OPTIMIZATION OF TURNING PROCESS PARAMETERS FOR ALUMINIUM USING DIFFERENT MACHINING ENVIRONMENT

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Abstract— The fact that every item we use on a daily basis has been subjected to machining, either directly or indirectly, serves to highlight the process's significance. The most frequent operation on a lathe is turning. The workpiece turns while being held inside the spindle, and then a tool is passed through it in a plane perpendicular to the axis of revolution. In contrast to orthogonal cutting, turning primarily uses the oblique cutting mechanism, including three different types of force. The primary goal of this investigation is to measure the surface roughness (SR) of aluminum bars that have been turned under various machining circumstances. An experimental analysis was used as the methodology for this investigation. Cooling fluid is used during machining to increase productivity and achieve higher surface finishes. Cutting fluids lower friction while speeding up heat dissipation. Aluminum oxide's lubricating properties and Mobilcut-220's use as a cutting fluid in this investigation Experimental investigation of nanoparticles on SR was done. To examine the effectiveness of dry machining, standard coolant machining, and fluid based on aluminum oxide nanoparticles, turning operations are conducted. A subset of all possible combinations of various cutting parameters (CP) at various levels was employed as the design of experiments (DOE) in this study. The cutting characteristics of aluminum bars cut with a TNMG 160408 tool are investigated using an orthogonal array (OA), S/N ratio, and ANOVA. This study demonstrated how aluminum oxide nanoparticles enhanced surface polish.

Keywords: Aluminium, Mobilcut-220, aluminium oxide nanoparticles, cut depth, feed rate, spindle speed, S/N ratio, ANOVA, TNMG 160408.

I. INTRODUCTION

The fact that everything we use on a daily basis has gone through this process, either directly or indirectly, can be used to highlight the significance of machining. The turning operation on a lathe is by far the most frequent. The work is kept in the spindle & rotated as the tool is given past it perpendicularly to the rotational axis. As opposed to orthogonal cutting, turning primarily uses the technique of oblique cutting, which results in three force components (Abas et al., 2020).

Good quality items that can be made quickly & at a low cost are now the most pressing need. Surface finishing, tool wear rate along with material removal rate (MRR) are three most studied response characteristics in manufacturing today (Saraswat et al., 2014). So, to optimize the input parameters of machining, Taguchi optimization techniques are used in this study, Taguchi guided that by performing experiments by choosing a subset of parameters & calculating (S/N) ratio helps find the optimal value of CP for superior surface finish (Selvaraj Dirviyam & Palanisamy, 2010; Chakraborty et al., 2023).

S/N ratio of the quality characteristic SR must be minimized to obtain desirable results. The standard deviation is denoted by noise & the required value of surface finish is denoted as signal. Efforts are made to analyse the variance ANOVA which gives the percentage contribution of various CP on SR. The previous literature on this topic is going to be discussed in greater depth in the sections that follow.

Dureja et al., (2014) utilised Taguchi L_9 OA to obtain S/N ratios for SR where spindle speed, feed rate & cut depth is the CP. They obtained optimum level for CP as cutting speed = 130 m/min, feed = .10 mm/rev, cut depth = .40 mm. On performing confirmation tests at the optimum level of CP they had favorable results

To discover the best turning parameters for milling aluminium alloy 6063 having carbon nitride inserts is the goal of **Saravanakumar et al., (2018)** study. In order to improve surface finish & reduce roundness error, process parameters; feed, speed, & cut depth were investigated with the aid of experiment design. The Taguchi technique L27 OA was used to guide the experiments, which were then assessed using the lower is better principle. This investigation pinpoints the primary & most influential variable influencing the outcomes of the turning process. The outcomes of the study demonstrated that the feed rate, & then the pace, significantly influenced the outcomes.

The authors **Li et al., (2019)** stated that among various metal oxide nanoparticles, Al_2O_3 nanoparticles are widely used to make nanofluids because of their spherical structure. Al_2O_3 nanoparticles enter the shear zone while machining & the spherical particles play an important role in creating a "roller effect". These spherical particles enter a cutting zone & can behave as a roller. The physics says that coefficient of rolling friction is less than coefficient of static friction & thus helps in a smooth experience while machining. Because of these reasons significant improvement in tool life is also found. However, using metal nanoparticles can lead to scratches on the machined surface because of agglomeration of such particles, despite the fact that the colloidal mixture of nanoparticles in the base fluid significantly improves the mixture's thermal conductivity.

According to **Abas et al. (2020),** the decreased lead time & rising demand for high-quality components require industry to create parts sustainably with higher precision, efficiency, & cost utilising new methods. Minimum quantity lubricant (MQL) is a cost-effective, environmentally beneficial method. In given investigation, we use a composite desirability function & CRITIC to investigate & optimise the CPs of Aluminium alloy 6026-T9 in both MQL & dry conditions. Surface roughness profile (Ra, Rq, Rz), tool life, & mean relative roughness (MRR) were analysed as dependent variables in this research. The insert was made of tungsten carbide, & the coolant was olive oil at a rate of 150 mL/h. Taguchi OA (L16) on a machine with 16 separate tests. According to ANOVA, feed rate, tool life, & MRR are the most crucial cutting process factors for SR profile (Ra, Rq, Rz) within dry & MQL conditions. In dry conditions, the optimum values for the cutting speed, feed rate, cut depth, & rake angle are 500 m/min, 0.3 mm/rev, 2 mm, & 15°, respectively. But, MQL conditions are 500 m/min cutting speed, 0.4 mm/rev feed rate, 2 mm cut depth, & 15° positive rake angle. Finally, SEM & EDX morphologically analyse the machined worked piece surface & inserts at varied CP.

According to **Chakraborty & Chakraborty (2022),** determining the ideal input parameters for any machining process is crucial to attaining the best response values & satisfying manufacturers & end users. This review paper will help decision-makers & process engineers choose the best experimental design plan (Taguchi's L9, L18, or L27 OA); entering parameters for turning, along with drilling, & also milling operations (cutting speed, along with feed rate, & cut depth); matching responses; difficult-to-cut sophisticated technical materials (composite, aluminium, titanium, & their alloys).

A. RESEARCH GAP: According to studies, turning is one of the operations with a large number of input parameters, so many parameters can vary individually & output parameters may vary linearly or nonlinearly depending on environmental conditions. To analyse SR, add more CP such cutting tool nose radius & cutting angles. Based on the literature review conducted on papers where the aim is to optimize the CP for superior surface finish. The goal is to identify the combination of cutting settings that produces the best surface quality from among a collection of candidates. Spindle RPM, feed rate, & cut depth are the chosen parameters. The scales here represent the relative importance of various elements. It is investigated which parameter has the most impact on SR & what percentage of that effect it has.

II. METHODOLOGY

Experiment will be conducted by turning of Aluminium specimen, in a CNC lathe for different levels of input parameters like cutting depth, feed rate, spindle speed. The experiments are performed as per Taguchi design, where a selected subset of combinations is chosen out of all the possible combinations. Table 1 displays the values for each of the cutting setting.

TABLE 1: CUTTING PARAMETERS & THEIR LEVELS

Symbol	Cutting Parameters	Unit	Level 1	Level 2	Level 3
A	Spindle speed	rpm	510	640	760
B	Feed rate	mm/rev	0.08	0.1	0.12
C	Depth of cut	mm	0.4	0.6	0.8

In this set of experiments, Taguchi table generated by MINITAB software is used. The subset of all combination of parameters is shown in table 2. The pattern of choice of different CP & their levels remains the same in all the three machining environments which is

1. Machining without coolant
2. Machining using coolant as a mixture of water & Mobilcut-220
3. Machining using coolant as a colloidal mixture of Al_2O_3 nanoparticles in Mobilcut-220

TABLE 2: TAGUCHI TABLE

Experiment Number	A	B	C	Spindle speed(rpm)	Feed rate (mm/rev)	Depth of cut(mm)
1	1	1	1	510	0.08	0.4
2	1	2	2	510	0.1	0.6
3	1	3	3	510	0.12	0.8
4	2	2	2	640	0.08	0.6
5	2	2	1	640	0.1	0.8
6	2	2	3	640	0.12	0.4
7	3	3	3	760	0.08	0.8
8	3	3	1	760	0.1	0.4
9	3	3	2	760	0.12	0.6

A. DESIGN & ANALYSIS OF CUTTING PARAMETERS

The results obtained after performing the experiments is studied using S/N ratio & ANOVA analysis. The optimum level of CP can be obtained by applying formulas for "lower-the-better" values for SNRA. ANOVA analysis is conducted to analyse the percentage contribution of various cutting parameters on SR. Predicting & verifying the enhancement of the quality characteristic utilising the optimum level of design parameters is the last step after the optimal level of design parameters has been chosen.

III. RESULTS & DISCUSSIONS

Surface finish is measured by a parameter called 'Ra' & this parameter gives the average value of undulation over a given area of the surface. It is necessary for this undulation's to be minimum to obtain superior surface finish.

The average SR is measured by the formula:

$$R_a = \frac{1}{L}\int_0^L |y(x)|\, dx \text{..eqn1}$$

Where: R_a=average SR in µm

L=choice of length in mm

y= undulation at location x

The mean value of R_a is calculated by:

$$\mu=\frac{1}{5}\sum_{i=0}^{i=5} R_a \text{………………………………………………………………eqn2}$$

Where R_a is the SR at five different locations.

S/N ratio: In the methods of Taguchi, signal refers to the desirable value(mean), & noise refers to undesirable value (standard deviation) of the output characteristics. Therefore, S/N ratio is basically the ratio of mean to S.D. Based on the requirement of the response Taguchi has classified S/N ratio in three distinct categories being: -

1. Larger the better
2. Nominal the better
3. Smaller the better

Since the chosen quality characteristic is SR, it is decided to go ahead with the formulas defined for smaller the better.

$$\text{S/N}=-10\log_{10}\left(\frac{\left(\sum_{i=1}^{i=5} y_i^2\right)}{5}\right) \text{.. eqn3}$$

Where y_i is SR value at i-th trial.

A. DRY RUN

To conduct dry run experiments, aluminium bars of diameter 50mm & length 150mm were machined without any coolant. Appropriate CNC codes were entered in the CNC machine & machining was conducted. Aluminium bar is turned for a length 50mm, & cut depth is varied according to the Taguchi table. Surface roughness values & signal to noise ratios are tabulated in table 3.

1. **Effect of process parameters on SR:**

TABLE 3: RESPONSE TABLE FOR DRY RUN EXPERIMENTS

Spindle speed(rpm)	Feed rate (mm/rev)	Depth of cut(mm)	surface roughness(µm)					Mean(µm)	SNRA (dB)
510	0.08	0.4	0.71	0.7	0.72	0.59	0.58	0.66	3.5714
510	0.1	0.6	0.72	0.79	0.82	0.65	0.62	0.72	2.8037
510	0.12	0.8	0.52	0.72	0.77	0.65	0.74	0.68	3.2757
640	0.08	0.6	0.75	0.6	0.86	0.86	0.78	0.77	2.20389
640	0.1	0.8	0.63	0.6	0.59	0.55	0.48	0.57	4.84683
640	0.12	0.4	0.58	0.65	0.5	0.5	0.52	0.55	5.14477
760	0.08	0.8	0.6	0.7	0.94	0.83	0.78	0.77	2.17398
760	0.1	0.4	1.2	0.78	1	0.95	0.97	0.98	0.09501
760	0.12	0.6	0.79	0.84	0.92	0.8	0.55	0.78	2.0501

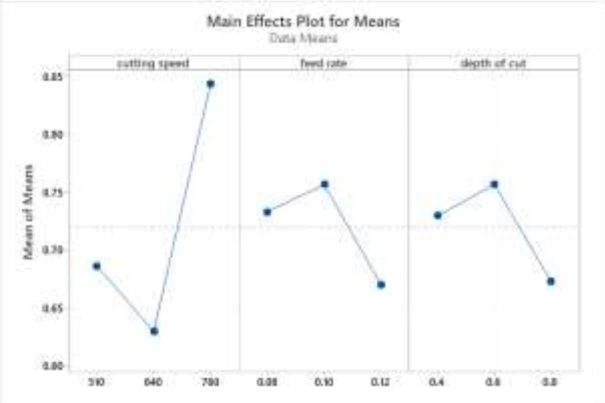

Figure 1: Plot of mean of means versus various Cutting Parameters

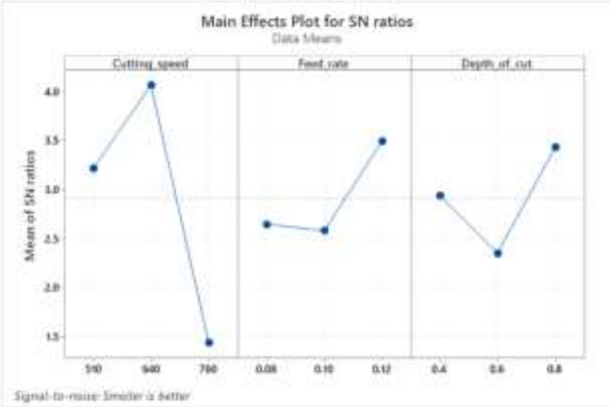

Figure 2: Plot of mean of SN ratio versus various Cutting Parameters

The optimum level of CP is tabulated in table 4.

TABLE 4: OPTIMAL LEVEL OF CUTTING PARAMETERS FOR SUPERIOR SURFACE FINISH OF DRY RUN EXPERIMENTS

Cutting parameters	level
Spindle speed	760 rpm
Feed rate	0.1 mm/rev
Depth of cut	0.6 mm

B. MACHINING USING COOLANT AS MIXTURE OF WATER & MOBILCUT -220:

While conducting machining using coolant, water & Mobilcut-220 was mixed in the ratio 1:20. 4 liters of conventional coolant is mixed in 80 liters of water. This mixture is then poured into the coolant tank & pumped through the CNC to ensure proper mixing of the mixture. Surface roughness values & signal to noise ratios are tabulated in table 5.

TABLE 5: RESPONSE TABLE FOR MACHINING USING COOLANT AS MIXTURE OF WATER & MOBILCUT 220

Spindle speed(rpm)	Feed rate(mm/rev)	Depth of cut(mm)	Surface Roughness(µm)					Mean(µm)	SNRA (dB)
510	0.08	0.4	0.44	0.17	0.43	0.5	0.21	0.35	8.5294
510	0.1	0.6	0.22	0.31	0.22	0.31	0.44	0.3	10.1538
510	0.12	0.8	0.3	0.28	0.2	0.21	0.26	0.25	11.9368
640	0.08	0.6	0.35	0.36	0.25	0.26	0.28	0.3	10.3565
640	0.1	0.8	0.25	0.32	0.31	0.27	0.4	0.31	10.0533
640	0.12	0.4	0.32	0.42	0.34	0.25	0.32	0.33	9.5133
760	0.08	0.8	0.6	0.54	0.56	0.57	0.57	0.568	4.908
760	0.1	0.4	0.48	0.52	0.56	0.6	0.6	0.552	5.1303
760	0.12	0.6	0.6	0.5	0.48	0.5	0.64	0.544	5.2288

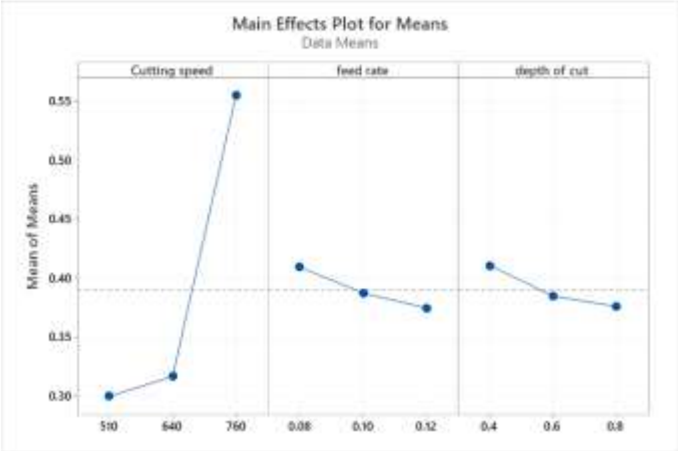

Figure 3: Plot of mean of means versus various Cutting Parameters

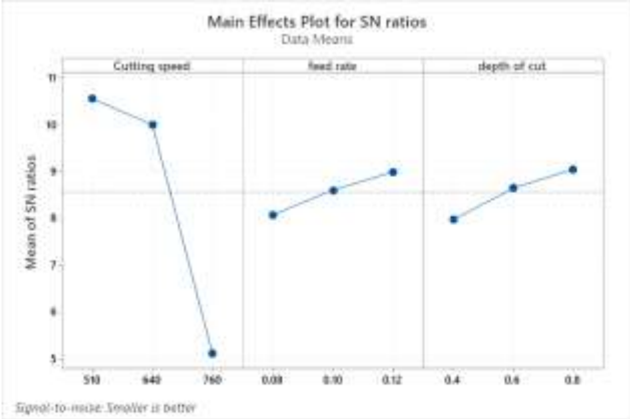

Figure 4: Plot of mean of SN ratio versus various Cutting Parameters

The optimum level of CP is tabulated in table 6.

TABLE 6: OPTIMAL LEVEL OF CUTTING PARAMETERS FOR MACHINING WHERE COOLANT IS A MIXTURE OF WATER & MOBILCUT-220

Cutting parameters	level
Spindle speed	760 rpm
Feed rate	0.08 mm/rev
Depth of cut	0.4 mm

C. *MACHINING USING COOLANT AS A COLLOIDAL MIXTURE OF NANOPARTICLES IN MOBILCUT-220:*

Nanofluid is a colloidal combination of metallic & non-metallic particles smaller than 100 nm in ordinary cutting fluid. Al_2O_3 nanoparticles was evenly distributed in the conventional coolant Mobilcut-220 using an ultrasonicator. The weight percentage of nanoparticles chosen is 1%. 30 grams of nanoparticles was evenly distributed in 3 liters of Mobilcut-220 & the mixture was poured in 60 liters of water so that the ratio of coolant to Water is 1:20. Surface roughness values & signal to noise ratios are tabulated in table 7

TABLE 7: RESPONSE TABLE FOR MACHINING USING COOLANT AS NANOPARTICLES SUSPENDED IN MOBILCUT- 22

Spindle speed(rpm)	Feed rate (mm/rev)	Depth of cut(mm)	Surface roughness(μm)					Mean(μm)	SNRA (dB)
510	0.08	0.4	0.19	0.2	0.22	0.29	0.25	0.23	12.76544
510	0.1	0.6	0.21	0.26	0.28	0.24	0.26	0.25	12.0412
510	0.12	0.8	0.14	0.15	0.12	0.1	0.14	0.13	17.72113
640	0.08	0.6	0.32	0.22	0.26	0.31	0.29	0.28	11.05684
640	0.1	0.8	0.18	0.19	0.23	0.23	0.22	0.21	13.55561
640	0.12	0.4	0.24	0.26	0.28	0.25	0.27	0.26	11.70053
760	0.08	0.8	0.47	0.44	0.48	0.43	0.43	0.45	6.93575
760	0.1	0.4	0.4	0.36	0.38	0.37	0.39	0.38	8.404328
760	0.12	0.6	0.29	0.25	0.26	0.24	0.31	0.27	11.37272

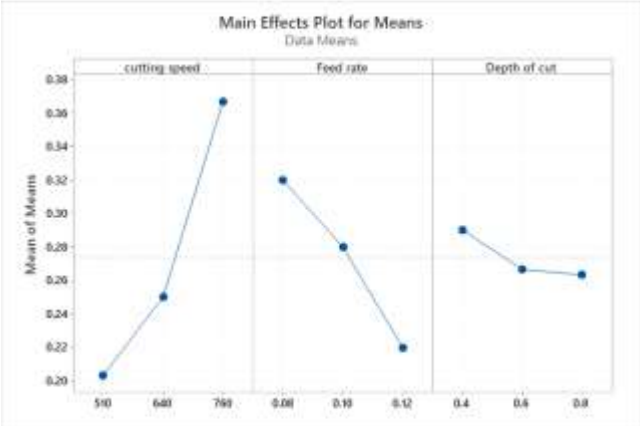

Figure 5: Plot of mean of means versus various Cutting Parameters

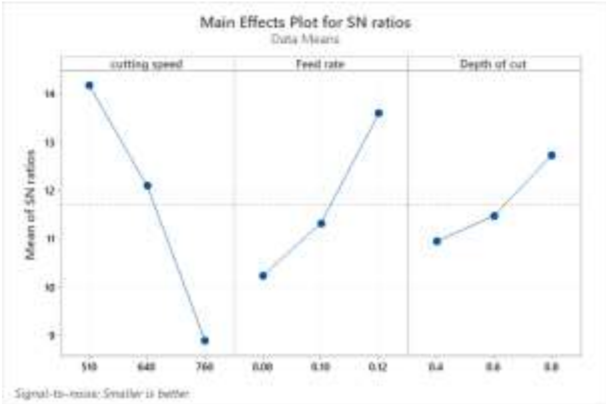

Figure 6: Plot of mean of SN ratio versus various Cutting Parameters

The optimum level of CP is tabulated in table 8.

TABLE 8: OPTIMAL LEVEL OF CUTTING PARAMETERS FOR MACHINING WHERE COOLANT IS A COLLOIDAL MIXTURE OF AL2O3 NANOPARTICLES & MOBILCUT-220

Cutting parameters	level
Spindle speed	760 rpm
Feed rate	0.08 mm/rev
Depth of cut	0.4 mm

D. ANOVA ANALYSIS:

ANOVA analysis helps one understand the percentage contribution of many factors on the quality characteristic. If there are i factors & there are j levels in each factor, & the total variance of this observation is to be understood, it can be done so by dividing the total variance into two parts namely: -

I. Variance due to different levels under each factor
II. Variance due to different factors.

The standard convention for total variance is SS_T, variance due to change in factors is SS_{levels} & variance due to different levels in each factor is SS_{error}.

SS_T, SS_{levels} & SS_{error} is related to each other by the equation.

$SS_T = SS_{levels} + SS_{error}$

Total variance SS_T is calculated using the formula.

$SS_T = \sum_{i=1}^{i=9}(y_i^2 - \bar{y}^2)$...eqn4

Where y_i is the SNRA values at different levels of different factors.

$\bar{y}$ is the grand mean of all SNRA values

Variance between levels is calculated using the formula

$SS_{levels} = \sum_{i=1}^{i=3}(y_G^2 - \bar{y}^2)$.. eqn5

where y_G is the mean of SNRA values of different levels in a particular group

$\bar{y}$ is the grand mean of all SNRA values

Variance within levels is calculated using the formula

$SS_{error} = \sum_{i=1}^{i=9}(y_i^2 - y_G^2)$.. eqn6

where y_i is the SNRA values at different levels of different factors

y_G is the mean of SNRA values of different levels in a particular group

Another statistical tool F-test is used to find out if the means of quality characteristic of different levels in each factor is varying significantly as the factors are changed. The Fisher ratio is calculated using the formula

F-ratio=$\frac{Mean\ of\ sum\ of\ squares\ of\ levels}{Mean\ of\ sum\ of\ squares\ of\ errors}$

Mean sum of squares of levels is calculated using the formula

$MSS_{levels} = \frac{SS_{levels}}{k-1}$…………………………………………………………
……….…..…eqn7

Where k is the number of factors.

Mean sum of squares of errors is calculated using the formula

$MSS_{errors} = \frac{SS_{error}}{n-k}$…………………………………………………….…
…………. eqn8

Where n is total number of SNRA values at different levels of different factors

K is the number of groups

To determine the percentage contribution of various input parameters, the corresponding sum of squares of each individual cutting parameter must be divided by the total sum of squares.

1. ANOVA ANALYSIS OF SURFACE ROUGHNESS FOR MACHINING WITHOUT COOLANT:

The ANOVA table for the set of experiments where machining has been performed without any coolant is shown in table 9.

TABLE 9: ANOVA TABLE FOR DRY RUN

	DF	Seq SS	Adj SS	Adj MS	F	P
spindle speed	2	10.771	10.771	5.3856	2.17	0.316
feed rate	2	1.536	1.536	0.768	0.31	0.764
depth of cut	2	1.752	1.752	0.8762	0.35	0.739
Residual Error	2	4.972	4.972	2.4862		
Total	8	19.032				

The percentage contribution of different CP on SR is tabulated in table 10.

TABLE 10: PERCENTAGE CONTRIBUTION OF VARIOUS CUTTING PARAMETERS WHILE MACHINING WITHOUT COOLANT

Cutting parameters	Percentage contribution
Spindle Speed	56.59%
Feed Rate	8.07%
Depth of Cut	9.205%

2. ANOVA ANALYSIS OF SURFACE ROUGHNESS FOR EXPERIMENTS WHERE COOLANT IS MIXTURE OF WATER & MOBILCUT-220 CONVENTIONAL COOLANT:

The ANOVA table for the set of experiments where machining has been performed using coolant as mixture of water & Mobilcut-220 is shown in table 11.

TABLE 11: ANOVA TABLE FOR MACHINING WHERE COOLANT IS A MIXTURE OF WATER & MOBILCUT-220

Source	DF	Seq SS	Adj SS	Adj MS	F	P
spindle speed	2	50.111	50.111	25.0554	20.74	0.046
feed rate	2	1.389	1.389	0.6947	0.58	0.635
depth of cut	2	2.423	2.423	1.2114	1	0.499
Residual Error	2	2.416	2.416	1.208		
Total	8	56.339				

The percentage contribution of different CP on SR is tabulated in table 12.

TABLE 12: PERCENTAGE CONTRIBUTION OF VARIOUS CUTTING PARAMETERS WHILE MACHINING WHERE COOLANT IS A MIXTURE OF WATER & MOBILCUT-220.

Cutting parameters	Percentage contribution
Spindle Speed	88.94%
Feed Rate	2.46%
Depth of Cut	4.3%
Error	4.28%

3. ANOVA ANALYSIS OF SURFACE ROUGHNESS FOR EXPERIMENTS WHERE COOLANT IS A COLLOIDAL MIXTURE OF NANOPARTICLES & MOBILCUT-220:

The ANOVA table for the set of experiments where machining has been performed using coolant as a colloidal mixture of nanoparticles & Mobilcut-220 is shown in table 13.

TABLE 13: ANOVA TABLE FOR MACHINING WHERE COOLANT IS A COLLOIDAL MIXTURE OF NANOPARTICLES AND MOBILCUT-220

Source	DF	Seq SS	Adj SS	Adj MS	F	P
spindle speed	2	41.433	41.433	20.717	4.2	0.192
feed rate	2	17.614	17.614	8.807	1.79	0.359
depth of cut	2	5.007	5.007	2.504	0.51	0.663
Residual Error	2	9.855	9.855	4.927		
Total	8	73.909				

The percentage contribution of different CP on SR is tabulated in table 14.

TABLE 14: PERCENTAGE CONTRIBUTION OF VARIOUS CUTTING PARAMETERS WHILE MACHINING WHERE COOLANT A COLLOIDAL MIXTURE OF NANOPARTICLES & MOBILCUT-220.

Cutting parameters	Percentage contribution
Spindle Speed	56.05%
Feed Rate	23.83%
Depth Of Cut	6.77%
Error	13.33%

4. DISCUSSIONS

For the dry run set of experiments, from analysis of SN ratio, an average SR value of 0.72μm was obtained. The high value of SR can be accounted to the absence of lubrication & due to built-up edge (BUE). BUE can be understood as the build-up of material on the rake face due to friction between the rake face of the tool & underside of the chips. The BUE behaves as a secondary cutting surface as it is harder due to strain hardening. The material of BUE may get adhered on the underside of the chip. This greatly influences the SR. From ANOVA of machining without coolant the results show that spindle speed has a percentage contribution of 56.59%. This value indicates that even a small change in magnitude of the spindle speed greatly affects the quality characteristic which is SR.

On machining in an environment of water & Mobilcut 220, an average SR value of 0.4 µm was obtained, which amounts to a reduction in SR by 80% when compared to the SR value obtained when machining is performed without any coolant. This reduction can be accounted to the effective rate of heat removal due to addition of coolant. On addition of the Mobilcut-220 semi synthetic oil to the shear zone through flood cooling, the oil takes away the heat from the tool tip through forced convection. From ANOVA of machining where coolant is a mixture of water & Mobilcut-220 the results show that spindle speed has a percentage contribution of 88.94%. This value indicates that even a small change in magnitude of the spindle speed greatly affects the quality characteristic which is SR. When machining is conducted using coolant as a colloidal mixture of Al_2O_3 nanoparticles & Mobilcut-220, results show that the average SR obtained is around 0. 3µm.There is a reduction in SR by 30%, when compared to machining where coolant is a mixture of water & Mobilcut-220. The reason for getting superior surface finish can be accounted to two main characteristic features of Al_2O_3 nanoparticles being: -

1. Al_2O_3 nanoparticles are spherical in shape & on entering the shear zone they behave as rollers help in reducing the coefficient of friction between the tool & the work piece. The rolling coefficient of friction is less than coefficient of sliding friction & taking advantage of this property heat generation due to friction is considerably reduced.

$$\mu_{rolling} < \mu_{static}$$

2. Al_2O_3 nanoparticles have a thermal conductivity of approximately 1 $Wm^{-1}K^{-1}$ which helps to increase the overall thermal conductivity of the colloidal mixture of Al_2O_3 nanoparticles with Mobilcut-220. Due to this increased thermal conductivity, there is greater heat transfer by convection. We have less BUE & energy for machining also drops.

From ANOVA of machining where the coolant is a colloidal mixture of Al_2O_3 nanoparticles & Mobilcut-220 the results show that spindle speed has a percentage contribution of 56.05%. This value indicates that even a small change in magnitude of the spindle speed greatly affects the quality characteristic which is SR.

5. CONFIRMATION TESTS:

On obtaining the optimal level of CP for superior surface finish for different set of experiments using different types of machining environments, the improvement in the quality characteristic must be predicted & verified using this optimal level of CP.

The predicted S/N ratio for the optimal level of CP is given by the equation:

$$\hat{\eta} = \eta_m - \sum_{i=1}^{i=3}(\eta_{im} - \eta_m) \quad \ldots\ldots\text{eqn9}$$

Where: -

$\hat{\eta}$ is the predicted S/N ratio at optimum level of Cutting Parameters.

η_{im} is the mean S/N ratio at the optimum levels

η_m is the total mean S/N ratio

6. MACHINING WITHOUT COOLANT:

The results for the confirmation tests conducted using the optimum level of CP,in a dry machining environment is tabulated in table 15.

TABLE 15: RESULTS OF CONFIRMATION TEST FOR SR WHERE MACHINING IS CONDUCTED WITHOUT COOLANT.

optimum cutting parameters		
	Prediction	**Experiment**
level	*A3-B2-C2*	*A3-B2-C2*
surface roughness(µm)	0.546	0.51
S/N ratio(dB)	5.2539	5.8485

7. MACHINING USING COOLANT AS MIXTURE OF WATER & MOBLCUT-220:

The results for the confirmation tests conducted using the optimum level of CP, where coolant is a mixture of water & Mobilcut-220 is tabulated in table 16.

TABLE 16: RESULTS OF CONFIRMATION TEST FOR MACHINING WHERE COOLANT IS A MIXTURE OF WATER AND MOBILCUT-220

optimum cutting parameters		
	Prediction	**Experiment**
level	*A3-B1-C1*	*A3-B1-C1*
surface roughness(µm)	0.225	0.28
S/N ratio(dB)	12.95	11.05

The results for the confirmation tests conducted using the optimum level of CP, where coolant is a colloidal mixture of nanoparticles & Mobilcut-220 is tabulated in table 17.

8. MACHINING USING COOLANT AS COLLOIDAL MIXTURE OF NANOPARTICLES IN MOBILCUT-220:

TABLE 17: RESULTS OF CONFIRMATION TEST FOR MACHINING WHERE COOLANT IS A COLLOIDAL MIXTURE OF NANOPARTICLES & MOBILCUT-220.

optimum cutting parameters		
	Prediction	Experiment
level	*A3-B1-C1*	*A3-B1-C1*
surface roughness(μm)	0.145	0.19
S/N ratio(dB)	16.73	14.42

From the above tables, it becomes clear that there is close agreement between predicted value of SR & value of SR obtained by conducting the experiment. Superior values of surface finish are obtained at the optimum level of CP.

IV. CONCLUSION

The following is a conclusion that may be drawn based on the analysis of this study:

- Optimum level of spindle parameters for experiments where machining is performed without coolant is N=760rpm, f=0.1 mm/rev & d=0. 6mm.The value of SR obtained at these levels of CP is 0. 51μm.The percentage reduction in SR when compared to levels N=640rpm, f=0.12 mm/rev & d=0.8 is 80%.

- Optimum level of CP for experiments where machining is performed using coolant as a mixture of water & Mobilcut-220 is N=760rpm, f=0.08 mm/rev & d =0.4mm. The value of SR obtained at these levels of spindle parameters is 0. 28μm.The percentage reduction in SR when compared to levels N=640rpm, f=0.1 mm/rev & d=0.6 is 65.25%.
- Optimum level of CP for experiments where machining is performed using coolant as a colloidal mixture of nanoparticles & Mobilcut-220 is N=760rpm, f=0.08 mm/rev & d =0. 4mm.The value of SR obtained at these levels of spindle parameters is 0. 19μm.The percentage reduction in SR when compared to levels N=640rpm, f=0.1 mm/rev & d=0.6 is 31.57%

According to the results of an ANOVA for dry run experiments, feed rate and depth of cut, contribute significantly less than spindle speed to SR. One may infer from this research that spindle speed has a considerable impact on SR whereas feed rate has no discernible consequence. From ANOVA for experiments where machining is conducted using coolant as a mixture of water & Mobilcut-220, it is found that spindle speed has the highest percentage contribution on SR, followed by cut depth & feed rate. From ANOVA for experiments where machining is conducted using coolant as a colloidal mixture of Al_2O_3 nanoparticles & Mobilcut-220, it is found that SR is significantly influenced by spindle speed. To conclude, this study found that spindle speed has the greatest influence on SR, regardless of the type of coolant utilized. When machining with coolant that is a colloidal mixture of Mobilcut-220 & nanoparticles, as opposed to machining with coolant that is a mixture of water & Mobilcut-220, the surface finish was improved by 40%. Therefore, it can be concluded that the Taguchi method is a reliable design for obtaining the best spindle parameter values. At the ideal spindle parameter setting, a superior surface finish can be achieved. Confirmation tests are also run to evaluate the Taguchi optimization method's efficacy.

REFERENCES

[1] Saraswat, N., Yadav, A., Kumar, A., & Srivastava, B. P. (2014). Optimization of Cutting Parameters in, Turning Operation of Aluminium". International Review of Applied Engineering Research, 4(3), 251–256.

[2] Selvaraj Dirviyam, P., & Palanisamy, C. (2010). Optimization of surface roughness of AISI 304 austenitic stainless steel in dry turning operation using Taguchi design method". Journal of Engineering Science & Technology, 5(3), 293–301.

[3] Dureja, J. S., Singh, R., & Bhatti, M. S. (2014). Optimizing flank wear & surface roughness during hard turning of AISI D3 steel by Taguchi & RSM methods. Production & Manufacturing Research, 2(1), 767-783.

[4] Li, G., Yi, S., Li, N., Pan, W., Wen, C., & Ding, S. (2019). Quantitative analysis of cooling & lubricating effects of graphene oxide nanofluids in machining titanium alloy Ti6Al4V. Journal of Materials Processing Technology, 271, 584-598.

[5] Abas, M., Sayd, L., Akhtar, R., Khalid, Q. S., Khan, A. M., & Pruncu, C. I. (2020). Optimization of machining parameters of aluminum alloy 6026-T9 under MQL-assisted turning process. Journal of Materials Research & Technology, 9(5), 10916-10940.

[6] Chakraborty, S., & Chakraborty, S. (2022). A scoping review on the applications of MCDM techniques for parametric optimization of machining processes. Archives of Computational Methods in Engineering, 29(6), 4165-4186.

[7] Palaniappan, S. P., Muthukumar, K., Sabariraj, R. V., Kumar, S. D., & Sathish, T. (2020). CNC Turning process parameters optimization on Aluminium 6082 alloy by using Taguchi & ANOVA. Materials Today: Proceedings, 21, 1013-1021.

[8] Saravanakumar, A., Karthikeyan, S. C., & Dhamotharan, B. (2018). Optimization of CNC turning parameters on aluminum alloy 6063 using TaguchiRobust design. Materials Today: Proceedings, 5(2), 8290-8298.

[9] Abas, M., Sayd, L., Akhtar, R., Khalid, Q. S., Khan, A. M., & Pruncu, C. I. (2020). Optimization of machining parameters of aluminum alloy 6026-T9 under MQL-assisted turning process. *Journal of Materials Research and Technology*, *9*(5), 10916-10940.

[10] Chakraborty, S., Raut, R. D., Rofin, T. M., & Chakraborty, S. (2023). Optimization of drilling processes of aluminium metal matrix composites using the robust ordinal priority approach. *Decision Analytics Journal*, 100258.