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Optimization of Process Parameters to Minimize Surface Roughness and Maximize MRR in Turned Parts by Experimentation

Somarapu Shiva Chandan
M.Tech In Advanced Manufacturing Systems,
Ellenki College of Engineering and Technology,
JNTU, Hyderabad, Telangana, India.

Sri.G.Gopi Nath
Assistant Professor,
Ellenki College of Engineering and Technology,
JNTU, Hyderabad, Telangana, India.

ABSTRACT
In this thesis, turning process parameters are optimized while turning EN8 steel to attain maximize surface roughness and maximize Material Removal Rate. The cutting parameters are cutting speed, feed, depth of cut, coolant and cutting tool material for turning of work piece material EN8 steel. The respective values are Speed 600rpm, 1200rpm, Feed rate – 0.1mm/rev, 0.2mm/rev, Depth of cut – 2mm, 6mm, Coolant – Vegetable oil, Synthetic Oil and Cutting Tool material – HSS, Tungsten Carbide.12 experiments are conducted by considering the above parameters as per L12 Taguchi Technique. Surface finish and Material Removal rates are validated experimentally. The cutting parameters are optimized for better surface finish quality and high material removal rates. The optimization of machining parameters is done using Taguchi technique in Minitab software.

INTRODUCTION TO TURNING
Turning is a machining methodology at intervals that a cutter, typically a non-rotary tool bit, describes a helical tool path by moving plenty of or less linearly whereas the work rotates. The tool's axes of movement may well be virtually a line, or they could be on some set of curves or angles.

LITERATURE SURVEY
In the paper by L. B. Abhang [1], the temperature generated on the cutter and experimental strategies for the mensuration of temperatures are reviewed. Special attention has been paid to tool- work thermometer technique and an experimental setup made-up to live the temperature on the cutter and work piece junction throughout metal cutting is represented. In the paper by Karin Kandananond[3], the aim of this paper is to work out the optimum cutting conditions for surface roughness in a very turning method. This method is performed within the final assembly department at a producing company that provides fluid dynamic bearing (FDB) spindle motors for hard disc drives (HDDs). The work pieces used were the sleeves of FDB motors product of ferritic chrome steel, grade AISI 12L14. The optimized settings of key machining factors, depth of cut, spindle speed, and feed rate on the surface roughness of the sleeve were determined mistreatment the response surface methodology (RSM). The results indicate that the surface roughness is decreased once the depth of cut is about to the bottom level, whereas the spindle speed and feed rate are set to the best levels. Although the results from this paper ar method specific, the methodology deployed is promptly applied to completely different turning processes.

EXPERIMENTAL INVESTIGATION
The experiments are done on the CNC turning machine with the following parameters:

CUTTING TOOL MATERIAL – HSS and Tungsten Carbide
WORK PIECE MATERIAL – EN8 Steel
FEED RATE – 0.1mm/rev, 0.2mm/rev
CUTTING SPEED –600rpm, 1200rpm,
DEPTH OF CUT –2mm, 6mm
Sample Size – Length - 215mm, Dia – 32mm

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Turning process is conducted on the EN8 steel pieces of size 210 mm lengths and Ø32mm dia. The effect of different cutting tool materials HSS & Tungsten Carbide and different coolants Vegetable oil & Synthetic oil on the surface finish and MRR are investigated. And also the effect of cutting speeds 600rpm, 1200rpm, feeds 0.1mm, 0.2mm and depth of cut 2mm, 6mm are also investigated.

Factors Affecting the Surface Finish

Whenever two machined surfaces come in contact with one another the quality of the mating parts plays an important role in the performance and wear of the mating parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as:

A) The machining variables which include

a) cutting speed

b) feed, and

c) depth of cut.

B) The tool geometry

MATERIAL REMOVAL RATE (MRR)

In turning, MRR= π * D * d * f * N

D = Dia of workpiece (mm)

f = feed rate (mm/rev)

d = depth of cut (mm)

N = Cutting Speed (rpm)

Selection of process parameters as per Taguchi Technique

Factors	Units	Level 1	Level 2
Cutting speed, N	RPM	600	1200
Feed Rate, f	mm/rev	0.1	0.2
Depth of cut, d	mm	2	6
Cutting tool		HSS	Tungsten Carbide
Cutting Fluid		Synthetic oil	Vegetable oil

Table – Process Parameters as per Taguchi Technique

PARAMETERS USED FOR MACHINING

JOB NO.	Speed (rpm)	Feed Rate (mm/rev)	Depth of cut (mm)	Cutting Tool	Cutting Fluid
1	600	0.1	2	HSS	Synthetic
2	600	0.1	2	HSS	Synthetic
3	600	0.1	6	Tungstencarbide	Vegetable
4	600	0.2	2	Tungstencarbide	Vegetable
5	600	0.2	6	HSS	Vegetable
6	600	0.2	6	Tungstencarbide	Synthetic
7	1200	0.1	6	Tungstencarbide	Synthetic
8	1200	0.1	6	HSS	Vegetable
9	1200	0.1	2	Tungstencarbide	Vegetable
10	1200	0.2	6	HSS	Synthetic
11	1200	0.2	2	Tungstencarbide	Synthetic
12	1200	0.2	2	HSS	Vegetable

Table – Process Parameters taken for machining

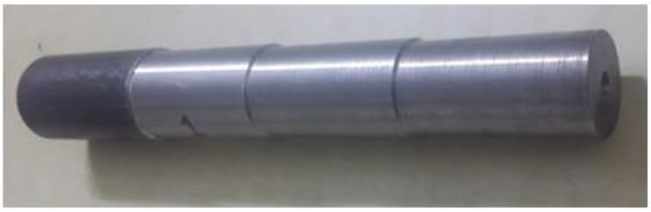

Fig – Final Turned Piece

OBSERVATION

The Surface Roughness values are measured for the machined pieces and the same are tabulated below:

SURFACE ROUGHNESS

JOB NO.	Speed (rpm)	Feed Rate (mm/rev)	Depth of cut (mm)	Cutting Tool	Cutting Fluid	Surface roughness (R_a) µm
1	600	0.1	2	HSS	Synthetic	3.72
2	600	0.1	2	HSS	Synthetic	3.72
3	600	0.1	6	Tungstencarbide	Vegetable	3.91
4	600	0.2	2	Tungstencarbide	Vegetable	2.88
5	600	0.2	6	HSS	Vegetable	3.59
6	600	0.2	6	Tungstencarbide	Synthetic	3.645
7	1200	0.1	6	Tungstencarbide	Synthetic	2.66
8	1200	0.1	6	HSS	Vegetable	2.92
9	1200	0.1	2	Tungstencarbide	Vegetable	2.43
10	1200	0.2	6	HSS	Synthetic	3.15
11	1200	0.2	2	Tungstencarbide	Synthetic	2.57
12	1200	0.2	2	HSS	Vegetable	2.61

Table – Measured Surface Roughness Values

MATERIAL REMOVAL RATE - MRR is calculated using the following formula

In turning, MRR= π * D * d * f * N

D = Dia of workpiece (mm)

f = feed rate (mm/rev)

d = depth of cut (mm)

N = Cutting Speed (rpm)

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JOB NO.	Speed (rpm)	Feed Rate (mm/rev)	Depth of cut (mm)	Cutting Tool	Cutting Fluid	Material Removal Rate (mm^3/sec)
1	600	0.1	2	HSS	Synthetic	200.96
2	600	0.1	2	HSS	Synthetic	200.96
3	600	0.1	6	Tungstencarbide	Vegetable	602.88
4	600	0.2	2	Tungstencarbide	Vegetable	401.92
5	600	0.2	6	HSS	Vegetable	1205.76
6	600	0.2	6	Tungstencarbide	Synthetic	1214.12
7	1200	0.1	6	Tungstencarbide	Synthetic	1217.55
8	1200	0.1	6	HSS	Vegetable	1205.76
9	1200	0.1	2	Tungstencarbide	Vegetable	401.92
10	1200	0.2	6	HSS	Synthetic	2411.52
11	1200	0.2	2	Tungstencarbide	Synthetic	803.84
12	1200	0.2	2	HSS	Vegetable	801.16

Table – Measured Material Removal Rate Values

OPTIMIZATION OF MACHINING PARAMETERS USING MINITAB SOFTWARE LESSER SURFACE ROUGHNESS

In this project, Taguchi method is used to optimize the process parameters Speed, Feed rate, Depth of cut, Cutting tool and Cutting fluid for lesser surface roughness values. The optimization is done in Minitab 17 software.

2-Level Design and No. of factors - 5
Select Display Available Designs
Select DesignL12 (2*5)
Options – Smaller is better

Results Table

Worksheet 1 ***

↓	C1	C2	C3	C4-T	C5-T	C6	C7
	Speed (rpm)	Feed Rate (mm/rev)	DOC (mm)	Cutting Tool	Coolant	Surface Roughness	SNRA1
1	600	0.1	2	HSS	Synthetic	3.720	-11.4109
2	600	0.1	2	HSS	Synthetic	3.720	*
3	600	0.1	6	Tungstencarbide	Vegetable	3.910	-11.8435
4	600	0.2	2	Tungstencarbide	Vegetable	2.880	-9.1878
5	600	0.2	6	HSS	Vegetable	3.590	-11.1019
6	600	0.2	6	Tungstencarbide	Synthetic	3.645	-11.2340
7	1200	0.1	6	Tungstencarbide	Synthetic	2.660	-8.4976
8	1200	0.1	6	HSS	Vegetable	2.920	-9.3077
9	1200	0.1	2	Tungstencarbide	Vegetable	2.430	-7.7121
10	1200	0.2	6	HSS	Synthetic	3.150	-9.9662
11	1200	0.2	2	Tungstencarbide	Synthetic	2.570	-8.1987
12	1200	0.2	2	HSS	Vegetable	2.610	-8.3328

Table – Calculated Signal to Noise Ratios for Smaller is better

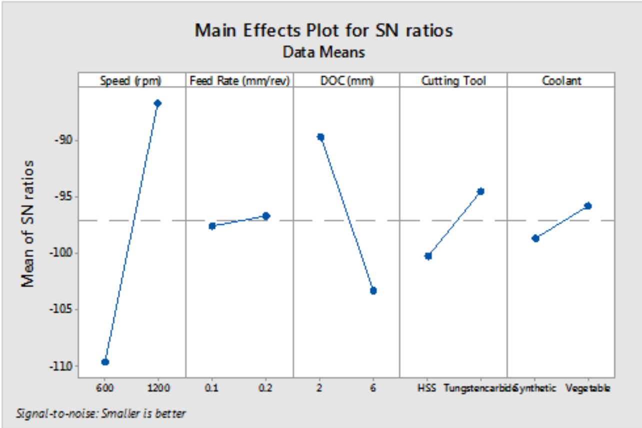

Fig - Effect of machining parameters on Surface Roughness for S/N ratio for Smaller is better

RESULTS

Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The Surface Roughness is considered as the quality characteristic with the concept of "the smaller-the-better".

Analysis and Discussion

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Speed: The effect of parameter Speed on Surface Roughness is shown above figure S/N ratio. So the optimum Speed is 1200rpm.

Feed Rate: The effect of parameter feed rate on Surface Roughness is shown above figure S/N ratio. So the optimum feed rate is 0.2mm/rev.

Depth of cut: The effect of parameter Depth of cut on Surface Roughness is shown above figure S/N ratio. So the optimum Depth of cut is 2mm.

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Cutting Tool: The effect of parameter cutting tool on Surface Roughness is shown above figure S/N ratio. So the optimum cutting tool is Tungsten Carbide.

Coolant: The effect of parameter Coolant on Surface Roughness is shown above figure S/N ratio. So the optimum Coolant is Vegetable oil.

HIGHER MRR

Options – Larger is better

Results Table

Worksheet 1 ***

↓	C1	C2	C3	C4-T	C5-T	C6	C7
	Speed (rpm)	Feed Rate (mm/rev)	DOC (mm)	Cutting Tool	Coolant	MRR	SNRA2
1	600	0.1	2	HSS	Synthetic	200.96	46.0622
2	600	0.1	2	HSS	Synthetic	200.96	*
3	600	0.1	6	Tungstencarbide	Vegetable	602.88	55.6046
4	600	0.2	2	Tungstencarbide	Vegetable	401.92	52.0828
5	600	0.2	6	HSS	Vegetable	1205.76	61.6252
6	600	0.2	6	Tungstencarbide	Synthetic	1214.12	61.6852
7	1200	0.1	6	Tungstencarbide	Synthetic	1217.55	61.7097
8	1200	0.1	6	HSS	Vegetable	1205.76	61.6252
9	1200	0.1	2	Tungstencarbide	Vegetable	401.92	52.0828
10	1200	0.2	6	HSS	Synthetic	2411.52	67.6458
11	1200	0.2	2	Tungstencarbide	Synthetic	803.84	58.1034
12	1200	0.2	2	HSS	Vegetable	801.16	58.0744

Table – Calculated Signal to Noise Ratios for Larger is better

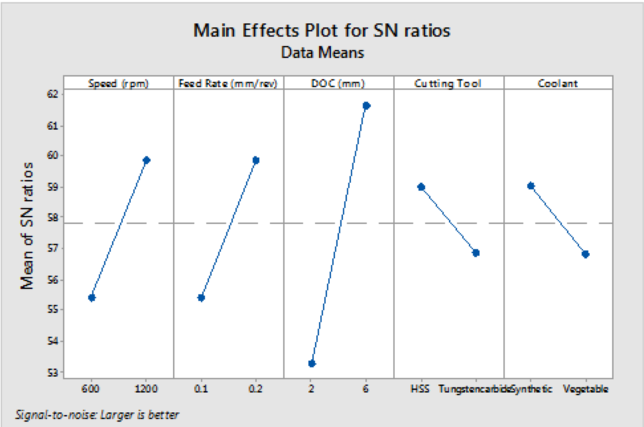

Fig - Effect of machining parameters on MRR for S/N ratio for Larger is better

Analysis and Discussion

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Speed: The effect of parameter Speed on MRR is shown above figure S/N ratio. So the optimum Speed is 1200rpm.

Feed Rate: The effect of parameter feed rate on MRR is shown above figure S/N ratio. So the optimum feed rate is 0.2mm/rev.

Depth of cut: The effect of parameter Depth of cut on MRR is shown above figure S/N ratio. So the optimum Depth of cut is 6mm.

Cutting Tool: The effect of parameter cutting tool on MRR is shown above figure S/N ratio. So the optimum cutting tool is HSS.

Cutting Fluid: The effect of parameter cutting Fluid on MRR is shown above figure S/N ratio. So the optimum cutting fluid is Synthetic.

CONCLUSION

By observing the experimental results the following conclusions can be made:

The main parameters that affect the surface roughness are Speed, Depth of cut and cutting tool. For minimum surface roughness values, the optimum parameters are Speed - 1200rpm, feed rate – 0.2mm/rev, Depth of cut - 2mm, cutting tool – Tungsten Carbideand Coolant – Vegetable oil. The main parameters that affect the Material Removal Rate are Depth of cut, Speed and Feed Rate. For maximum MRR values, the optimum parameters are Speed - 1200rpm, feed rate - 0.2mm/rev, Depth of cut –6mm, cutting tool – HSSand Coolant – Synthetic oil.

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