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Optimization of turning process parameters for surface roughness in dry and wet condition of AISI 1045 steel using Taguchi method

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ABSTRACT

The main purpose of today's manufacturing industries is to produce low cost, high-quality products in short time. They mainly focused on achieving high quality, in term of part accuracy, surface finish, high production rate etc. So, the selection of optimal cutting parameters is a very important issue for every machining process in order to reduce the machining costs and increase the quality of machining products. In this paper, the cutting of AISI 1045 steel material under the wet and dry condition is carried out using CNC lathe machine. Taguchi method is used to formulate the experimental layout. The effect of cutting condition (spindle speed, feed rate and depth of cut) on surface roughness were studied and analyzed. The CNC turning machine is used to conduct experiments based on the Taguchi design of experiments (DOE) with the orthogonal L9 array. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to find minimum surface roughness. Optimum results are finally verified with the help of confirmation experiments.

Keywords: *ANOVA, Dry turning, Wet turning, Design of experiment, Surface roughness.*

1. INTRODUCTION

Nowadays modern machining industries mainly emphasized on the achievement of high dimensional accuracy, good surface finish, high production rates, less wear on the cutting tools, the economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact [1]. Turning process is one of the most fundamental and important machining processes in which the unwanted material is removed from the surface of a rotating cylindrical workpiece by a single point cutting tool. For better performance of any machining process, high machining rate and better surface finish and good power consumption are desirable. To achieve high cutting performance, selecting of cutting parameters is very important [2-3]. Dry machining is the process where no cutting fluid is used for economic and environmental reasons. In this process, the temperature of the cutting tool is very high and this induces excessive tool wear thus decreasing tool life. Also, the chips generated at machining cannot wash away and these chips cause deterioration on the machined surface. The problems of cutting fluid contamination and disposal are not seen in dry machining. The advantages of dry machining include non-pollution of the atmosphere (or water); no residue on the swarf which will be reflected in reduced disposal and cleaning costs; no danger to health; and it is non-injurious to skin and is allergy free. Moreover, it offers cost reduction in machining. However, in dry cutting operations, the friction and adhesion between chip and tool tend to be higher, which causes higher temperatures, higher wear rates and, consequently, shorter tool lives [4].

Taguchi method is a powerful tool for the design of high-quality systems. It provides a simple, efficient and systematic approach to optimize designs for performance, quality, and cost. Taguchi method is an efficient method for a designing process that operates consistently and optimally over a variety of conditions [6]. In this paper, the S/N ratio and a statistical analysis of variance (ANOVA) are been employed to indicate the impact of process parameters on output response values. The cutting parameters are taken and both the material removal rate and surface finish are optimized by using the Taguchi method and Analysis of variance (ANOVA) [7].

2. EXPERIMENTATION

A. Workpiece

The material selected was AISI 1045 MS bars (of diameter 50 mm and length 140 mm) on the basis that it was suitable for most engineering and construction applications.
AISI 1045 is a low-cost alloy, medium-carbon steel with adequate strength and toughness characteristics, AISI 1045 is valuable for induction- or flame-hardened components. The hardness of bar is 187 HB.

Table 1: Chemical Composition of AISI 1045 steel in %

C	Si	Mn	P	S	Cu	Ni	Cr
0.45	0.20	0.72	0.015	0.018	0.10	0.09	0.07

B. Tool Material

Carbide cutting tool also known as cemented carbides is used for machining the workpiece. It is a hard material used to machining the tough materials such as carbon steel or stainless steel, also used where other tools would wear away, high-quantity production runs. Carbide tools can also withstand higher temperatures than standard high-speed steel tools.

C. COOLANTS

MAK SHEROL B is used as a coolant for machining. It is premium quality soluble cutting oil blended from refined mineral oil, emulsifier and other additives. It forms an extremely stable milky emulsion of the "Oil in Water" type. This soluble cutting oil is recommended for use in a variety of cutting operations on ferrous and non-ferrous materials. It is used at the water to oil ratios between 20:1 and 30:1.

E. PARAMETERS OF THE EXPERIMENT

The working ranges of the parameters for the subsequent design of the experiment, based on Taguchi's L9 Orthogonal Array (OA) design have been selected using MINITAB 15 software. In the present experimental study, spindle speed, feed rate and depth of cut have been considered as process variables. The process variables with their units (and notations) are listed in Table 2.

Table 2: Process variables and their limits

Parameters/Factors		level		
		1	2	3
A	Spindle speed (rpm)	160	320	620
B	Feed rate (mm/rev)	0.3	0.4	0.5
C	Depth of cut (mm)	0.7	0.8	0.9

F. DESIGN OF EXPERIMENTS

Table 3 shows the experimental results for material removal rate and surface roughness and the corresponding S/N ratio for dry and wet machining. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. Lower the better quality characteristic is used for surface roughness respectively.

Table 3: Cutting Parameters and Levels for Dry and Wet Turning

Experiment no.	Spindle speed (rpm), N	Feed rate (mm/rev), f	Depth of cut (mm), a
1	160	0.3	0.7
2	160	0.4	0.8
3	160	0.5	0.9
4	320	0.3	0.8
5	320	0.4	0.9
6	320	0.5	0.7

7	620	0.3	0.9
8	620	0.4	0.7
9	620	0.5	0.8

Table 4: Experimental Data Related to Surface Roughness Characteristics for dry turning

Experiment no.	**Spindle speed (rpm), N**	**Feed rate (mm/rev), f**	**The depth of cut (mm), d**	**Surface roughness, Ra (µm)**	**S/N ratio of surfaces roughness**
1	160	0.3	0.7	3.24	-10.21
2	160	0.4	0.8	4.67	-13.39
3	160	0.5	0.9	4.93	-13.86
4	320	0.3	0.8	5.38	-14.62
5	320	0.4	0.9	4.26	-12.59
6	320	0.5	0.7	5.17	-14.27
7	620	0.3	0.9	2.24	-7.00
8	620	0.4	0.7	4.36	-12.79
9	620	0.5	0.8	3.47	-10.81

Table 5: Experimental Data of Surface Roughness Characteristics for Wet Turning

Experiment no.	**Spindle speed (rpm), N**	**Feed rate (mm/rev), f**	**The depth of cut (mm), d**	**Surface roughness, Ra (µm)**	**S/N ratio of surfaces roughness**
1	160	0.3	0.7	2.12	-6.52
2	160	0.4	0.8	3.40	-10.62
3	160	0.5	0.9	3.62	-11.17
4	320	0.3	0.8	2.37	-7.49
5	320	0.4	0.9	3.69	-11.34
6	320	0.5	0.7	2.8	-8.94
7	620	0.3	0.9	2.11	-6.48
8	620	0.4	0.7	3.78	-11.54
9	620	0.5	0.8	2.80	-8.94

3. RESULTS AND ANALYSIS

A. ANALYSIS OF S/N RATIO FOR SURFACE ROUGHNESS FOR DRY AND WET TURNING

Table 4.5 and Table 4.6 shows the ANOVA calculations for the S/N ratio for dry and wet turning. The analysis was carried out at a significance of $\alpha=0.05$. The main effect is shown in figure 4.3 and figure 4.4 for dry and wet turning. Table 4.4 shows the response table for S/N for surface roughness. It was found that only feed is a significant factor with F value of 2.86.

Table 6: Analysis of variance for S/N ratios for surface roughness (Ra) in Dry Turning

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage Contribution %
Spindle speed (rpm), N	2	20.147	20.147	10.074	1.76	0.363	42.28 %
Feed rate (mm/rev), f	2	10.948	10.948	5.474	0.95	0.512	22.97 %
Depth of cut (mm), d	2	5.075	5.075	2.537	0.44	0.693	10.65 %
Error	2	11.479	11.479	5.74			11.3 %
Total	8	47.649					

Table 7: Response table for S/N Ratios of surface roughness (Ra) in Dry Turning

Level	Spindle Speed (rpm), N	Feed rate (mm/rev), f	The depth of Cut (mm), d
1	-12.48	-10.61	-12.42
2	-13.82	-12.92	-12.94
3	-10.2	-12.98	-11.15
Delta	3.62	2.37	1.79
Rank	1	2	3

Table 8: Analysis of variance for S/N ratios for surface roughness (Ra) in Wet Turning

Source	DF	Adj SS	Adj MS	F	P	Percentage Contribution %
Spindle speed (rpm), N	2	5.3878	0.01539	0.09	0.914	16.34 %
Feed rate (mm/rev), f	2	29.148	14.574	8.91	0.101	66.84 %
Depth of cut (mm), d	2	4.5985	0.4292	0.26	0.792	13.68 %
Error	2	3.2715	1.6357			3.14 %
Total	8	33.586				

Table 9: Response table for S/N Ratios of surface roughness (Ra) in Wet Turning

Level	Spindle Speed (rpm), N	Feed rate (mm/rev), f	The depth of Cut (mm), d
1	-9.443	-6.836	-9.007
2	-9.260	-11.173	-9.023
3	-8.993	-9687	-9.667
Delta	0.451	4.338	0.66
Rank	3	1	2

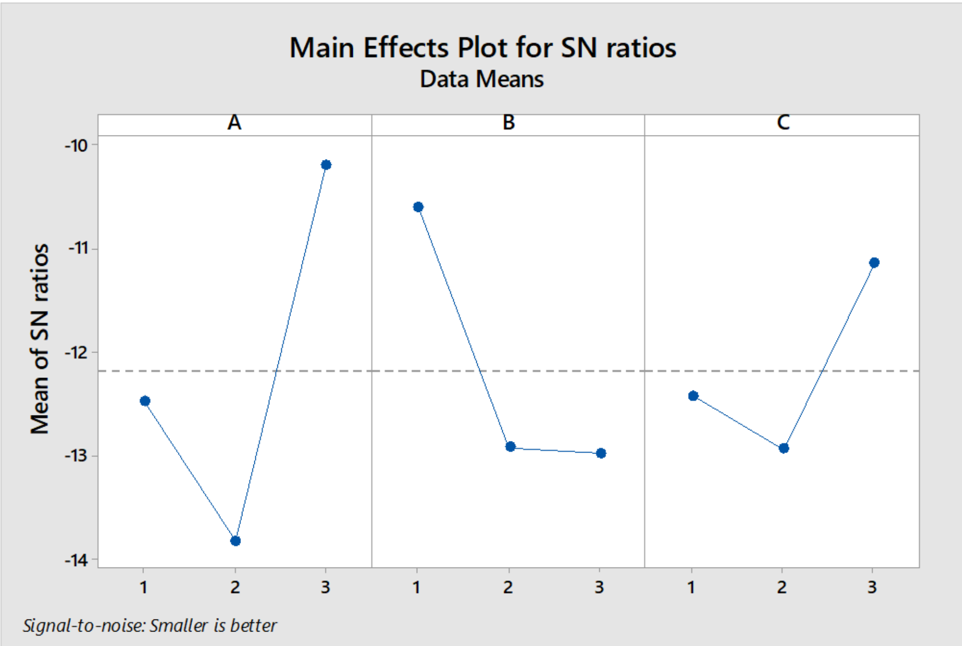

Figure 4.3: Main effects plot for S/N ratios for surface roughness in Dry Turning

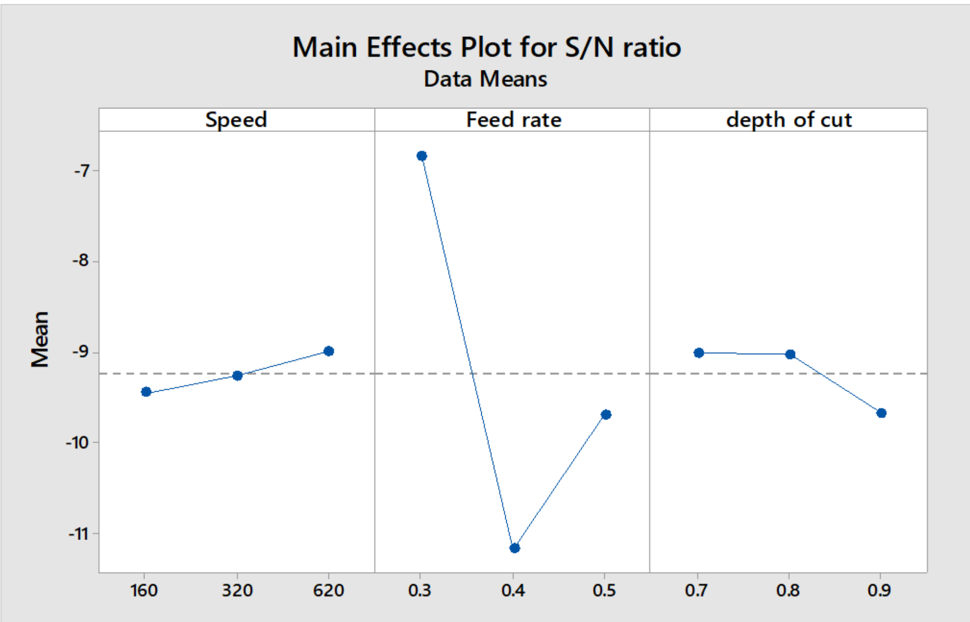

Figure 4.4: Main effects plot for S/N ratios for surface roughness in Wet Turning

4. DETERMINATION OF OPTIMUM SOLUTION

Optimum condition of the turning process is concerned with minimizing the surface roughness but this cannot be achieved simultaneously with a particular combination of control parameter settings. Optimal parameter setting for surface roughness in dry and wet turning has been determined from Figure 4.3 & 4.4. The optimal settings and the predicted optimal values for surface roughness in dry and wet turning are determined individually by Taguchi's approach. Table 4.5 & 4.6 shows these individual optimal values and its corresponding settings of the process parameters for the specified performance characteristics. The optimal result has been verified through confirmatory test showed the satisfactory result.

Table 10: Parameters and their selected levels for optimal surface roughness in dry turning

Parameter designation	Process parameters	Optimal levels
A	Spindle speed (rpm), N	(320 rpm)
B	Feed rate (mm/rev), f	(0.5 mm/rev)
C	The depth of cut (mm), d	(0.8 mm)

Table 11: Parameters and their selected levels for optimal surface roughness in wet turning

Parameter designation	Process parameters	Optimal levels
A	Spindle speed (rpm), N	(620 rpm)
B	Feed rate (mm/rev), f	(0.3 mm/rev)
C	The depth of cut (mm), d	(0.8 mm)

5. CONFIRMATION TEST

The last step of Taguchi parameter design is to verify and predict the improvement of surface roughness (response) using optimum combination of cutting parameters.

The predicted optimal value (η_{opt}) can be calculated by means of additive law.

$$\eta_{opt} = m + \sum_{j=1}^{n} [(m_{i,j})_{max} - m]$$

Where m= overall mean of η with nine trials; (m_{ij}) max = S/N ratio at an optimal level and the parameter; n is the number of main designing parameters that affect the machining process.

Table 12: Verification of result for surface roughness in dry turning

Optimized Settings	Predicted	Observed	Percentage Deviation	Optimum Range of Surface Roughness
A3B1C1	2.96 µm	2.58 µm	12.83 %	2.58 µm <Ra< 2.96 µm

Table 13: Verification of Result for surface roughness

Optimized Settings	Predicted	Observed	Percentage Deviation	Optimum Range of Surface Roughness
A3B1C2	2.25 µm	2.10 µm	7.14 %	2.10 µm <Ra< 2.25 µm

6. CONCLUSION

A. CONCLUSIONS FROM SURFACE ROUGHNESS IN DRY TURNING

- The following conclusions are done from the study:
- It has been found that spindle speed is found to be the most significant factor & its contribution to surface roughness is 42.28 %. The best results for surface roughness (lower is better) would be achieved when AISI 1045 work piece is machined at a spindle speed of 320 rpm, the feed rate of 0.5 mm/rev and depth of cut of 0.8 mm. With 95% confidence interval, the spindle speed effects the surface roughness most significantly
- The Surface roughness is mainly affected by feed rate, depth of cut and spindle speed. With the increase in feed rate, the surface roughness also increases, as the depth of cut increases the surface roughness first increase and decrease and as the spindle speed increase surface roughness decreases.
- From ANOVA analysis, parameters making a significant effect on surface roughness are feed rate and depth of cut.
- Optimal machining parameters for minimum surface roughness were determined. The percentage error between experimental and predicted result is 12.83 %.
- The parameters taken in the experiments are optimized to obtain the minimum surface roughness possible. The optimum setting of cutting parameters for high quality turned parts is as:-
- Spindle speed = 320 rpm
- Feed rate = 0.5 mm/ rev
- Depth of cut = 0.8 mm

B. CONCLUSIONS FROM SURFACE ROUGHNESS IN WET TURNING

- It has been found that depth of cut is found to be the most significant factor & its contribution to surface roughness is 66.84 %. The best results for surface roughness (lower is better) would be achieved when AISI 1045 work piece is machined at a spindle speed of 620 rpm, the feed rate of 0.3 mm/rev and depth of cut of 0.8 mm. With 95% confidence interval, the depth of cut effects the surface roughness most significantly
- The Surface roughness is mainly affected by the depth of cut, feed rate, and spindle speed. With the increase in depth of cut, the surface roughness also increases, as the feed rate decreases and as the spindle speed increase surface roughness decreases.
- From ANOVA analysis, parameters making a significant effect on surface roughness are the depth of cut, feed rate, and spindle speed.
- Optimal machining parameters for minimum surface roughness were determined. The percentage error between experimental and predicted result is 7.14 %.
- The parameters taken in the experiments are optimized to obtain the minimum surface roughness possible. The optimum setting of cutting parameters for high quality turned parts is as:-
    1. Spindle speed = 620 rpm
    2. Feed rate = 0.3 mm/ rev
    3. Depth of cut = 0.8 mm

7. REFERENCES

[1] Pytlak, B.; (2010) "Multicriteria optimization of hard turning operation of the hardened 18HGT steel", International Journal Advance Manufacturing Technology, Volume 49: pp. 305-312.
[2] Sieben, B., Wagner, T. and Biermann, D.; (2010) „ "Empirical modeling of hard turning of AISI 6150 steel using design and analysis of computer experiments", Production Engineering Research Development, Volume 4: pp. 115 - 125.
[3] Cappellini, C., Attanasio, A., Rotella, G. and Umbrello, D.; (2010) "Formation of dark and white layers in hard turning: influence of tool wear", International Journal of Material Forming, Volume 3 No.1: pp. 455 - 458.
[4] D. Philip Selvaraj, P. Chandramohan; (2010) "Optimization of surface roughness of AISI 304 Austenitic stainless steel in dry turning operation using Taguchi design method", Journal of Engineering Science and Technology, Volume 5, No. 3: pp 293-301.
[5] R. Ramanujam, R. Raju, N. Muthukrishnan; (2010) "Taguchi-multi machining characteristics optimization in turning of Al-15% SiCp composites using desirability function analysis", Journal of Studies on Manufacturing, Volume 1 Issue2-3: pp 120-125.
[6] J.S.Senthilkumaar, P.Selvarani, RM. Arunachalam; (2010) "Selection of machining parameters based on the analysis of surface roughness and flank wear in finish turning and facing of Inconel 718 using Taguchi Technique", Emirates Journal for Engineering Research, Volume 15, No.2: pp 7-14.
[7] H. Yanda, J.A. Ghani, M.N.A.M. Rodzi, K. Othman, and C.H.C. Haron; (2010) "Optimization of material removal rate, surface roughness and tool life on conventional dry turning of FCD 700", International Journal of Mechanical and Materials Engineering, Volume 5 No. 2: pp 182-190.
[8] D. Mittal, M.P. Garg, R. Khanna; (2011) "An investigation of the effect of the process parameters on MRR in turning of pure Titanium (Grade -2)", International Journal of Engineering Science & Technology, Volume 3 No. 8: pp 6345-6349.
[9] S. Pahda, S. M Sharma, N. Malhotra; (2011) "Analysis of variance and Optimization of surface roughness in CNC Turning of EN-8 steel by Taguchi method", International Journal of Advanced Engineering Technology, Volume 3 Issue 1: pp 264-267.
[10] M. Vellibor, M. milos; (2011) "Optimization of surface roughness in turning alloy steel by using Taguchi method", Scientific Research and Essays, Volume 6(16): pp 3474-3484.

[11] S.Khrais, A.M. Hassan, A. Gazawi; (2011) "Investigations into the turning parameters effect on the surface roughness of flame hardened medium carbon steel with TiN-Al2O3-TiCN coated inserts based on Taguchi techniques", Word Academy of Science, Engineering and Technology, published online: pp 2137-2141.
[12] U. K. Yadav, D. Narang, P.S. Attri; (2012) "Experimental investigation and optimization of machining parameters for surface roughness in CNC turning by Taguchi method", International Journal of Engineering Research and Applications, Volume 2 Issue 4: pp 2060-2065.
[13] M. V. Ramana, A. V. Vishnu, G. K.M. Rao, D.H. Rao; (2012) "Experimental investigations, optimization of process parameters and mathematical modeling in turning of Titanium alloy under different lubricant conditions", Journal of Engineering, Volume 2 Issue 1: pp 86-101.
[14] K. Hassan, A. Kumar, M.P. Garg; (2012) "Experimental investigation of Material removal rate in CNC turning using Taguchi method", International Journal of Engineering Research and Applications, Volume 2 Issue 2: pp 1581-1590.

