Optimization of Machining Parameters for Turning on CNC Machine of Stainless Steel 316 Steel

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Abstract *In this study an experimental investigation of cutting parameters (cutting speed, feed rate and depth of cut) in turning operation of stainless steel316 was done and influence of cutting parameters on surface roughness, tool wear, material removal rate was studied. The machining was performed using tool such as tungsten carbide tool (0.4, 0.8). Taguchi method is used to find optimum result. Orthogonal array, signal to noise ratio and used to study the performance characteristics in turning operation*

Key Words: Stainless steel, Cutting Parameters, Taguchi Method, ANOVA, S/N Ratio

1. INTRODUCTION

Turning is an important and widely used manufacturing process in engineering industries. The study of metal removal focuses on the features of tools, input work materials, and machine parameter settings. The technology of metal removal using turning operations has grown substantially over the past decades and several branches of engineering have contributed to this to achieve the various objectives of the process. Selection of optimal machining conditions is a key factor in achieving these objectives. There are large numbers of variables involved in the turning process. These can be categorized as input variables and output variables. Various input variables involved in the turning process are: cutting speed, feed rate, depth of cut, number of passes, work material and its properties, tool material and tool geometry, cutting fluid properties and characteristics, etc. Similarly, the output variables associated with the turning process are: production cost, production time, tool life, dimensional accuracy, surface roughness, cutting forces, cutting temperature, and power consumption, etc. For optimization purposes, each output variable is taken as a function of a set of input variables. To achieve several conflicting objectives of the process, optimum setting of the input variables is very essential, and should not be decided randomly on a trial basis or by using the skill of the operator. Use of appropriate optimization techniques is needed to obtain the optimum parameter settings for the process. [1]

2. Literature review

Jadhav and Kulkarni have studied on cutting speed, feed, depth of cut and various insert materials in wet condition on surface roughness (Ra) using Design of experiments (DOE) and statistical techniques for Al-SiC Metal matrix composite on specified compact CNC turning centre. Since, this material belongs to a special class i.e. MMC, not much research have been done on the same and this would be helpful in improving productivity at a reasonable level of quality. Saraswat et.al.have done the work related to optimization of cutting parameter in turning operation of mild steel. By using conventional machine process the turning operation is carried out. Cutting parameters are depth of cut, feed rate and spindle speed have been optimized in turning of mild steel and He results that the combination of optimal levels of the factors was obtained to get the lowest surface roughness. Davis has done the experimental study is concerned with the optimization of cutting parameters (depth of cut, feed rate, spindle speed) in wet turning of EN24 steel (0.4% C) with hardness 40+2 HRC. In the present work, turning operations were carried out on EN24 steel by carbide P-30 cutting tool in wet condition and the combination of the optimal levels of the parameters was obtained. The Analysis of Variance (ANOVA) and Signal-to-Noise ratio were used to study the performance characteristics in turning operation. The results of the analysis show that none of the factors was found to be significant. Taguchi method showed that feed rate followed by depth of cut and spindle speed was the combination of the optimal levels of factors while turning EN24 steel by carbide cutting tool. Verma and shikawar studied on Optimizing Turning Process by Taguchi Method under Various Machining Parameters. In this paper the experimental results shows that the optimal combination of parameters for surface roughness are at spindle speed of 620 rpm, feed rate of 0.3 mm/min, depth of cut of 0.7 mm while for material removal rate are at spindle speed of 620 rpm, feed rate of 0.5 mm/min, depth of cut of 0.9 mm. The optimum value of the surface roughness (Ra) comes out to be 2.35 µm. While the optimum value of the material removal rate (MRR) comes out to be 44.15 mm^3/min. Prasad has studied in a turning process in which surface roughness depend on machining parameters and tool geometry. In this work considering three machining parameters and two tool geometrical parameters 243 experiments were conducted for full factorial design. Using ANOVA analysis the influence of these parameters on surface roughness was studied. It is observed that minimum surface roughness is obtained at a speed of 550 rpm, feed of 0.1 mm/rev, depth of cut of 1mm, side rake angle of 18º and back rake angle of 14º the surface finish is 1.465μm and feed is the significant parameter influencing surface roughness and side rake angle is having very less effect on surface roughness. Vipin and raganath have done the work related to optimization of cutting parameter in turning operation. In this paper Taguchi's Design of Experiment (DOE) approach used by many researchers to analyze the effect of process parameters like cutting speed, feed, and depth of cut on Surface Roughness and to obtain an optimal setting of these parameters that may result in good surface finish. He also concluded that, Taguchi optimization method revealed that cutting Speed should be kept at the highest level, while both feed rate and depth of cut should be kept at the lowest level. Pridhviji and Yeldose have studied an experimental investigation of cutting parameters (cutting speed, feed rate and depth of cut) in turning operation of Aluminium alloy-2014 was done and influence of cutting parameters on surface roughness was studied. The machining was performed using two different tools such as carbide tool and TiN coated carbide tool. Taguchi method is used to find optimum result. Orthogonal array, signal to noise ratio and ANOVA is used to study the performance characteristic in turning operation. The result shows that better surface finish is achieve at low feed rate (0.05mm/rev), high cutting speed (314m/min) and at high depth of cut. Experimental data collected are tested with regression model and ANN technique, and a comparison study of model has been done. Tonk and Ratol [9], the study was aimed to investigate the effect of several input parameters of turning operation (cutting tool, cutting oil, cutting speed, feed and depth of cut) on the different response parameters such as thrust force and feed force in turning process on EN31. The result showed that the response variables were strongly influenced by the input parameters. The experiments were performed on conventional lathe machine. Taguchi's robust design methodology has been used for statistical planning of the experiments. Experiments were conducted on conventional lathe machine in a completely random manner to minimize the effect of noise factors present while turning EN31 under different experimental conditions. Two type of tools and three types of coolant were used with three different values of machining parameters (speed, feed and depth of cut). Magdum and Naik(2013) [10], have studied on the optimization and evaluation of machining parameters for turning on EN8 steel on Lathe machine. This study investigates the use of tool materials and process parameters for machining forces for selected parameter range and estimation of optimum performance characteristics. Develop a methodology for optimization of cutting forces and machining parameters. Makadia and Nanavati (2013) [11], have studied on optimization of machining parameters for turning operations based on response surface methodology. In this paper, application of response surface methodology (RSM) on the AISI 410 steel is carried out for turning operation. Response surface optimization shows that the optimal combination of machining parameters are (255.75 m/min, 0.1 mm/rev, 0.3 mm, 1.2 mm) for cutting speed, feed rate, depth of cut and tool nose radius respectively. He also concluded that 3D surface counter plots are useful in determining the optimum condition to obtain particular values of surface roughness. Abdelmaguid and Tarek (2012) [12], they have studied this paper, a new mathematical model is proposed for a turning operation in which multiple parts are produced successively. In this model, the tool wear compensation is taken into consideration and represented as a decision variable whose value is to be determined for each part. Losses due to deviations from target diameter and surface roughness are taken into consideration in the model in addition to the traditional cost elements defined for the machining processes. A non-linear programming model is formulated for the studied problem and an optimization approach is proposed. Savadamuthu et.al. (2011) [13], has done the work related to quality improvement in turning process using Taguchi loss function. The orthogonal array, the signal-to-noise ratio and analysis of variance are employed to study the performance characteristics in turning operations of AISI 1030 steel bars using TiN coated tools. He concluded that- The Adaptive Neuro Fuzzy Inference System (ANFIS) control scheme is applied to control the turning process with constant cutting force under various cutting conditions. The Taguchi-genetic method is applied to search for the optimal control parameters of both the predictor and the fuzzy controller such that the ANFIS controller provides optimum output. The proposed quality improvement methodology caused significant reductions in the defect rate in a very short period of time. This reduction in defects implies that the selected tools are suitable for establishing the required improvement.

3. Experimental setup

For the present experimental work four process parameters each at three levels have been decided. It is desirable to have minimum three levels of process parameters to reflect the true behavior of output parameters under study. The L18orthogonal array with all values selected for the experimental run is shown in table. There are 18 parameter combinations that need to be tested. Each parameter combination is tested for replications for effective error reduction and for accurate S/N ratio. The process parameters are renamed as factors and they are given in the adjacent column. The levels of the individual process parameters / factors are given in and shows L18 Orthogonal Array of Process Parameter. [1]

Table 3.1- parameters and their levels

Sr. No.	Notation	Name of Parameter	levels		
1	S	Spindle Speed (rpm)	1050	1100	1200
2	F	Feed rate (mm/min)	100	120	140
3	C	Depth of cut (mm)	0.05	0.10	0.2
4	T	Tool Nose Radius	0.4	0.8	-

Fig. 3.1 – Experimentation Setup

3.1 Mechanism and Evaluation of MRR:

MRR is the rate at which the material is removed the workpiece.. The MRR is defined as the ratio of the difference in weight of the workpiece before and after machining to the machining time.

i. Metal removing rate (mm3/sec) :

Turning is most common process in whole manufacturing, for turning process the CNC machine is selected.
Material Specification.
Ø 40mm and length 70mm.
Currently, the MRR for turning is calculated by the formula:

ii. Removal Rate (mm. cu./Min) :

MRR = v f D
MRR = Material Removal Rate (mm.cu./Min)
v = Cutting Speed (SFPM)
f = Feed (Dist./Rev.)
D = Depth of Cut (mm)

Sample calculation for case 1:
N = 1050 RPM
Do= 40 mm
F = 100 mm/min
D = 0.05

Cutting speed , v = π Do N = 131880 SFPM
Feed , f = F/N =100/1050 =0.09523 mm/rev
DOC = D= 0.05 mm
MRR = vfD = 627.94 mm3/min

Rotational Speed: N (RPM's)
N = V/πD
N = Rotational Speed (RPM's)
v = Cutting Speed (SFPM)
DO = Original Diameter

Feed Rate: F (Dist/Min)
F = N f
F = Feed Rate (Dist/Min)
N = Rotational Speed (RPM's)
f = Feed (Dist/Rev)

Table 3.2- parameters and their levels

Sr. No.	Tool	Speed	Feed rate	Depth of Cut
1	0.4	1050	100	0.05
2	0.4	1050	120	0.1
3	0.4	1050	140	0.2
4	0.4	1100	100	0.05
5	0.4	1100	120	0.1
6	0.4	1100	140	0.2
7	0.4	1200	100	0.1
8	0.4	1200	120	0.2
9	0.4	1200	140	0.05
10	0.8	1050	100	0.2
11	0.8	1050	120	0.05
12	0.8	1050	140	0.1
13	0.8	1100	100	0.1
14	0.8	1100	120	0.2
15	0.8	1100	140	0.05
16	0.8	1200	100	0.2
17	0.8	1200	120	0.05
18	0.8	1200	140	0.1

Table 3.3- A NOVA table

Source	DF	Seq. SS	Contri.	Adj SS	Adj MS	F- Value	P - Value
Depth of cut	2	158293	92.58	158293		388.37	0.000
Feed Rate	2	944644	5.53	944644		23.18	0.000
Speed	2	51957	0.30	51957	25979	1.27	0.321
Tool Nose Radius	1	67862	1.19	67862	67862	3.33	0.098
Error	10	203790	1.19	203790	20379		
Total	17	170976	100				
Model Summary							
S – 142.755 R-sq 98.81% R-sq(adj) 97.97%							

The main effect values are plotted in Figure no for the cutting speed, feed rate, tool nose radius and depth of cut respectively. The main effects plot shows the influence of each level of factors and the mean with maximum value is taken as the optimum values of material removal rate

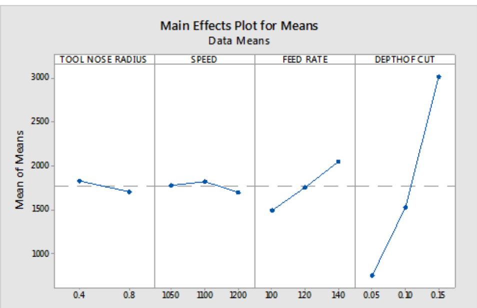

Fig. 3.1 – Main effect Plot for Mean for MRR

The plot shows that as the speed and tool nose radius increases material removal rate decreases. Depth of cut increase material removal rate increases. [2]

Table 3.4- ANOVA table

Source	DF	Seq. SS	Contri.	Adj SS	Adj MS	F- Value	P – Value
Depth of cut	2	8.2804	10.25	8.2804	4.1402	27.27	0.000
Feed Rate	2	0.6627	55.94	0.6627	0.3314	2.18	0.163
Speed	2	0.2327	1.57	0.2327	0.1163	0.77	0.490
Tool Nose Radius	1	4.1089	27.76	4.1089	4.1089	27.07	0.000
Error	10	1.5180	10.25				
Total	17	14.8026	100				
Model Summary							
S – 142.755 R-sq 98.81% R-sq(adj) 97.97%							

After the experiment we find the speed ,feed rate, tool nose radius, depth of cut Create an effect on material removal rate .in this experiment we got that depth of cut which affect significantly on material removal rate followed by tool nose radius, feed rate, speed respectively. Speed is less significant to material removal rate, contribution of depth of cut is 92.58%

The main effect values are plotted in Figure no for the cutting speed, feed rate, tool nose radius and depth of cut respectively. The main effects plot shows the influence of each level of factors and the mean with maximum value is taken as the optimum values of surface roughness.

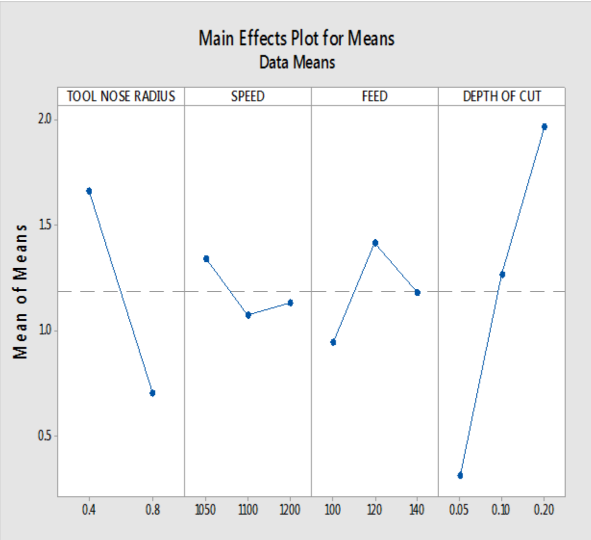

Fig. 3.1 – Main effect Plot for Mean for SR

The plot shows that as the speed and tool nose radius increases surface roughness decreases. Depth of cut increase surface roughness increases.

Table 3.5- ANOVA table

Source	DF	Seq. SS	Contri.	Adj SS	Adj MS	F- Value	P - Value
Depth of cut	2	0.01121	26.55	0.01121	0.005606	0.29	0.044
Feed Rate	2	0.01488	16.72	0.01488	0.007439	0.38	0.236
Speed	2	0.06471	3.84	0.06471	0.032356	1.67	0.690
Tool Nose Radius	1	0.10276	2.90	0.10276	0.102756	5.31	0.754
Error	10	0.19342	49.98				
Total	17	0.38698	100				
Model Summary							
S – 142.755 R-sq 98.81% R-sq(adj) 97.97%							

After the experiment we find the speed ,feed rate, tool nose radius, depth of cut Create an effect on surface roughness .in this experiment we got that depth of cut which affect significantly on surface roughness followed by tool nose radius, feed rate, speed respectively. Speed is less significant to surface roughness. Contribution of depth of cut 55.94%

The main effect values are plotted in Figure no for the cutting speed, feed rate, tool nose radius and depth of cut respectively. The main effects plot shows the influence of each level of factors and the mean with maximum value is taken as the optimum values of tool wear.

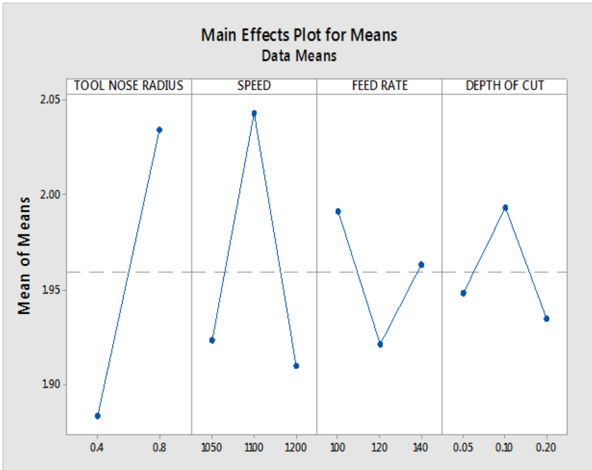

Fig. 3.3 – Main effect Plot for Mean for TWR

The plot shows that as the speed and depth of cut increases tool wear decrease, feed rate first decreases after increase tool wear increases. [2]

Table 3.6- AOVA table

Source	DF	Seq. SS	Contri.	Adj SS	Adj MS	F- Value	P - Value
Depth of cut	2	0.01121	2.90	0.01121	0.005606	0.29	0.754

Feed Rate	2	0.01488	3.84	0.01488	0.007439	0.38	0.690
Speed	2	0.06471	16.72	0.06471	0.032356	1.67	0.236
Tool Nose Radius	1	0.10276	26.55	0.10276		5.31	0.044
Error	10		49.98				
Total	17		100				
Model Summary							
S – 142.755 R-sq 98.81% R-sq(adj) 97.97%							

After the experiment we find the speed ,feed rate, tool nose radius, depth of cut Create an effect on tool wear in this experiment we got that tool nose radius rate which affect significantly on tool wear followed by , feed rate, speed, depth of cut respectively. Tool nose radius is more significant to tool wear. Contribution of tool nose radius is 26.55%.

Table 6 – Rank for Response Variable

	Responses Variable		
Process Parameter	TWR (g/min.)	MRR (mm^3/min.)	SR (μm)
Tool Nose Radius	2	1	1
Depth of Cut	2	2	1
Feed Rate	1	3	2
Speed	2	3	3

conclusion :

The experiments are done in CNC Machine, using four process parameters speed , feed rate, depth of cut, tool nose radius. The aim of this experiment is to find out Tool Wear Rate, Material Removal Rate and Surface Roughness and4L the effects of the variables used on these characteristics. The material used in this experiment is stainless steel 316. In this investigation L_{18} orthogonal array are used and experiments are done accordingly for confirmation. By doing experiments following conclusion can be drawn:

i. Depth of cut is most significant factor for MRR while significance of MRR is less and that of tool nose radius. As depth of cut increase MRR increases slight linearly. As feed rate.
ii. Tool wear increase with increase speed first and then decrease. As feed rate increases the tool wear first decrease and then increase .
iii. For Surface Roughness tool nose radius is most significant followed by depth of cut and feed rate at last. As depth of cut increases SR increases and it increases rapidly as depth of cut values is more.
iv. In this research depth of cut is significant parameter.

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