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Cutting Parameters Optimization in Turning Operation using Taguchi Method

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Abstract

The objective of this study is to optimise the cutting parameters in Turning Operation. For this objective Taguchi Method was used. S/N ratio, ANNOVA was used to investigate the cutting force components & Material removal rate (MRR). In results optimal cutting parameters were obtained and the factors affecting cutting performance were analysed. It was concluded that cutting parameters i.e. depth of cut has influence on cutting force and material removal rate.

Keywords: Cutting Parameters, Taguchi Method, MRR, Turning Operations

1. Introduction

In cutting process, tribology plays an important role to evaluate the surface quality and product performance. Metal machining is an example of open type tribological system in which the body can be replaced by a tool, the counter body can be replaced by work material, and the interface material can be replaced by the lubricant used for cooling purposes in the machining. So it is necessary to monitor the tool tribology. The main reason for cutting tool failure is excessive forces and shocks. Gradual wear of the cutting tools, which causes failure of the flank surface and the rake surface of the tool, is also important [1-4].

2. Materials and Method

According to Taguchi, to optimize a process there is three major steps: system design, parameters design, and the tolerance design. Cutting speed, feed rate and depth of cut are taken as three cutting parameters and three levels of each parameter are taken which is shown in Table1.

Table 1 Parameters for study

Symbol	Cutting parameter	unit	Level1	Level2	Level3
V	Cutting speed	m/min	40	55	70
f	Feed rate	mm/rev.	.04	.06	.08
d	Depth of cut	mm	.5	.75	1.00

Taguchi design is created by using **MINITAB15** software. From the initial and final weight of work piece MRR is calculated by the relationship given below:

MRR= $(W_1-W_2)/t_m$ …………(1)

The experimental data and observations are shown with the help of Table 2

.Table 2. Experimental Data and Observations

Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)	MRR (g/sec)	Fx(N)	Fy(N)	Fz(N)
40	.04	.5	1.06	15.12	44.7	35.2
40	.06	.75	1.275	42.82	78.6	73.1
40	.08	1.0	1.5083	71.3	108.2	133.2
55	.04	.75	1.22	33.13	67.3	62.5
55	.06	1.0	1.407	61.33	90.4	104.7
55	.08	.5	1.288	17.06	52.48	48.1
70	.04	1.0	1.377	50.73	71.7	76.3
70	.06	.5	1.29	14.62	46.15	33.0
70	.08	.75	1.545	35.13	73.15	84.4

S/N ratio for each level of process parameters is calculated with the help of MINITAB15 software. An optimal level of the process parameters is the level with greatest S/N ratio. Using ANOVA analysis it was evaluated which parameter is statistically significant. Using S/N and ANOVA analyses the value of optimised process parameter can be evaluated [5-8].

S/N ratio is calculated using MINITAB15 software and by using standard equation MRR and cutting forces was also calculated .The values are shown in Table 3.

Table 3. S/N ratio calculated for MRR, Fx, Fy and Fz

Cutting speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)	S/N for MRR(dB)	S/N for Fx(dB)	S/N for Fy(dB)	S/N for Fz(dB)
40	.04	.5	.506	-23.591	-33.006	-30.9309
40	.06	.75	2.110	-32.632	-37.9228	-37.2783
40	.08	1.0	3.568	-37.061	-40.7326	-42.4901
55	.04	.75	1.727	-30.404	-36.5474	-35.9176
55	.06	1.0	2.965	-35.753	-39.1138	-40.3989
55	.08	.5	2.198	-24.639	-35.3534	-33.6429
70	.04	1.0	2.734	-34.105	-37.0861	-37.6505
70	.06	.5	2.211	-23.298	-33.298	-30.3703
70	.08	.75	3.778	-30.913	-37.3257	-38.5268

3. Analysis of variance (ANOVA)

The purpose of the analysis of variance (ANOVA) is to find which design parameters significantly affect the quality characteristic [9]. Result of Analysis of variance (ANOVA) at 5% level of significance for MRR, Fx, Fyand Fz is shown in Table 4.

Usually, when F>4, it means that change of design parameter has a significant effect on quality characteristic. If for all three cutting parameters F value is greater than 4 so, they are statistically significant and they have significant effect on quality characteristics. Contribution (%) is found by dividing sum of square of individual cutting parameter to the total sum of square. From Table 5. We conclude that contribution order of cutting parameters for MRR is Feed rate, Depth of cut and the cutting speed. For Fx we found that all three cutting parameters are statistically significant & they have a significant effect on quality characteristics & the contribution order of cutting parameters for (Fx) is depth of cut, cutting speed and feed rate. For Fy we found that all three cutting parameters are statistically significant & they have a significant effect on quality characteristics & the contribution order of cutting parameters for (Fy) is depth of cut, feed rate& cutting speed. For Fz we found that only two cutting parameters are statistically significant i.e. depth of cut & feed rate and they have a significant effect on quality characteristics but cutting speed is statistically insignificant.

Table 4. ANOVA for MRR, Fx, Fy and Fz

Symbol	Cutting parameter	Degree of freedom	Sum of square	Mean square	F	Contribution (%)
			ANOVA For MRR			
V	Cutting speed	2	.024	.012	12	13.6
f	Feed rate	2	.0797	.0398	39.8	44.8
d	Depth of cut	2	.0711	.0355	35.5	40.4
Error		2	.0020	.001		1.2
Total		8	.1768			100
			ANOVA For F_x			
V	Cutting speed	2	140.34	70.17	9.82	4.14
f	Feed rate	2	112.74	56.370	7.89	3.34
d	Depth of cut	2	3111.6	1555.83	217.9	92.1
Error		2	14.28	7.14		.42
Total		8	3378.96			100
			ANOVA For F_y			
V	Cutting speed	2	281.4	140.7	4.11	7.96
f	Feed rate	2	443.9	221.9	6.48	12.54
d	Depth of cut	2	2744.54	1372.27	40.08	77.56
Error		2	68.46	34.23		1.94
Total		8	3538.36			
			ANOVA For F_z			
V	Cutting speed	2	381.98	190.9	1.99	4.48
f	Feed rate	2	1419.6	709.8	7.46	16.6
d	Depth of cut	2	6532.4	3266.2	34.34	76.6
Error		2	190.22	95.11		2.32
Total		8	8524.20			100

In this research work each cutting parameter was studied at different levels. S/N ratio response table for MRR, Fx, Fy and Fz is shown in table 5

Table 5. S/N variation for MRR, Fx, Fy and Fz

Symbol	**Cutting parameters**	**Mean S/N ratio(dB)**		
S/N response **For MRR**				
		Level 1	Level 2	Level 3
V	(m/min)	2.06	2.29	2.90
f	(mm/rev.)	1.65	2.42	3.18
d	(mm)	1.638	2.538	3.089
		Total mean=2.41 dB		
S/N response **For Fx**				
V	(m/min)	-31.09	-30.2	-29.4
f	(mm/rev.)	-29.36	-30.561	-30.871
d	(mm)	-23.84	-31.31	-35.6
		Total mean=-30.26 dB		
S/N response **For Fy**				
V	(m/min)	-37.22	-37.004	-35.90
f	(mm/rev.)	-35.54	-36.77	-37.80
d	(mm)	-33.88	-37.26	-38.9775
		Total mean=-36.7dB		
S/N response **For Fz**				
V	(m/min)	-36.89	-36.65	-35.51
f	(mm/rev.)	-34.83	36.01	-38.21
d	(mm)	-31.64	-37.24	-40.17
		Total mean=-36.35dB		

4. Confirmation Tests

The estimated S/N ratio using the optimal cutting parameters for the MRR,Fx,Fy and Fz can then be obtained by using eqn.(4) and the corresponding MRR can also be obtained by using eqn. (1) and(2).For Fx,Fyand Fz eqn.(1) and(3) are used to find corresponding values of Fx,Fy and Fz. Results of confirmation tests with improvement in S/N ratios, increase in MRR& reduction in Fx,Fy and Fz are provided in Table 6.

Table 6 Results of confirmation test

	Initial cutting parameters	Optimal cutting parameters. Prediction	Optimal cutting parameters. Experiment
Result of Confirmation test For MRR			
Level MRR(g/sec) S/N ratio	v2f2d2 1.42 3.04	v3f3d3 1.65 4.356	v3f3d3 1.59 4.04
Improvement in S/N ratio= 1 dB& MRR increased by .17g/sec			
Result of Confirmation test For Fx			
Level Fx N S/N ratio(dB)	v2f2d2 64.2 -36.15	v3f1d1 12.17 -22.13	v3f1d1 15.3 -23.16
Improvement in S/N ratio= 12.99dB& reduction in Fx=48.9N			
Result of Confirmation test For Fy			
Level Fy N S/N ratio(dB)	v2f2d2 70.3 -36.9	v3f1d1 39.4 -31.92	v3f1d1 43.03 -32.6
Improvement in S/N ratio= **4.3dB& reduction in Fy=27.28N**			
Result of Confirmation test For Fz			
Level Fz N S/N ratio(dB)	v2f2d2 60.1 -35.57	v3f1d1 32.06 -30.12	v3f1d1 34.8 -30.83
Improvement in S/N ratio= 4.74dB& reduction in Fz=25.3N			

5. Main Effect Plot

The main effect plot for MRR, Fx, Fy and Fz is shown in Fig.1.From this Fig. it is concluded that MRR is increased by increasing cutting speed, feed rate and depth of cut. Fx appears to be a decreasing function of cutting speed and Fx is almost linear increasing function of depth of cut but feed has little effect on Fx. Fy appears to be a decreasing function of cutting speed and Fy is almost linear increasing function of depth of cut but feed rate has little effect on Fy. Fz appears to be a decreasing function of cutting speed and Fz is almost linear increasing function of depth of cut and feed.

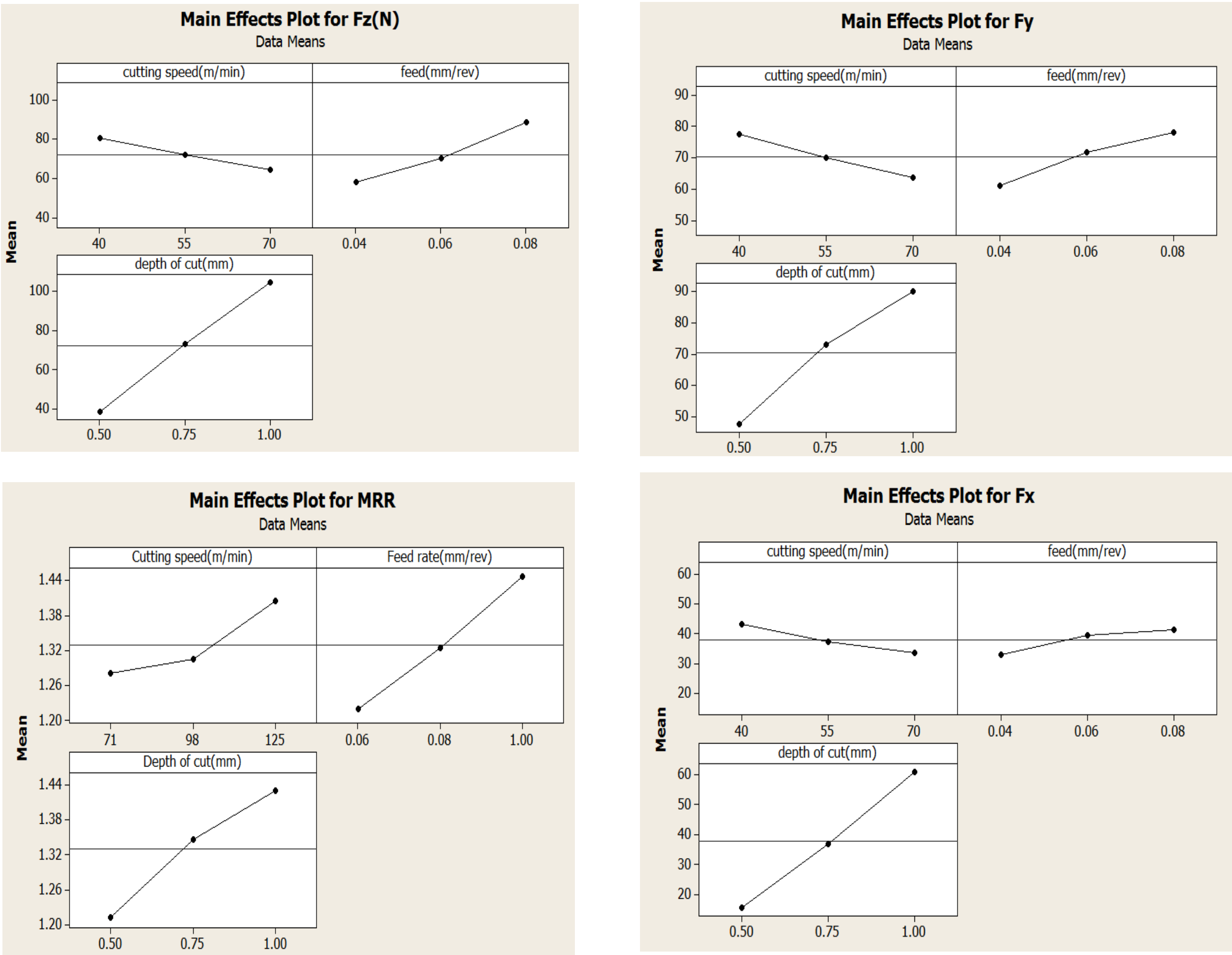

Figure 1: Main effect plot for MRR, Fx, Fy and Fz

6. Conclusion

Turning operation was performed on EN36B steel work billet with tungsten carbide tool. Following conclusion were drawn for material removal rate and cutting force components.

- The depth of cut influences cutting force and material removal rate in a considerable way. Its contribution on MRR is 40.4% and on Fx, Fy and Fz are 92.1, 77.56 and 76.6% respectively.
- Feed rate influences material removal rate in a significant manner but it has little effect on Fx, Fy & Fz.
- It was observed that MRR and cutting forces components can be improved significantly for turning operations.

Researchers have also used ANNOVA and other optimization techniques [10-14] for the study of vibration characteristics, fracture analysis [15-16] and in biomedical applications [17-19]. Latest computational tools FEA, RSM and Taguchi are useful in design and optimization.

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