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Calculating Surface Roughness Values with Different Parameters by Turning Process Using Taguchi Method

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Abstract

Turning process is one of the most fundamental machining processes used in the manufacturing industry. The process of turning is influenced by many factors such as cutting velocity, feed rate, depth of cut, geometry of cutting tool, and cutting conditions etc., to name a few. In machining operations, achieving the desired surface quality of the machined product is really a challenging job.

This is due to the fact that quality is highly influenced by process parameters directly or indirectly.The present experimental study is concerned with the optimization of cutting parameters in wet turning of EN31 steel. In the present work, turning operations were carried out on EN31 steel by carbide P-30 cutting tool in wet condition and the combination of the optimal levels of the parameters was obtained by using the Taguchi optimization method.

The Analysis of Variance (ANOVA) and Signal-to-Noise ratio were used to study the performance characteristics in turning operation. The results obtained by this research will be useful to other similar type of study and can be helpful for further research on tool vibrations, cutting forces etc.

INTRODUCTION

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters.

Chucking the work piece

We will be working with a piece of 3/4" diameter 6061 aluminum about 2 inches long. A work piece such as this which is relatively short compared to its diameter is stiff enough that we can safely turn it in the three jaw chuck without supporting the free end of the work. For longer work pieces we would need to face and center drill the free end and use a dead or live center in the tailstock to support it. Without such support, the force of the tool on the work piece would cause it to bend away from the tool, producing a strangely shaped result. There is also the potential that the work could be forced to loosen in the chuck jaws and fly out as a dangerous projectile.

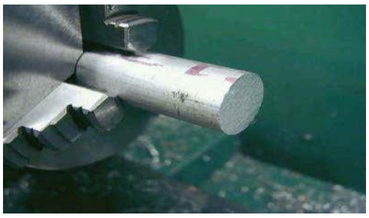

Fig 1: fixing of work piece

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Adjusting the Tool Bit

Choose a tool bit with a slightly rounded tip, like the one described above in the tool grinding section. This type of tool should produce a nice smooth finish. For more aggressive cutting, if you need to remove a lot of metal, you might choose a tool with a sharper tip. Make sure that the tool is tightly clamped in the tool holder.

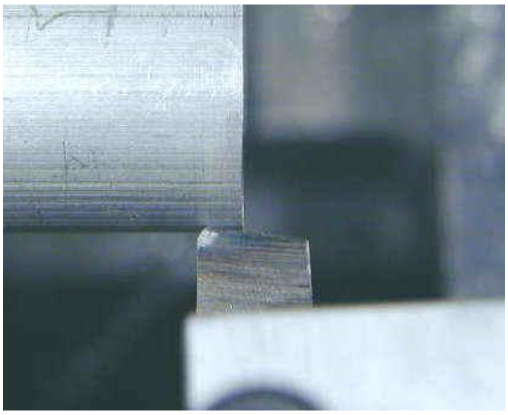

Fig 2: fixing of tool bit

Turning With Power Feed

One of the great features of the 7x10 is that it has a power lead screw driven by an adjustable gear train. The lead screw can be engaged to move the carriage under power for turning and threading operations.

Turning with power feed will produce a much smoother and more even finish than is generally achievable by hand feeding. Power feed is also a lot more convenient than hand cranking when you are making multiple passes along a relatively long work piece.

Fig 3:turning with power feed

Most of time, a turning operation is used to reduce the work piece to a specified diameter. It is important to recognize that, in a turning operation, each cutting pass removes twice the amount of metal indicated by the cross slide feed divisions. This is because you are reducing the radius of the work piece by the indicated amount, which reduces the diameter by twice that amount. Therefore, when advancing the cross slide by .010", the diameter is reduced by .020".

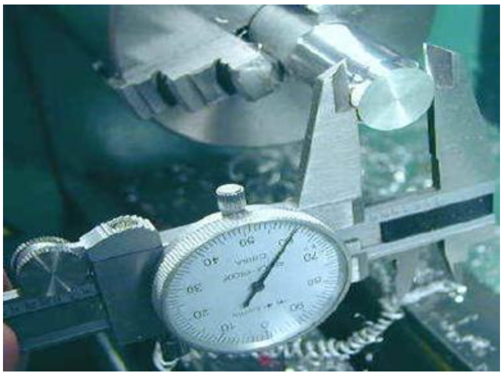

Fig4:measuring of diameter

A shoulder is a point at which the diameter of the work piece changes with no taper from one diameter to the other. In other words, there is a 90 degree face moving from one diameter to the other as you can see in the next photograph.

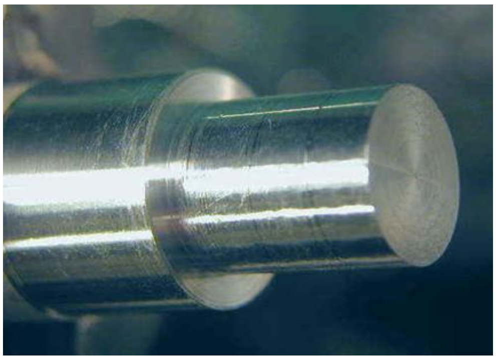

Fig 5:turning a shoulder

To get a nice square face on the shoulder you will need to make a facing cut. This works best if you have made a carriage lock on your lathe. Lock the carriage and clean up the face of the shoulder until it is square. If you use the sharp pointed tool you will need to use fairly high RPM, say 1500, and advance the tool

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slowly or you will get little grooves from the pointed tip instead of a nice smooth finish.

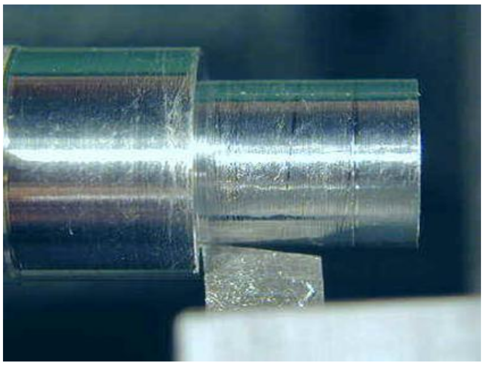

Fig 6: pointed tool to work piece

EN 31 work tool steel

Physical Properties	Metric
Density	7.81 g/cc
Mechanical Properties	**Metric**
Hardness, Brinell	290 - 341
Tensile Strength, Ultimate	1010 MPa
Tensile Strength, Yield	800 MPa
Modulus of Elasticity	205 GPa
Compressive Yield Strength	850 - 1000 MPa
Chirpy Impact	5.02 - 10.0 J
Thermal Properties	**Metric**
CTE, linear	12.6 µm/m-°C
Specific Heat Capacity	0.460 J/g-°C
Thermal Conductivity	29.0 W/m-K
Component Elements Properties	**Metric**
Carbon, C	0.370 %
Chromium, Cr	2.0 %
Manganese, Mn	1.40 %
Molybdenum, Mo	0.20 %
Nickel, Ni	1.0 %
Silicon, Si	0.30 %
Sulfur, S	<= 0.010 %

Cutting tool material - cemented carbide

Physical Properties	Metric
Density	14.95 g/cc
Mechanical Properties	**Metric**
Hardness, Rockwell A	91.9
Hardness, Vickers	1575
Rupture Strength	2200 MPa
Compressive Strength	6200 MPa
Component Elements Properties	**Metric**
Cobalt, Co	6.0 %
WC	94 %

EXPERIMENTAL INVESTIGATION

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

Cutting Tool Material –cemented Carbide Tool
Work Piece Material – EN 31Tool Steel
Feed – 200mm/min, 250mm/min, 300mm/min
Cutting Speed – 600rpm, 1200rpm, 1800rpm,
Depth of Cut – 0.4mm, 0.5mm, 0.6mm

Fig 7: CNC turning machine

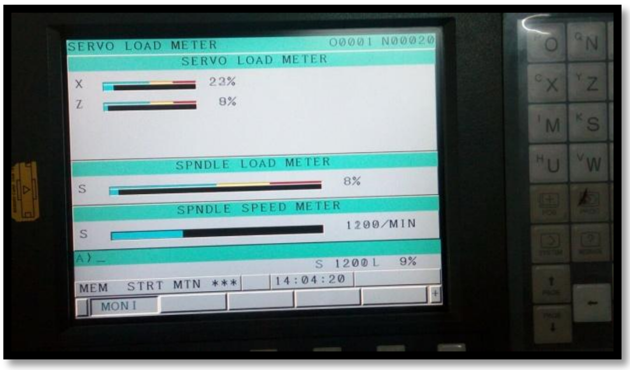

Fig 8:machine specification

Fig 9:operation process

Fig 10:step turning operation

Fig 11:final work piece job-1

Fig 12:final work pieces

PROCESS PARAMETERS	LEVEL1	LEVEL2	LEVEL3
CUTTING SPEED(rpm)	600	1200	1800
FEED RATE (mm/rev)	200	250	300
DEPTH OF CUT(mm)	0.4	0.5	0.6

JOB NO	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)
1	600	200	0.4
1	600	250	0.5
1	600	300	0.6
2	1200	200	0.4
2	1200	250	0.5
2	1200	300	0.6
3	1800	200	0.4
3	1800	250	0.5
3	1800	300	0.6

SURFACE FINISH

JOB NO	SPINDLE SPEEDrpm	FEED RATE (mm/min)	DEPTH OF CUT (mm)	Surface finish (R_a)
1	600	200	0.4	0.62
1	600	250	0.5	0.78
1	600	300	0.6	0.91
2	1200	200	0.4	1.21
2	1200	250	0.5	1.46
2	1200	300	0.6	1.94
3	1800	200	0.4	2.41
3	1800	250	0.5	2.84
3	1800	300	0.6	3.12

STRUCTURAL ANALYSIS

FORCE (N)	Total deformation(mm)	Stress (N/mm^2)	Strain
1150	0.0004346	6.23	3.01e-05
992	0.0003749	5.78	2.90e-05
688	0.0002600	4.00	2.01e-05
550	0.00020787	3.20	1.608e-05
375	0.00014173	2.18	1.096e-05
270	0.00010205	1.57	7.89e-06
465	0.00017515	2.70	1.35e-05
297	0.00011225	1.73	1.42e-05
206	7.785e-5	1.20	6.0235e-06

TAGUCHI PARAMETER DESIGN FOR TURNING PROCESS

In order to identify the process parameters affecting the selected machine quality characteristics of turning, the following process parameters are selected for the

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present work: cutting speed (A), feed rate (B) and depth of cut (C). The selection of parameters of interest and their ranges is based on literature review and some preliminary experiments conducted.

Selection of Orthogonal Array

The process parameters and their values are given in table. It was also decided to study the two – factor interaction effects of process parameters on the selected characteristics while turning. These interactions were considered between cutting speed and feed rate (AXB), feed rate andusing randomization technique, specimen was turned and cutting forces were measured with the three – dimensional dynamometer. The experimental data for the cutting forces have been reported in Tables. Feed and radial forces being 'lower the better' type of machining quality characteristics, the S/N ratio for this type of response was and is given below:

$$S/N\ ratio = -10\log\left[\frac{1}{n}(y_1^2 + y_2^2 + \ldots + y_n^2)\right] \qquad \ldots (1)$$

Where $y_1, y_2, \ldots, y_n$ are the responses of the machining characteristics for each parameter at different levels.

FACTORS	PROCESS PARAMETERS	LE VEL1	LEVEL2	LEVEL3
A	CUTTING SPEED(rpm)	600	1200	1800
B	FEED RATE (mm/rev)	200	250	300
C	DEPTH OF CUT(mm)	0.4	0.5	0.6

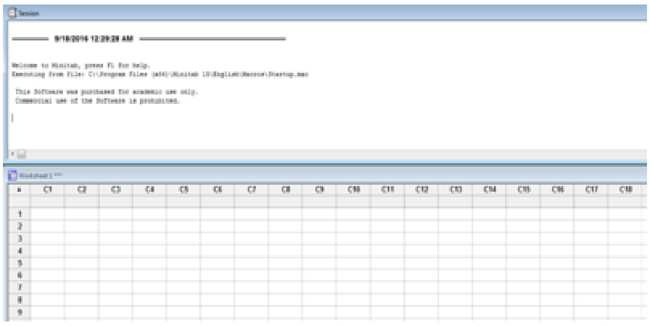
TAGUCHI ORTHOGONAL ARRAY

JOB NO	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)
1	600	200	0.4
2	600	250	0.5
3	600	300	0.6
4	1200	200	0.4
5	1200	250	0.5
6	1200	300	0.6
7	1800	200	0.4
8	1800	250	0.5
9	1800	300	0.6

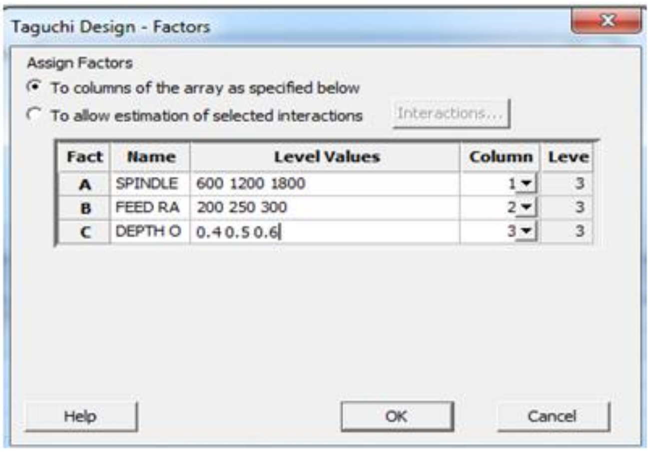
OPTIMIZATION OF SURFACE FINISH USING MINITAB SOFTWARE

Design of Orthogonal Array

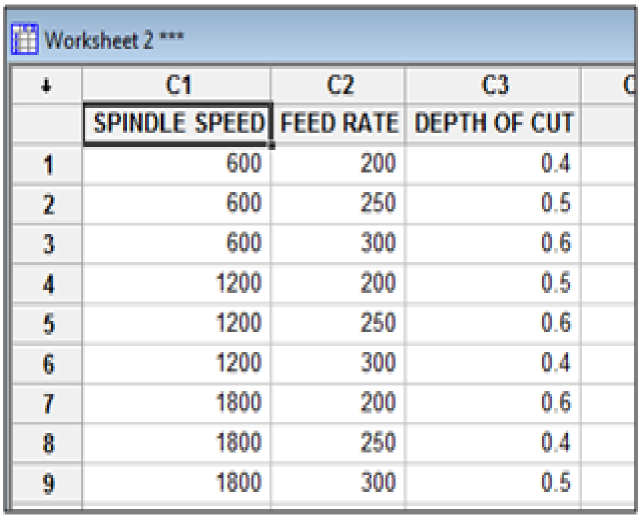
First Taguchi Orthogonal Array is designed in Minitab15 to calculate S/N ratio and Means which steps is given below:



Factors



Optimization of Parameters



Worksheet 2 ***

↓	C1	C2	C3
	SPINDLE SPEED	FEED RATE	DEPTH OF CUT
1	600	200	0.4
2	600	250	0.5
3	600	300	0.6
4	1200	200	0.5
5	1200	250	0.6
6	1200	300	0.4
7	1800	200	0.6
8	1800	250	0.4
9	1800	300	0.5

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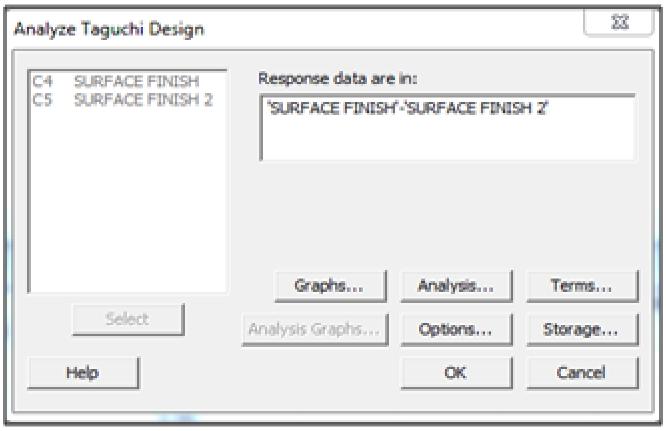
Worksheet 1 ***

↓	C1	C2	C3	C4	C5
	SPINDLE SPEED	FEED RATE	DEPTH OF CUT	SURFACE FINISH	SURFACE FINISH 2
1	600	200	0.4	0.62	0.70
2	600	250	0.5	0.78	0.85
3	600	300	0.6	0.91	0.99
4	1200	200	0.5	1.21	1.30
5	1200	250	0.6	1.46	1.55
6	1200	300	0.4	1.94	2.10
7	1800	200	0.6	2.41	2.50
8	1800	250	0.4	2.84	2.93
9	1800	300	0.5	3.12	3.20

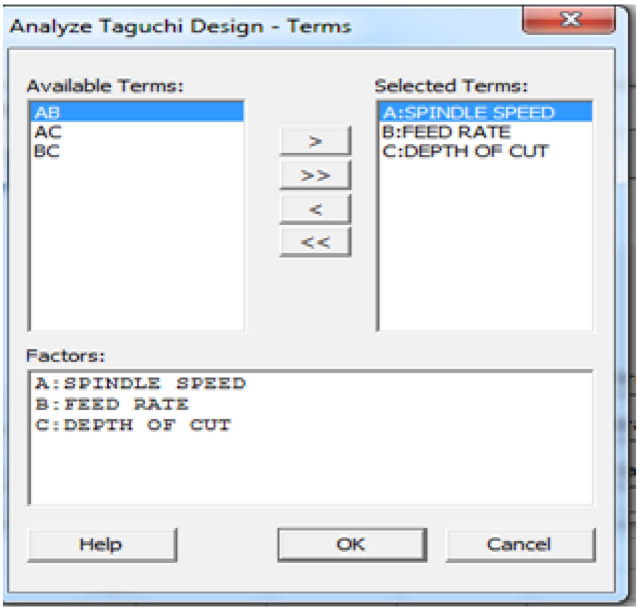
Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7
	SPINDLE SPEED	FEED RATE	DEPTH OF CUT	SURFACE FINISH	SURFACE FINISH 2	SNRA1	MEAN1
1	600	200	0.4	0.62	0.70	-3.65701	0.660
2	600	250	0.5	0.78	0.85	-1.80088	0.815
3	600	300	0.6	0.91	0.99	-0.46863	0.950
4	1200	200	0.5	1.21	1.30	1.96612	1.255
5	1200	250	0.6	1.46	1.55	3.53908	1.505
6	1200	300	0.4	1.94	2.10	6.08659	2.020
7	1800	200	0.6	2.41	2.50	7.79665	2.455
8	1800	250	0.4	2.84	2.93	9.19975	2.885
9	1800	300	0.5	3.12	3.20	9.99165	3.160

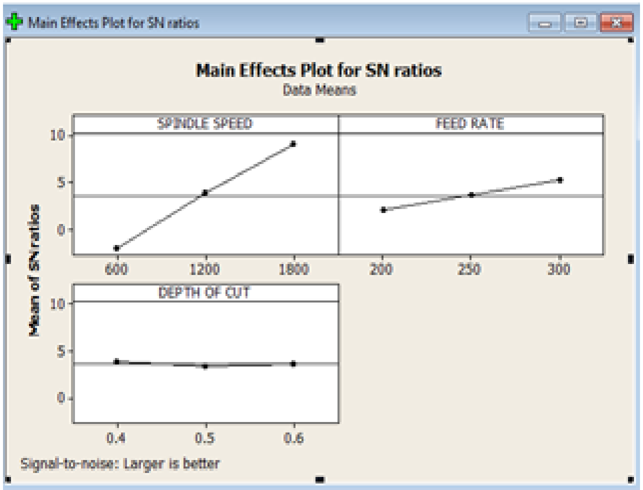
Analyze Taguchi Design – Select Responses



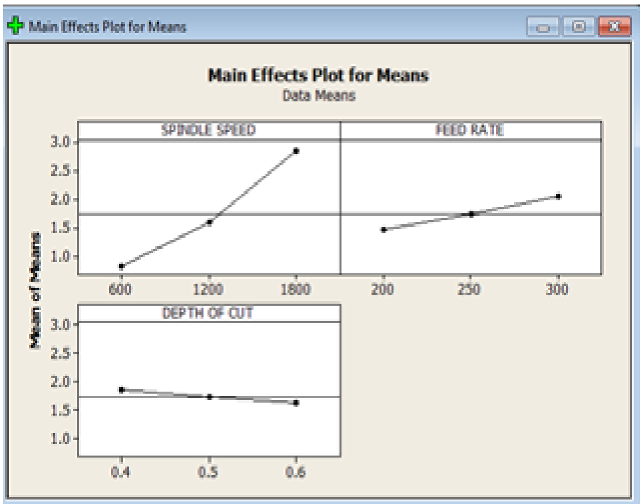
Terms



Effect of turning parameters on force for S/N ratio



Effect of turning parameters on force for Means



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SUMMARY

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 cutting force is considered as the quality characteristic with the concept of "the smaller-the-better". The S/N ratio for the smaller-the-better is:

$$S/N = -10 * \log(\Sigma(Y^2)/n))$$

Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration above Eqn. with the help of software Minitab 17.

The force values measured from the experiments and their corresponding S/N ratio values are listed in Table

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6	C7
	SPINDLE SPEED	FEED RATE	DEPTH OF CUT	SURFACE FINISH	SURFACE FINISH 2	SNRA1	MEAN1
1	600	200	0.4	0.62	0.70	-3.65701	0.660
2	600	250	0.5	0.78	0.85	-1.80088	0.815
3	600	300	0.6	0.91	0.99	-0.46863	0.950
4	1200	200	0.5	1.21	1.30	1.95612	1.255
5	1200	250	0.6	1.46	1.55	3.53908	1.505
6	1200	300	0.4	1.94	2.10	6.08659	2.020
7	1800	200	0.6	2.41	2.50	7.79665	2.455
8	1800	250	0.4	2.84	2.93	9.19975	2.885
9	1800	300	0.5	3.12	3.20	9.99165	3.160

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.

Spindle Speed:-The effect of parameters spindle speed on the surface finish is shown above figure for S/N ratio. So the optimum spindle speed is 1800 rpm.

Feed Rate:-The effect of parameters feed rate on the surface finish is shown above figure S/N ratio. So the optimum feed rate 250 mm/min.

Depth of Cut:-The effect of parameters depth of cut on the surface finish is shown above figure for S/N ratio. So the optimum depth of cut is 0.6mm.

CONCLUSION

In this thesis an attempt to make use of Taguchi optimization technique to optimize cutting parameters during high speed turning of EN 31 tool steel using cemented carbide cutting tool.

The cutting parameters are cutting speed, feed rate and depth of cut for turning of work piece EN 31 tool steel. In this work, the optimal parameters of cutting speed are 600rpm, 1200rpm and 1800rpm, feed rate are 200mm/min, 250mm/min and 300mm/min and depth of cut are 0.4mm, 0.5mm and 0.6mm. Experimental work is conducted by considering the above parameters. Cutting forces, surface finish and cutting temperatures are validated experimentally.
By observing the experimental results and by taguchi, the following conclusions can be made:

- To minimize the cutting forces, the optimal parameters are spindle speed – 600rpm, feed rate – 200mm/min and depth of cut – 0.4mm.
- To get better surface finish, the optimal parameters are spindle speed – 1800rpm, feed rate – 300mm/min and depth of cut – 0.6mm.
- To maximize material removal rate, the optimal parameters are spindle speed – 600rpm, feed rate – 200mm/min and depth of cut – 0.6mm.
- The effects of these parameters on the cutting forces are calculated using theoretical calculations and using the forces stresses and displacements are analyzed using Ansys. 3D modeling is done in Pro/Engineer.

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