Effect of Nano Cutting Fluid & Process Parameters on Material Removal Rate and Surface Finish of SS304 Alloy on Turning Operation

Javvadi Eswara Manikanta
Assistant Professor in Mechanical Engineering Department in BVC Engineering College, India.

B Srinivas
Professor in Mechanical Engineering Department in BVC Engineering College, India.

D Santha Rao
Professor in Mechanical Engineering Department in BVC Engineering College, India.

Abstract – Turning is the one of the machining process used to reduce the diameter of cylindrical work piece. The quality of machining operation depends on output parameters like surface finish (S.F) and material removal rate (MRR). Further Material removal rate and surface finish of machined components mainly depends on different process variables like speed, feed, depth of cut and type of cutting fluid. The present work is focused on machining of Austenitic Stainless Steel Alloy: SS304. It has an excellent corrosion resistance and forming characteristics and is most widely used in chemical, petro-chemical, fertilizer industries, food processing, Dairy equipment, pharmaceutical industries, hospitals, cryogenic vessels and heat exchangers in Refrigeration & Air conditioning.

An attempt was made by using Vegetable cutting fluids mixed with 0, 2, 4 and 6 Wt. % Nano Titanium Di-boride particles during turning of stainless steel 304 with varying process parameters: speed, feed and depth of cut. The output machining characteristics like surface finish and material removal rate are evaluated. The process parameters are optimized using Taguchi Design of Experiments. The best parameters are predicted and % contribution of process parameters is analyzed by using ANOVA analysis. Based on the results, it can be concluded that MRR is influenced predominantly by depth of cut and wt. % of Nano cutting fluid and surface finish is influenced by wt. % of Nano cutting fluid and cutting speed.

Key Words: Turning Operation, Nano Cutting Fluid, Material Removal Rate, SS304 Alloy.

1. INTRODUCTION

A lathe is a machine tool which turns cylindrical material, touches a cutting tool to it, and removes the material from the work piece to get the required shape and size. The lathe is one of the machine tools mostly used in material removal process. A material is firmly fixed to the chuck of a lathe and switched on and the chuck is rotated. And since the table which fixed the byte can be moved in the vertical direction and the right-and-left direction by operating some handles. It touches a byte's tip into the material by the operation, and makes a mechanical part.

1.1 Lathe Machine

The experimental setup and the experiment is designed and carried out at Mini Industries Machine Tools, Balangar at Hyderabad. The primary goal of the dissertation work is to predict the MRR, surface roughness. The work is carried out for Turning of SS 304 material by varying machining parameters. The LATHE GSK 980 TD is a machine tool comprised of, a power supply unit and computer numerical control. The most operations handle by the automatic control system as programmed by the operator. A view of the Lathe GSK 980 TD.

Fig 1.1: GSK LATHE 980 TD

2. TURNING PROCESS PARAMETERS AND RESPONSE VARIABLES

2.1 PROCESS PARAMETERS

The input process parameters affecting the response of turning process are:

- Cutting speed
- Depth of cut
- Feed
- Cutting fluid

2.2 Response Variables

Turning process performance can be measured by the Material Removal Rate (MRR), Surface Roughness (SR) of the work piece that has been machined. These two machining characteristics have to be calculated for the selected input parameters. The process parameters should be chosen properly so as to have maximum MRR, minimum SR.

2.2Material removal rate (MRR)

The material removal rate (MRR) of the work piece is the amount of the material removed per minute. MRR and Cutting speed capabilities of Turning have increased enormously over the years. They are influenced by the age and type of machine along with the properties and characteristics of the work piece being cut. The machine settings set by the operator and programmer also affect the MRR and cutting speed.

Material removal rate has been calculated by the following formula:

$$MRR=\frac{Wi-Wf}{\rho X t}$$

Where W_i = initial weight of work piece material

W_f = final weight of the work piece material

t = machining time and

ρ = density of the material.

2.3 Surface roughness (Ra) or surface finish

Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. It is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough. If small, the surface is smooth. The Surface Roughness is represented as Ra.

3. DESIGN OF EXPERIMENT TECHNIQUES

1. Factorial Design
2. Response Surface Methodology
3. Mixture Design
4. Taguchi Design

Among those, Taguchi Design is selected for finding the relative significance of various parameters.

3.1 Taguchi Method

The general steps involved in the Taguchi Method are as follows:

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. Parameters are variables within the process that affect the performance measure such as temperatures, pressures, etc. that can be easily controlled.
3. Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment. The selection of orthogonal arrays is based on the number of parameters and the levels of variation for each parameter.
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.

3.2 ORTHOGONAL ARRAYS

In order to reduce the total number of experiments “Sir Ronald Fisher” has developed the solution: “Orthogonal Arrays”. Taguchi employs design experiments using specially constructed table, known as "Orthogonal Arrays” (OA) to treat the design process, such that the quality is built into the product during the product design stage.

In this array, the columns are mutually orthogonal. That is for any pair of columns all combination of factors occurs and they occur an equal number of times and parameters. If there was an ‘L_{16}’ design; it indicates 16 sixteen rows, configurations or prototypes to be tested. Specific test characteristics for each experimental evaluation are identified in the associated row of the table. Thus ‘L16 (4^4) means that sixteen experiments are to be carried out to study four variables with four levels.

4. ANALYSIS OF EXPERIMENTAL DATA

Once the experimental design has been determined and the trials have been carried out, the measured performance characteristic from each trial can be used to analyze the relative effect of the different parameters. To determine the effect each variable has on the output, the signal-to-noise ratio, or the S/N ratio, needs to be calculated for each experiment conducted.

4.1 SIGNIFICANCE OF SIGNAL-TO-NOISE RATIO

The signal-to-noise concept is closely related to the robustness of a product design. A Robust Design or product delivers strong ‘signal’. It performs its expected function and can cope with variations (“noise”), both internal and external. In signal-to-

Noise Ratio, signal represents the desirable value and noise represents the undesirable value. There are three Signal-to-Noise ratios of common interest for optimization of Static Problems. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore a method of calculating the Signal-to-Noise ratio has gone for quality characteristic.

They are: (i) Smaller-the better, (ii) Larger-the better and (iii) Nominal the best.

4.2 SMALLER-THE BETTER

Impurity in drinking water is critical to quality. The less impurities customers find in their drinking water, the better it is. Vibrations are critical to quality for a car, the less vibration the customers feel while driving their cars the better, the more attractive the cars are:

The Signal-to-Noise ratio for smaller the better is:

$$S/N = -10log_{10}\left(\frac{\sum y^2}{N}\right)$$

4.3 THE LARGER-THE BETTER

If the number of minutes per dollar customers get from their cellular phone service provider is critical to quality, the customers will want to get the maximum number of minutes they can for every dollar they spend on their phone bills.

The Signal-to-Noise ratio for the bigger-the-better is:

$$S/N \ = \ -10log_{10}\left(\frac{1}{n}\sum\frac{1}{y^2}\right)$$

4.4 NOMINAL - THE BEST

When a manufacturer is building mating parts, he would expect every part to match the predetermined target. For instance, when he is creating pistons that need to be anchored on a given cylinder, failure to have the length of the piston to match a predetermined size will result in it being either too small or too long resulting in lowering the quality of the machine. In that case, the manufacturer wants all the parts to match their target.

The S/N equation for the Nominal-The-Best is:

$$S/N \ = 10log_{10}\left(\frac{y^2}{s^2}\right)$$

After calculating the S/N ratio for each experiment, the average S/N value is calculated for each factor level. Then range R (R = high S/N- low SN) of the S/N ratio for each parameter is calculated. The larger the R values for a parameter, the larger the effect the variable. This is because of the same change in signal causes a larger effect on the output variable

4.5 ANALYSIS OF VARIANCE (ANOVA)

Analysis of Variance (ANOVA) is a statistical method for determining the existence of differences among several population means. The aim of ANOVA is the detect differences among several population means, the technique requires the analysis of different forms of variance associated with the random samples under study. The Analysis of Variance is used to find out the percentage contribution of input process parameters for response variables.

5. OBJECTIVES OF PRESENT WORK

- Investigation of the working ranges and levels of the TURNING process parameters.
- Experimental determination of the effects of the various process parameters , % wt. of Nano powder, cutting speed, feed, and depth of cut on the performance measures like material removal rate and surface roughness in TURNING process.
- Single variable optimization of the process parameters of TURNING process using Taguchi.

Validation of the results by conducting confirmation experiment.

5.1 SELECTION OF WORK MATERIAL

Stainless Steel 304 Alloy: SS 304 is chosen to study and this material can find various applications .Because of its as-welded and good corrosion resistance. Due to this this was used in most of the industrial applications, for manufacturing of interior parts of automobiles .In view of the present research objectives, experimental investigation and analysis were carried out in different parametric combinations, for deriving effective parametric combination.

Table 5.1: Chemical composition of SS 304

Element	C	Mn	P	S	Si	Cr	Ni	N_2	Iron
%	0.08	2.00	0.045	0.03	0.75	20.0	10.00	0.1	Bal

The work piece dimensions are length 50mm and diameter is 16mm.

Table 5.2: Mechanical and Thermal properties of Material

Mechanical Properties	
Density(g/cc)	8
Poison's ratio	0.29
Elastic Modulus(Gpa)	193-200

Ultimate Tensile Strength(Mpa)	1260-1390
Yield Point(Mpa)	1041-1160
Elongation at break(%)	70
Hardness(HRC) BRINELL	123
Thermal Properties	
Melting Point(^{0}C)	1400-1455
Thermal Conductivity(W/m.K)	16.2
Specific Heat(J/Kg.K)	435

5.3 CUTTING TOOL AND SPECIFICATIONS

The tool is Cemented carbide cutting tool.

Insert seat size code - 09

Insert seat size code - 3/8

Operation type - Finishing

Cutting edge length - 9.6719 mm

Insert thickness - 3.175 mm

Inscribed circle diameter - 9.525 mm

Corner radius - 0.8 mm

Fixing hole diameter - 3.81 mm 36

Hand - N

Tool style code CNMG-PF

Grade - 4325

Insert shape code – C

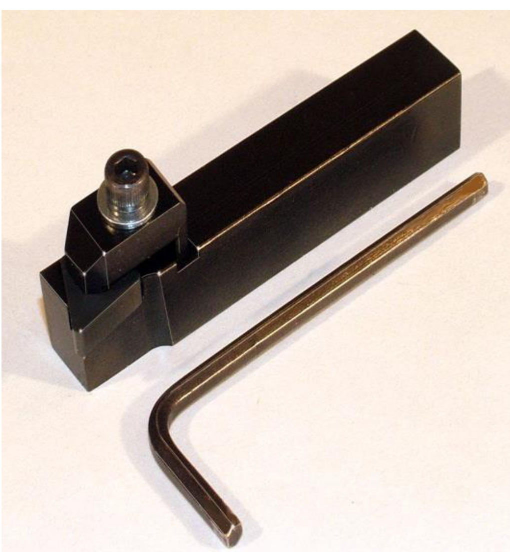


Fig 5.1: Carbide insert tool

5.4 EXPERIMENTAL SETUP

Preparation of tib$_2$ Nano Cutting Fluid:

For preparation of Titanium di boride (TiB_2) Nano cutting fluid the Magnetic stirring method is used. In this process, the TiB_2 nanoparticles are mixed with vegetable oil (base fluid) to make TiB_2 Nano fluid. Nano TiB_2 particles are selected due to their superior tribological and antitoxic properties. The method used to make Nano fluid is given below.

A magnetic stirrer or magnetic mixer is a laboratory device that employs a rotating magnetic field to cause a stir bar (also called "flea") immersed in a liquid to spin very quickly, thus stirring it. The rotating field may be created either by a rotating magnet or a set of stationary electromagnets, placed beneath the vessel with the liquid.

Magnetic stirrers are often used in chemistry and biology, where they can be used inside hermetically closed vessels or systems, without the need for complicated rotary seals. They are preferred over gear-driven motorized stirrers because they are quieter, more efficient, and have no moving external parts to break or wear out (other than the simple bar magnet itself). Magnetic stir bars work well in glass vessels commonly used for chemical reactions, as glass does not appreciably affect a magnetic field. The limited size of the bar means that magnetic stirrers can only be used for relatively small experiments, of 4 liters or less. Stir bars also have difficulty in dealing with viscous liquids or thick suspensions. For larger volumes or more viscous liquids, some sort of mechanical stirring is typically needed.

Because of its small size, a stirring bar is more easily cleaned and sterilized than other stirring devices. They do not require lubricants which could contaminate the reaction vessel and the product. Magnetic stirrers may also include a hot plate or some other means for heating the liquid.

5.5 Weight Proportions of Nano-cutting fluids:

- 0 Weight % of Nano fluid: 100ml vegetable oil and no Nano particles are added.
- 2Wt % of Nano fluid: 100ml vegetable oil and 2 grams of Titanium di boride Nano particles are mixed.
- 4Wt % of Nano fluid: 100ml vegetable oil and 4 grams of Titanium di boride Nano particles are mixed.

- 6Wt % of Nano fluid: 100ml vegetable oil and 6 grams of Titanium di boride Nano particles are mixed.

Symbol	Input Parameter	Level 1	Level 2	Level 3	Level 4
% wt.	% Wt. of Nano	0	2	4	6
S	Speed (rpm)	1100	1200	1300	14000
F	Feed(mm/rev)	0.11	0.12	0.13	0.14
D	Depth of cut(mm)	0.5	0.6	0.7	0.8

Table 5.5 Process Parameters and their levels

A 16 run experiment is selected based on Taguchi's technique by the information from the above table Process Parameters and their levels, the L_{16} orthogonal array was created by using the MINITAB 17 software.

5.6 Steps involved in creating L_{16} Orthogonal Array using MINITAB 17

1. Open the MINITAB 17 window, then an empty worksheet will be displayed.
2. Go to STAT > DOE > Taguchi > Create Taguchi Design

Then select 4-level design, number of factors 4 and enter factors (%Weight of Nano, speed, feed, depth of cut) and their levels. Then the required orthogonal array was displayed.

6. EXPERIMENTATION PROCEDURE

A CNC lathe (model: GSK 980 TD, make: ACE DESIGNERS LTD, Bangalore, India) as shown in the figure is used for experimentation. The power of spindle motor is 7.5 kW and the power supply given is 230V, 50 Hz single phase supply. The Coolant used is TiB_2 Nano cutting fluid.

The model of the machine is super jobber, CNC system used is Fanuc controller with Beta 8i CNC package.

The experiments are conducted on the GSK 980 TD Lathe Machine. The following steps are followed in the cutting operation.

Work piece material with dimensions length 50mm and diameter 16 mm is to be prepared in the lathe for all the 16sets of experiments.

The present experiments has been done through the following way.

a. Checked and prepared the CNC Lathe for performing the machining operation.

b. The specimens are mounted over measured automatic chuck and weight of each specimen by the high precision digital balance meter before machining.

c. Turning operation was carried out after selecting the process parameters and coolant.

d. All the experiments are only single cut and process is repeated for remaining experiments.

e. The final specimen sizes are weighed by using digital balance meter.

f. The coolant used in the turning operation is TiB_2 Nano cutting fluid by MQL technique.

Fig 6 Work Piece after Machining

6.1 MATERIAL REMOVAL RATE (MRR)

Material removal rate (MRR) has been calculated by taking the difference of weight of specimens before and after experiment.

Material removal rate has been calculated by the following formula:

$$MRR = \frac{Wi - Wf}{\rho * t}$$

$$= \frac{68.77 - 64.04}{8.03 * 0.67}$$

$$= 983.33 \text{ mm}^3/\text{min}$$

Where,

Wi is the initial weight of work piece (gm),

Wf is the final weight of work piece (gm),

t is the machining time in minutes(min),

ρs is the density of SS 304(8.03gm/cm^3)

The weight of the work piece has been measured in a high precision digital balance meter (Model: DHD – 200 Macro single pan DIGITAL reading electrically operated analytical balance made by Dhona Instruments), which can measure up to the accuracy of 10-4 *g*and thus eliminates the possibility of large error while calculating material removal rate (MRR) in straight turning operation.

6.2 Measurement of surface roughness

The surface roughness was founded using the Mitutoyo SJ-201P.

a. Surface Roughness test was carried out on the teas micro hite and leveling of surface plate by using spirit level.

b. Work piece is placed on the surface plate which was flat.

c. Talysurf is also placed on the surface plate such that both work piece and Taly surf levels are equal to each other and confirmed using dial indicator.

d. Switch on power supply then Ra mode is selected.

e. Sampling length of 2.4 mm over incremental steps of 0.8mm.

f. The surface finish is measured perpendicular to lay surface and three trails are taken then average of three values as a Surface Roughness of the specimen.

EXPERIMENTAL RESULTS FOR MRR AND SF:

RUNS	% Wt. of Nano fluid	SPEED rpm	FEED Mm/rev	DEPTH OF CUT(mm)	SURFACE FINISH(R_a)	MRR Mm^3/min
01	0%	1100	0.11	0.5	2.18	883.6
02	0%	1200	0.12	0.6	1.48	928.15
03	0%	1300	0.13	0.7	1.84	1071.3
04	0%	1400	0.14	0.8	1.39	1425.5
05	2%	1100	0.13	0.6	1.576	1075
06	2%	1200	0.14	0.5	1.814	1079.4
07	2%	1300	0.11	0.8	1.532	991.31
08	2%	1400	0.12	0.7	1.475	1096.2
09	4%	1100	0.14	0.7	1.39	1211.33
10	4%	1200	0.13	0.8	2.032	1229
11	4%	1300	0.12	0.5	1.532	829.64
12	4%	1400	0.11	0.6	**1.22**	1196.3
13	6%	1100	0.12	0.8	1.85	**1625.15**
14	6%	1200	0.11	0.7	1.758	968.2
15	6%	1300	0.14	0.6	1.35	1083.1
16	6%	1400	0.13	0.5	1.382	954.7

6.3 Microstructure Observations of workpieces using "SCANNING ELECTRON MICROSCOPE":

The microstructure of machine work surface was performed for assessment of the surface quality obtain using MQL process. The specimens were observed with scanning electron microscope. Hitachi S-3400N with an accelerating voltage of 10.0 kv. Etching of the specimens was done in a mixture composed of 50ml HCL, 50ml distilled water and 5 grams of copper sulphate for 1 min. The three specimens for selected for microstructure observation with low value of surface finish, high value of surface finish and one standard work piece.

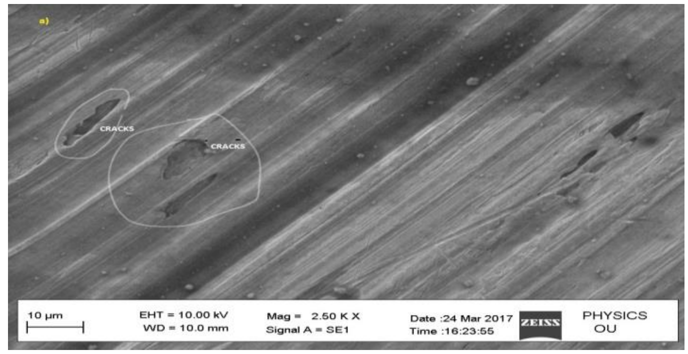


Fig 6.1 SEM image for standard work piece

Fig 6.2 Micro structure of the machined sample at experiment no 1, low surface finish

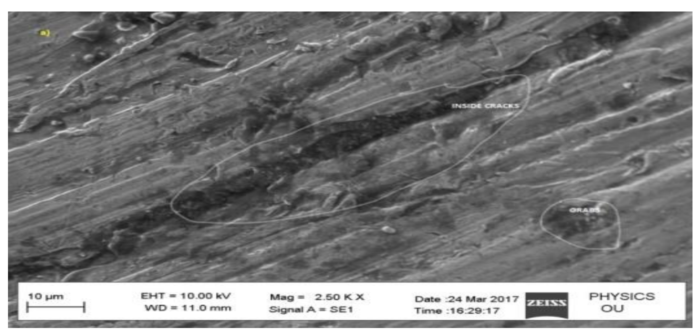


Fig 6.3 micro structure of the machining sample at experiment no 14 , high surface finish

At low level of surface finish fig .3.92 a micro craters ,cracks and small debris .It is possible at low speed 1200 and without nano mixing.At high level of surface finish fig 3.9.3 there is less cracks when compare with low surface finish . At same feed and depth of cut the material will posses low surface finish and high surface finish ,it clearly says that speed and volumetric % of nano fluids are the important parameter which influence the surface finish.

7. OPTIMIZATION OF PROCESS PARAMETERS

Procedure to calculate Mean and S/N ratio in MNITAB 17

After creating Orthogonal Array L_{16} for the selected levels of process parameters, the next step is to enter the values of response variables i.e. Material Removal Rate, Surface Roughness which were calculated after the experimentation.

Then go to STAT-DOE-TAGUCHI-DEFINE CUSTOM TAGUCHI DESIGN. In this enter the factors (process parameters that effect output responses).Then again go to STAT-DOE-TAGUCHI-ANALYZE TAGUCHI DESIGN. In this enter response data (response variable for which we want MEANS and S/N ratios) and in storage select S/N ratios and MEANS. In options give the S/N criteria whether Larger is better, Smaller is better or Nominal is better.

Then we can see the generation of MEANS and S/N ratios for all 16 experimental runs.

Exp. No	Wt.% of Nano	Cutting speed (rpm)	Feed (mm/rev)	Depth of cut	MRR (mm³/min)	S/N ratio	SR (μm)	S/N ratio
01	0%	1100	0.11	0.5	883.6	4.77176	2.188	-3.95112
02	0%	1200	0.12	0.6	928.15	7.10903	1.48	-5.17275
03	0%	1300	0.13	0.7	1071.3	9.85437	1.845	-3.37584
04	0%	1400	0.14	0.8	1625.5	12.50048	1.39	-3.70518
05	2%	1100	0.13	0.6	1075	5.562995	1.576	-4.24375
06	2%	1200	0.14	0.5	1079.4	9.596975	1.814	-3.40523
07	2%	1300	0.11	0.8	991.31	7.177724	1.532	-5.31993
08	2%	1400	0.12	0.7	1096.2	10.20285	1.475	-2.8603
09	4%	1100	0.14	0.7	1211.33	13.5346	1.39	-6.80095
10	4%	1200	0.13	0.8	1229	14.94255	2.032	-6.15847
11	4%	1300	0.12	0.5	829.64	5.46299	1.532	-3.70518
12	4%	1400	0.11	0.6	1196.3	12.94766	**1.22**	-1.7272
13	6%	1100	0.12	0.8	**1625.15**	16.56353	2.22	-6.92706
14	6%	1200	0.11	0.7	968.2	15.0123	1.758	-4.90038
15	6%	1300	0.14	0.6	1083.1	10.57011	1.35	-2.60668
16	6%	1400	0.13	0.5	954.7	11.60321	1.382	-2.81016

Table 7.1 Signal to Noise Ratios for MRR, SR

PROCESS	LEVEL	S/N ratio				Mean			
		Wt. %of Nano	S	F	D	Wt. %of Nano	S	F	D
Average Value	L1	8.559	10.108	9.859	5.977	2.832	3.778	2.607	3.522
	L2	8.481	11.665	9.047	9.835	2.61	4.126	2.995	4.528
	L3	11.722	8.266	12.151	10.491	4.163	2.662	4.182	6.599
	L4	**13.437**	**11.814**	**12.796**	**11.551**	7.886	3.294	4.705	8.841
	Delta	4.956	1.022	2.524	5.302	4.8	0.9	1.52	4.956
	Rank	2	4	3	1	2	4	3	1

Table 7.2 Taguchi Analysis: SR versus N, S, F, D

PROCESS	LEVEL	S/N ratio				Mean			
		Wt. %of Nano	S	F	D	Wt. %of Nano	S	F	D
Average Value	L1	-3.468	-5.481	-4.051	**-3.975**	1.599	1.904	1.492	1.600
	L2	**-3.438**	-4.909	**-3.957**	-4.666	1.586	1.771	1.503	1.739
	L3	-4.484	-3.752	-4.325	-4.147	1.743	1.551	1.703	1.630
	L4	-5.528	**-2.776**	-4.32	-4.130	1.678	1.381	1.907	1.638
	Delta	2.790	2.105	0.641	0.692	2.65	2.012	0.715	0.869
	Rank	1	2	4	3	1	2	3	4

Table 7.3 Taguchi Analysis: SR versus N, S, F, D

7.1 PREDICTION OF OPTIMAL VALUES

Prediction of Optimal Value for Material Removal Rate

The optimum value of Material Removal Rate (MRR) is predicted at the selected levels of significant parameters. The predicted optimal mean of the response characteristics (MRR) can be computed as

$$\bar{Y}_{predicted} = \bar{Y}_{exp} + (\bar{Y}_n - \bar{Y}_{exp}) + (\bar{Y}_s - \bar{Y}_{exp}) + (\bar{Y}_f - \bar{Y}_{exp}) + (\bar{Y}_d - \bar{Y}_{exp})$$

(or)

$$\bar{Y}_{predicted} = \bar{Y}_n + \bar{Y}_s + \bar{Y}_f - 3*\bar{Y}_{exp}$$

Where, $\bar{Y}_{predicted}$= Predicted MRR

From Table:

$\bar{Y}_{exp}$= Total average response of the experiments in the array = ΣY

i.e., ΣY= $\frac{T}{N}$=15695/16 =980.23 mm^3/min

Where T = sum of all experiments MRR mean values

N = number of experiments=16

$\bar{Y}_N$= average MRR at fourth level wt. % of Nano, 6%

i.e. Σ N_{L4}/4 = (1625+968+1083+954)/4 =1157.5 mm^3/min

$\bar{Y}_S$= average MRR at fourth level of speed, 1400

i.e. Σ S_{L2}/4 = (1625+1096+1196+954)/4 = 1217.75 mm^3/min

$\bar{Y}_F$= average MRR at fourth level of feed, 0.14mm/rev

i.e. Σ F/4 = (1625+1079+1211+1083)/4 = 1249.5 mm^3/min

$\bar{Y}_D$= D_{L4} is the average MRR at fourth level of depth of cut, 0.8mm

i.e. Σ D_{L4}/4 = (1625.5+991+1229+1083)/4 = 1232mm^3/min

Therefore the predicted optimal values of MRR are

$\bar{Y}_{predicted}$= $\bar{Y}_n$ + $\bar{Y}_s$ + $\bar{Y}_d$ -3* $\bar{Y}_{exp}$

=1157.5+1217.75+1249.5+1232-980.322

=1672.2

7.2 Confirmation Test for Material Removal Rate

The final step in verifying the improvement in Material Removal Rate was done by conducting experiments using optimal conditions. The confirmation experiment was conducted at the optimum setting of process parameters namely Wt. % of Nano at level 4(6%), Speed level 1 (1100rpm), feed level 2(0.12mm/rev) and depth of cut level 4(0.8mm) and the Material Removal Rate observed to be 1625.15mm^3/min, which was around the confidence interval of the predicted optimal Material Removal Rate 1670.32mm^3/min.

7.3Predicted values For Surface Roughness

$\bar{Y}_{exp}$ = Total average response of the experiments in the array = ΣY

i.e., ΣY= $\frac{T}{N}$=26.424/16=1.6515µm

Where T= sum of all experiments SR mean values

N=number of experiments=16

From above Tables

$\bar{Y}_N$ = average SR at second level of wt. % of Nano, 4%

i.e. Σ N/4 = (1.63+1.48+1.845+1.39)/4 = 1.58625µm

$\bar{Y}_S$ = average SR at first level of speed, 1100rpm

i.e. Σ S/4 = (1.532+1.39+1.22+1.382)/4 = 1.381µm

$\bar{Y}_F$= average SR at fourth level of feed, 0.14mm/rev

i.e. Σ F/4 = (1.814+1.63+1.22+1.35)/4 = 1.5035µm

$\bar{Y}_D$ = average SR at second level of depth of cut, 0.6mm

i.e. Σ D/4 = (1.576+1.845+1.22+1.758)/4 = 1.59975µm

Therefore the predicted optimal values of Surface Roughness are

$\bar{Y}_{predicted}$ = $\bar{Y}_N$ + $\bar{Y}_S$ + $\bar{Y}_F$ - 3* $\bar{Y}_{exp}$

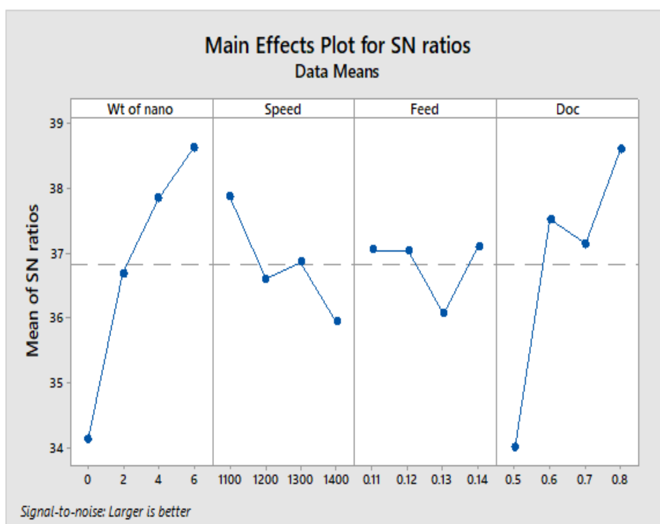
= 1.58625+1.381+1.5035+1.59975– 3 x 1.6515

= 1.116µm

	Means					S/N ratios				
Source	DF	SS	MS	F	% of contribution	DF	SS	MS	F	% of contribution
N	3	0.06414	0.02138	2.68	32.2	3	0.9931	0.3310	2.56	33.95
S	3	0.6446	0.21487	1.09	15.24	3	17.48	5.826	1.05	16.25
F	3	0.4609	0.15363	0.2	5.16	3	11.83	3.943	0.3	4.84
D	3	0.04401	0.01467	4.11	38.23	3	1.09	0.3634	4.21	39.24
Residual Error	3	0.13074			9.82	3	3.567			8.3
Total	15	1.34439			100	15	34.96			100

Table7.4 ANOVA for Material Removal Rate

8. RESULTS AND DISCUSSION



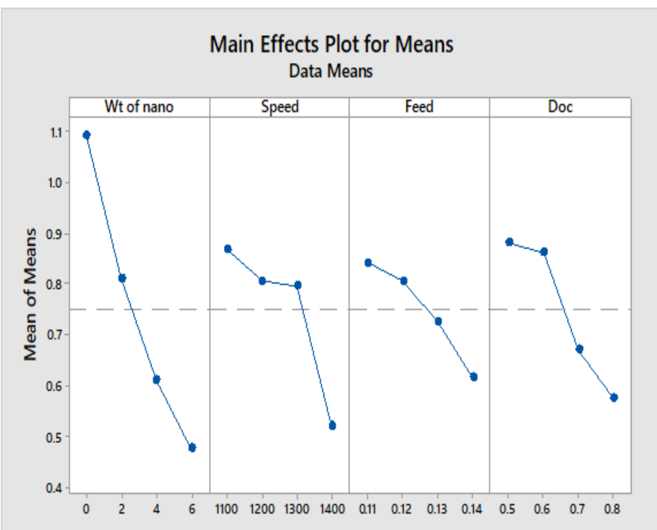
8.1 Graph of Input Parameters v/s MRR

After performing the experiment for all 16 runs and measuring the output parameters like material removal rate, surface roughness for Turning of SS304.

Main Effect Plots for Input Parameters V/S Output Parameters

This graph shows the effect of Wt. % of Nano on material removal rate. From it is clearly shown that with increase in % of Nano powder, material removal rate increased. Initially when Wt. % of Nano is 0% MRR is 883.6 mm^3/min. When the Wt. % of Nano increased to 6%, material removal rate increased to 1625.15 mm3/min. it is clearly shown that with increase in Speed, material removal rate decreased except in some conditions.

When Speed increased from 1100 to 1200 rpm, material removal rate decreased. from 1200 to 1300 material removal rate increased .When speed from 1300 to 1400 material removal rate decreased This non-linearity is due to effect of other process parameters on material removal rate.



8.2 Graph of Input Parameters v/s SR

This graph shows the effect of Wt. % of Nano on surface roughness. From it is clearly shown that with increase in Wt. % of Nano, surface roughness was decreased. Initially when Wt. % of Nano is 0% surface roughness is 2.188 µm. When the Wt. % of Nano increased to 2%, surface roughness is decreased from 2.188 to 1.85 µm. When Wt. % of Nano again increased from 2% to 4% then surface roughness decreased from 1.85 to 1.2 µm. When Wt. % of Nano further increased to 6%, then surface roughness slightly increased from 1.2 to 1.35 µm.

8.1 ANOVA Analysis

The ANOVA analysis is conducted to know the percentage contribution of the input parameters on output parameters. ANOVA analysis results shows that the, for material removal rate percentage contribution of Wt. % of Nano is 33.2%, speed is 16%, feed is 3%, depth of cut is 38.6%. This shows that the influence of Wt. % of Nano and depth of cut are more compare to other parameters on material removal rate. While for surface roughness, percentage contribution of Wt. % of Nano is 50.3%, speed is 34.6% and feed is 3% and depth of cut is 2.4%. This shows that the influence of Wt. % of Nano & speed more on surface roughness compare to other parameters.

9. CONCLUSIONS

Experiments were conducted to optimize the different machining parameters like Wt. % of Nano powder in Lubricant, Cutting speed, Feed, Depth of cut in Turning of SS 304.

Finally it can be concluded that:

1. Surface finish and MRR can be improved by using different process parameters.

2. The surface finish (1.22µm) is better at high speed (1400 rpm), low feed (0.11 mm/rev) and depth of cut (0.6 mm) and % wt. of Nano (4%).

3. The MRR(1625.15 mm3/min) is better at high depth of cut(0.8 mm),speed(1400 rpm) and feed(0.14 mm/rev) and % wt. of Nano (6%).

4. SS 304 material can be machined with carbide insert tool material.

5. It is found that at high speed and high % wt. of Nano fluid more surface finish is occur. From this speed and Nano fluid ratio are the major parameters that influence the surface finish.

6. It is found that at high depth of cut more MRR is occur. From this, depth of cut is the major parameter that influenced the material removal rate.

From Taguchi analysis it can be concluded that:

a)The material removal rate was found to be 1625.15mm^3/min at optimal parameter levels of % of Nano powder at level 4(6 %), Cutting speed at level 1(1100 rpm), Feed at level 2(0.12 mm/rev), Depth of cut at level 4(0.8mm).

b) The Surface Roughness was found to be 1.22µm at optimal parameter levels of % of Nano powder at level 3(4%),Cutting speed level 4 (1400 rpm), Feed at level 1(0.11mm/rev),), Depth of cut at level 2(0.6mm).

From ANOVA

a) Depth of cut and % wt. of Nano powder are the most influential parameters in increasing of Material Removal Rate.

% of Nano powder and Cutting speed are the most influential parameters in decreasing of Surface Roughness.

REFERENCES

[1] Abhang L.B &Hameedullah M. "Optimization of machining parameters in steel Turning operation by Taguchi method" International conference on Modeling,Optimization and Computing. Procedia Engineering 38(2012) pp.40–48.

[2] Hrelija Marko,Klancnik Simon,IrgolocTomaz,PaulicMatej, BalicJoze,BrezocnikMiran. "Turning parameters optimization using particle swarm Optimization" 24th DAAAM International Symposium on Intelligent Manufacturing and Automation. Procedia Engineering 69 (2014) p.p 670 – 677

[3] Komson Jirapattarasilp & Choobunyen Kuptanawin "Effect of Turning Parameters on Roundness and Hardness of Stainless Steel: SUS 303", 2012 AASRI Conference on Modelling, Identification and Control AASRI Procedia 3 (2012) 160 – 165.

[4] Manjunatha.R &Umesh c.k "Optimization of tangential force,feed force and surface roughness using Taguchitechnique in Turning operation" International conference on Advances in Manufacturing and Material Engineering,AMME 2014 Procedia Materials Science 5 (2014) p.p1685 – 1691.

[5] Shree moy kumar nayak, Jatin Kumar Patro, Shailesh Dewavyam, Sowmya Gangopadhyaya. "Multi-Objective Optimization of Machining Parameters During Dry Turning of AISI 304 Austenitic Stainless Steel Using Grey Relational Analysis" 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014) Procedia Materials Science 6 (2014) p.p701 – 708. 6

[6] Ramanujam R,Venkatesan.K,Vimal Saxena,Philip Joseph's "Modelling and Optimization of cutting parameters in dry turning of Inconel 718 usingcoated carbide inserts", International conference on Advances in Manufacturing and Material Engineering, IC AMME 2014 Procedia Materials Science 5 (2014) p.p2550 – 2559.

[7] VenkataRao.R & Kalyankar.V.D. "Multi-pass turning process parameter optimization using teaching–learning-based optimization algorithm". Production and hosting by Elsevier B.V. Scientia Iranica E (2013) 20 (3), pp.967–974.

[8] Harsha y Valera, SanketvBhavsar "Experimental Investigation of Surface Roughness and power consumption in turning operation of EN 31 Alloy steel" 2nd International conference on Innovations in Automation and Mechatronics Engineering. ICIAME 2014. Procedia Technology 14(2014) 528-534.

[9] Chowdary , S.M.A. (2009). "Study of the Effects of Minimum Quantity Lubricants on turning steels using uncoated carbide insert", phd thesis submitted to Department IPE, BUET.

[10] Ali S.M. , Dhar, N.R. "Effect of minimum quantity lubrication on cutting performance in Turning medium carbon steel by uncoated carbide insert at different speed feed combinations". Advances in Production Engineering and Management 6(2011) 3, 185-196 ISSN 1854-6250.

[11] Jeevansingh, Harvindersingh "Influence of minimal quantity lubrication technique in machining evolution". International Journal of Advance Research and Innovations, Volume 3 Issue 4 (2015) 657-660.

[12] Aronson,R.B."Why dry machining", Manufacturing Engineering, pp. 33-66, January 1995.

[13] Chinchanikar ,S.Kulakarni" Hard Turning under dry and minimum quantity lubrication (MQL). Journal of Production Engineering, JPE (2015) Vol .18 (2).

[14] Diniz, A.E.., Ferreria, J.R.,F.T.: Influence of lubrication condition on SAE 52100 hardened steel turning at several cutting speed, International Journal of Machine Tools and Manufacturers, 43,p.p. 317-326, 2003.

[15] Khan, M.M.A.,Mithu , M.A.H., Dhar, N.R.: Effects of Minimum Quantity Lubrication on Turning AISI 9310 alloy steel using vegetable oil based cutting fluid , Journal of Materials Processing Technology , 2009, p.p. 333 – 338 , 2006.

[16] E.A.Rahim , M.R. Ibrahim , A.A.Rahim " Experimental Investigation of Minimum Quantity Lubrication (MQL) as a sustainable cooling technique". Procedia CIRP 26 (2015) 351- 354