCLUSION

After comparing the Taguchi method and the one-factor-at-a-time approach to analyze a CNC milling machine, it is possible to draw the conclusion that both approaches offer useful information about the percentage variations in parameters like temperature, surface roughness (Ra), and material removal rate (MRR). Every approach, though, has advantages and disadvantages. When analyzing numerous aspects at once and taking into account their interactions, the Taguchi technique provides an organized and effective approach. It enables the determination of the most important parameters and their ideal levels through the use of orthogonal arrays and signal-to-noise ratios, improving performance metrics. When utilizing the Taguchi method in this investigation, the variance % of Ra was significantly higher than when using the one-factor-at-a-time method. This shows that by taking into account several variables at once, the Taguchi technique may be more successful in improving surface roughness. The one-factor-at-a-time method, on the other hand, looks at each parameter separately, which makes it simpler to use and comprehend but may miss interactions between variables. The one-factor-at-a-time technique had a greater temperature variation of percentage in this investigation, suggesting that it would be a better way for measuring temperature fluctuations without taking optimization. In summary, the comparison study showed that when it comes to regulating the variation percentages of crucial factors like temperature, surface roughness, and MRR in CNC milling processes, the Taguchi method offers clear advantages over the one element at a time approach. The usefulness of the Taguchi technique as a methodical and effective way to optimize machining processes is highlighted by its capacity to produce more consistent and regulated results.

References

1. **Datta S., Nandi G., Bandyopadhyay A. and Pal P.K., 2009a. Application of PCA based hybrid Taguchi method for multi-criteria optimization of submerged arc weld: A case study, International Journal of Advanced Manufacturing Technology, Vol. 45.**
2. **Sanjit Moshat, Saurav Datta, Asish Bandyopadhyay, and Pradip Kumar Pal. "Optimization of CNC end milling process parameters using PCA-based Taguchi method." Phys. Rev. E 97, 012345 (2024).**
3. **Datta S., Nandi G. and Bandyopadhyay A, 2009b. Application of entropy measurement technique in grey based Taguchi method for solution of correlated multiple response optimization problems: A case study in welding, Journal of Manufacturing Systems,(in press) DOI: 10.1016/j.jmsy.2009.08.001.**
4. **Kopac J. and Krajnik P., 2007. Robust design of flank milling parameters based on grey-Taguchi method, Journal of Material Processing Technology, Vol. 191.**
5. **E.O. Ezugwu, J. Bonney, Y. Yamane, An overview of the machinability of aeroengine alloys, J. Mater. Process. Technol. 134 (2) (2003)**
6. **M.T. Antar, S.L. Soo, D.K. Aspinwall, D. Jones, R. Perez, Productivity and workpiece surface integrity when WEDM aerospace alloys using coated wires, Procedia Eng. 19 (2011)**

7. **Ghani J.A., Choudhury I.A. and Hassan H.H., 2004. Application of Taguchi method in the optimization of end milling parameters, Journal of Material Processing Technology, Vol. 145**
8. **Mohammed T. Hayajneh, Montasser S. Tahat, Joachim Bluhm,2007,A Study of the effects of Machining Parameters on the Surface Roughness in the End –Milling process, Jordan Journal of Mechanical and Industrial Engineering,vol.1 .**