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An Experimental Investigation to Optimize the Process Parameters of Surface Finish in Turning AISI 202 Stainless Steel Using Taguchi Approach

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ABSTRACT:
This paper aims at optimization of process parameters of surface finish for turning AISI 202 austenitic stainless steel using Taguchi approach. Nine cylindrical bars of AISI 202 of diameter 20mm are turned to a length of 20 mm in each experiment for a constant spindle speed of 73.5 rpm on conventional lathe machine. Coolant concentration, Feed rate, Depth of cut and rake angle of tool are taken as the process parameters. A Taguchi orthogonal array is designed with three levels of machining parameters and analysis of S/N ratios, response table and regression equations were made with the help of Minitab 16 software.

KEYWORDS: *AISI 202. DOE. taauchi method. turnina. S/N ratio.*

I. INTRODUCTION

Attaining optimum surface finish in the presence of constraints like MRR and economics of machining is one of the challenging tasks encountered by many growing industries these days. Several factors influence surface finish and there is a need to optimize these parameters. Taguchi method can help in optimizing these parameters taking into consideration of economy.The Taguchi method is a well-known technique that provides a efficient and systematic methodology for optimization of process parameters and this is a powerful tool for the design of high quality systems with low development and manufacturing costs. Signal to noise ratio and orthogonal array are two major tools used in robust design. The S/N ratio characteristics can be divided into following three categories when the characteristic is continuous [1]:
a) Nominal is the best
b) Smaller the better
c) Larger is better characteristics.
For surface roughness, the solution is "smaller is better" and S/N ratio is determined by the following equation:

$$n = -10\log_{10}[1/n\,(\Sigma y_i^2)]\ \text{---Equation 1}$$

Where n = No. of Measurements, y = Measured Value which is in Ra.

In this experiment, 4 parameters are chosen having 3 levels. Without using Taguchi method total number of experiments should be 3^4=81 experiments. But using taguchi L9 array as shown in figure 1, 9 experiments are proposed providing nearly same accuracy. Those nine experiments will give 96% accurate result. By using this method number of experiments reduced to 9 instead of 81 with almost same accuracy.

Experiment	P1	P2	P3	P4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Figure 1: Taguchi L9 orthogonal array

II. EXPERIMENTAL DETAILS"

Work material : AISI 202 is an austenitic stainless steel with relatively low nickel content as compared to 300 and 300L series. Martensitic stainless steels have better properties than austenitic stainless steels but nowadays due to the rising prices of nickel the use of austenitic stainless steel is increasing tremendously. AISI 202 austenitic stainless steel finds its application in general industrial and process-industry machinery and equipment, automotive industry, structural, bus body, electrical machinery etc [2]. Figure 2 is showing the chemical properties of AISI 202 and Figure 3 is showing the mechanical-thermal properties of AISI 202.

elements	Composition (percent)
C	-< 0.15
Si	< 1.00
Mn	7.5-10.0
P	< 0.06
S	< 0.03
Cr	17.0-19.0
Ni	4-6
Mo	0

Figure 2: Chemical composition of AISI 202

Sr. no	Mechanical property	Value
1	Density(Kg/m3)	7800
2	Poisson's ratio	0.27-0.30
3	Elastic modulus (GPa)	190-210
4	Tensile strength (MPa)	515
5	Yield strength (MPa)	275
6	Thermal expansion(/degree C)	0.0000175
7	Thermal conductivity(W/m-K)	16.2
8	Specific heat(J/kg-K)	500
9	Hardness(HRC)	38-43

Figure 3: Mechanical and thermal properties of AISI 202

As seen from the table because of high hardness & lower thermal conductivity, it becomes difficult to machine AISI 202 at higher speed and without the application of cutting fluid. Sometimes at higher temperatures without using cutting fluids chromium reacts with carbon to form carbides which get deposited on grain boundaries and depletes the properties of AISI 202. Proper set of parameters are to be chosen to obtain optimum surface finish without degrading the properties of the material.

Tool material : S-400(T-42) which is a high cobalt high speed steel tool having a hardness of 66-68 HRC was used in the experiment. There are two grades of HSS tools available, namely T series and M series. These two series differ mainly in the composition of tungsten, cobalt and molybdenum. T series has higher content of tungsten and cobalt while M series has higher molybdenum. Red hardness and tempering retention of T series is larger than M series due to the large cobalt and tungsten content as compared to M series but M series possesses good grindability and higher strength in tension, shear and bending .[3].

Element	Composition
C	1.25-1.40
Si	0-0.04
Mn	0-0.04
P	0.35
S	0.35
Cr	3.75-4.50
Mo	2.75-3.50
V	2.75-3.25
W	8.50-9.50
Co	9-10
Ni	0-0.04

Figure 4: Chemical Composition of AISI T-42 tool

All the six angles along with the appropriate nose radius were ground on the tool as shown in table 1. In the experiment, three HSS tools with top rake angle 8, 12 and 16 degrees were used to observe the effect of rake angles along with 3 other parameters on the surface finish.

Table 1: Geometry of AISI T-42 tool

S No	Angle	Value
1	Side rake angle	7°
2	Back rake angle	variable
3	Side cutting edge angle	13°
4	End cutting edge angle	12°
5	Side relief angle	6º
6	End relief angle	8°
7	Nose radius	0.2mm

Cutting fluid : Cutting fluid plays a major role in machining process. Emulsifier or emulsion is used as a cutting fluid in this experiment. Emulsions are the mixture of mineral oils and water. Water provides good cooling and oil provides good lubrication. Therefore both serve the function of removing heat from the cutting zone as well as reducing wear-tear and friction. It is a brown color, paraffinic oil soluble, bio-stable semi-synthetic product which turns into white color on adding water. It is particularly recommended for all machining operations. In this study, ratio of water and oil in the emulsion is varied between 20:1 and 40:1 to optimize between cooling property and lubricating property of the emulsion used.

III. EXPERIMENTAL PROCEDURE

Nine round bars of equal diameter 20mm and equal length 30mm are prepared from a long rod of AISI 202. Feed, depth of cut, rake angle and coolant concentration are the variables of the process with following the levels given in table 2

Table 2: Machining parameters and levels

	Coolant Concentration (V/V)	Feed (mm/rev)	Depth of cut (mm)	Rake angle (degrees)
Level 1	20	0.1701	0.5	8º
Level 2	30	0.3868	0.7	12º
Level 3	40	0.6939	1.0	16º

Using taguchi L9 array and DOE, the experiments are designed as shown in the Table 3 below

Table 3: Design of Experiment

	Concentration of coolant (V/V)	Feed (mm/rev)	Depth of cut(mm)	Rake angle(degrees)
1	20	0.1701	0.5	8º
2	20	0.3868	0.7	12º
3	20	0.6939	1.0	16º
4	30	0.1701	0.7	16º
5	30	0.3868	1.0	8º
6	30	0.6939	0.5	12º
7	40	0.1701	1.0	12º
8	40	0.3868	0.5	16º
9	40	0.6939	0.7	8º

The Workpiece is turned to a length of 20 mm in each experiment for a constant spindle speed of 73.5 rpm and their surface finish is measured on surface testing machine and following results were obtained as shown in table 4

Table 4: Experimental values of surface roughness

	Concentration (V/V)	Feed (mm/rev)	Depth of cut(mm)	Rake (deg)	Surface roughness Ra
1	20	0.1701	0.5	8º	16.367
2	20	0.3868	0.7	12º	6.260
3	20	0.6939	1.0	16º	3.342
4	30	0.1701	0.7	16	8.810
5	30	0.3868	1.0	8º	2.560
6	30	0.6939	0.5	12º	9.200
7	40	0.1701	1.0	12º	24.061
8	40	0.3868	0.5	16º	12.687
9	40	0.6939	0.7	8º	3.888

Figure 5: Machined samples

IV. DATA ANALYSIS"

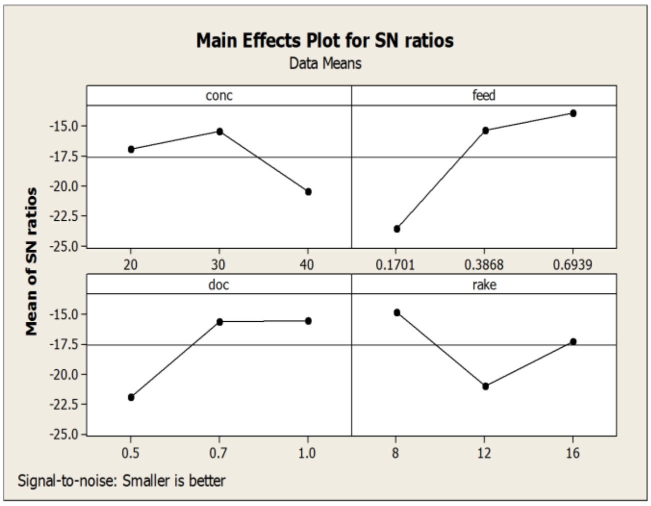
After performing experiments, parameters are optimized by using Minitab 16 software. The calculation, results and graphs of S/N ratio, response table and regression equation are provided by Minitab 16 software.

S/N ratios:

Table 5: S/N ratios @ Minitab 16

Experiment no	S/N ratios
1	-24.279
2	-15.932
3	-10.480
4	-18.899
5	-8.1648
6	-19.276
7	-27.626
8	-22.067
9	-11.795

4.2. S/N plots:



Plot 1: S/N plot @ Minitab 16

It is seen from the above graph that:
a. S/N ratios increases as coolant concentration increases, reaches maximum at 30:1 V/V and then decreases.
b. S/N ratio increases as the feed increases; maximum S/N ratio is obtained at a feed of 0.6939.
c. S/N ratio increases as the depth of cut increases achieves maximum value at a depth of cut of 0.7mm and then becomes almost constant.
d. S/N ratio reduces as rake angle increases, achieves minimum value and then increases with concentration. Maximum S/N ratio is obtained at a rake angle of 8°.

Response table:

Table 6: Response table obtained @ Minitab 16

Level	Concentration	Feed	Depth of cut	Rake angle
1	-16.90	-23.60	-21.87	-14.75
2	-15.45	-15.39	-15.54	-20.94
3	-20.50	-13.85	-15.42	-17.15
Delta	5.05	9.75	6.45	6.20
Rank	4	1	2	3

The response table has provided feed has rank 1, depth of cut rank 2, rake angle rank 3 and coolant concentration rank 4.

V. REGRESSION ANALYSIS

Regression equation was implemented to obtain the correlation between the machining parameters and the measured surface roughness.
The regression equation is:
Surface Roughness R_a= 12.6 + 0.244 concentration - 19.9 feed - 4.1 doc + 0.084 rake.

VI. RESULTS AND CONCLUSIONS

[1] An experiment having feed of 0.6939 mm/rev, depth of cut of 0.7mm, rake angle of 8° and concentration of 30:1 V/V will give the optimum machining parameters.
[2] The most prominent parameter is feed followed by depth of cut, rake angle and coolant concentration.

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