Enhancement of Cutting Tool Performance in Cnc Turning through Innovative Designs

B Saikumar, Dr. N. Jeevan Kumaar

M. Tech Scholar Department Of Mechanical Engineering

Hod& Professor, Mechanical Engineering Department

Holy Mary Institute Of Technology And Science

Abstract: The imperative objective of the science of metal cutting is the solution of practical problems associated with the efficient and precise removal of metal from work piece. It has been recognized that the reliable quantitative predictions of the various technological performance measures, preferably in the form of equations, are essential to develop optimization strategies for selecting cutting conditions in process planning. This paper summarizes an experimental study on the vibration damping based process strategies of surface finish enhancement presented in CNC milling operations. The paper considers the relation of surface finish to manufacturing industries in general and vibration as a factor that most influences quality of machined surfaces. The experimental and numerical analysis presented in this work provides an evaluation of various passive/active damping strategies to control vibrations during milling operations. The success of these methods is judged on their ability to decrease chatter, increase stability and ultimately deliver the surface quality demanded by my customer. The results of the study provide important resources for machining engineers in Academia and Industry, to improve surface finish by optimizing CNC milling processes. In this thesis experiments will be conducted to improve the surface finish quality of aluminum alloy work piece by using carbide tips. The type is bull nose tip. A series of experiments will be done by varying the milling parameters spindle speed, feed rate and depth of cut. The spindle speeds are 3500rpm, 3000rpm and 2000rpm. The feed rates are 200mm/min, 300mm/min and 400mm/min. Depth of cut is 0.2mm and 0.3mm and 0.4mm. Taguchi method is used to study the effect of process parameters and establish correlation among the cutting speed, feed and depth of cut with respect to the major machinability factor, surface finish. Validations of the modeled equations are proved to be well within the agreement with the experimental data.

Key words: Turning process, vibration damping technique

1. Introduction

1.1 Turning

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.

1.2 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.

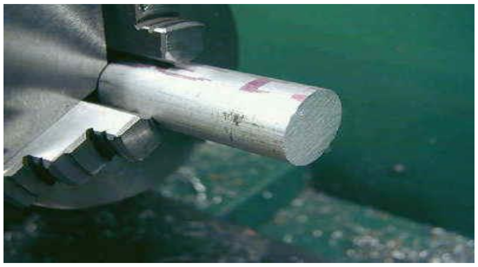


Fig 1.1 chucking the work piece

1.3 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. Adjust the angle of the tool holder so the tool is approximately because the front edge of the tool is ground at an angle, the left side of the tip should engage the work, but not the entire front edge of the tool. The angle of the compound is not critical; I usually keep mine at 90 degrees so that the compound dial advances the work .001" per division towards the chuck.

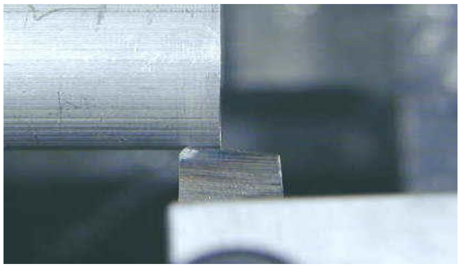


Fig 1.2 Adjusting the Tool Bit

1.4 Cutting Speeds

If you read many books on machining you will find a lot of information about the correct cutting speed for the movement of the cutting tool in relation to the work piece you must consider the rotational speed of the work piece and the movement of the tool relative to the work piece. Basically, the softer the metal the faster the cutting don't worry too much about determining the correct cutting speed: working with the 7x10 for hobby purposes, you will quickly develop a feel for how fast you should go.

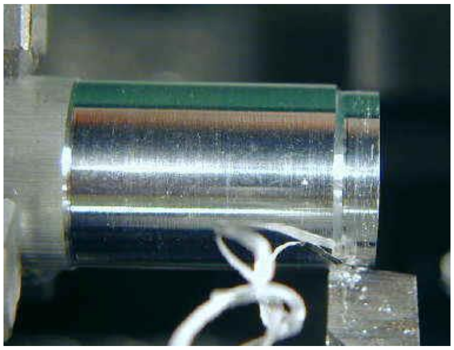


Fig 1.3 cutting speeds

1.5 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 1.4 Turning with Power Feed

1.6 Measuring the Diameter

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".

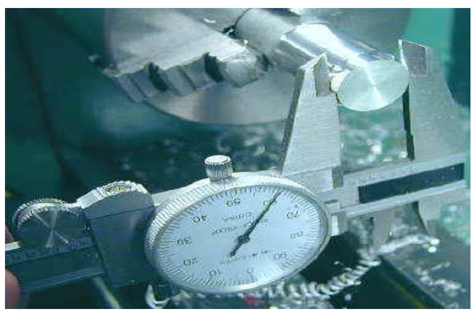


Fig 1.5 Measuring the Diameter

1.7 Introduction to en 31 work tool steel

Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools. Their suitability comes from their distinctive hardness, resistance to abrasion, their ability to hold a cutting edge, and/or their resistance to deformation at elevated temperatures (red-hardness). Tool steel is generally used in a heat-treated state. With carbon content between 0.7% and 1.5%, tool steels are manufactured under carefully controlled conditions to produce the required quality. The manganese content is often kept low to minimize the possibility of cracking during water quenching. However, proper heat treating of these steels is important for adequate performance, and there are many suppliers who provide tooling blanks intended for oil quenching.

2. Related study

The aim of this research was to optimize the turning process of the FDB sleeve in HDDs. The effects of the depth of cut, spindle speed, and feed rate on surface roughness were quantified using the Box-Menken design, which is one of the most commonly used RSM techniques. The ANOVA results demonstrate that the feed rate is the most significant factor that affects the response variable. The graphical method was also employed to indicate the range of the controllable factors at which the minimization of surface roughness is achieved. Moreover, the second-order response surface model for the surface roughness was derived, and it indicates that the depth of cut provides the quadratic effect. With model validation, the quadratic model developed proved to be accurate and has the capability to predict the value of the response within the limits of the factors investigated. After the model was implemented to improve the cutting conditions, the surface roughness was significantly reduced by about 13%.

3. Methodology

Companies use Pro/ENGINEER to create a complete 3D digital model of their products. The models consist of 2D and 3D solid model data which can also be used downstream in finite element analysis, rapid prototyping, tooling design, and CNC manufacturing. All data is associative and interchangeable between the CAD, CAE and CAM modules without conversion. A product and its entire bill of materials (BOM) can be modelled accurately with fully associative engineering drawings, and revision control information.

3.1 Modules in pro/engineer

- Part design
- Assembly
- Drawing
- Sheet metal
- Manufacturing

3.2 3D models

3.2.1 Cutting tool

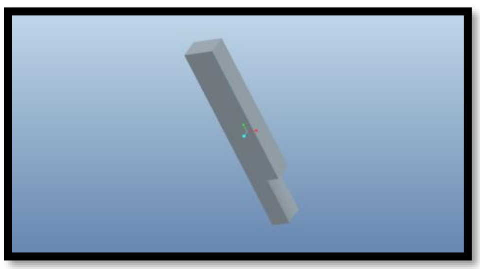


Fig 3.1 cutting tool

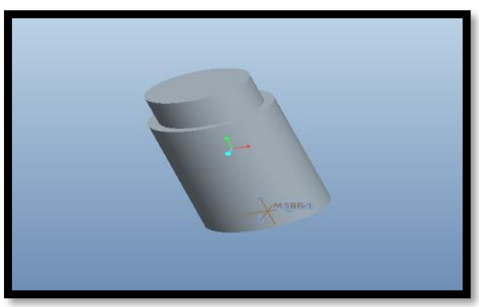


Fig 3.2 Work piece

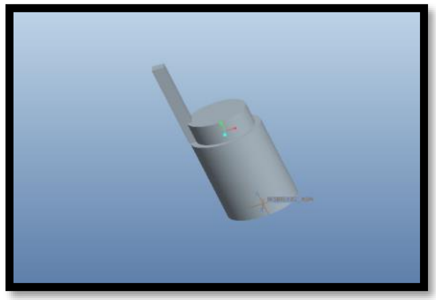


Fig 3.3 assembly

3.3 CUTTING FORCE CALCULATIONS

SPEED – 1800rpm

Feed = 200mm/min, Depth of cut – 0.4mm

Cutting Force

Ne = (Depth X Feed X Cutting Speed X Ks) / (60 X 10^3 X Coefficient of Efficiency)

Ne = 4.65KW

Ks = (Ne X 60 X 10^3 X Coefficient of Efficiency)/ (Depth of cut X Feed X Cutting Speed)

Coefficient of Efficiency = 0.8

Ks = **(**4.65×60 X 10^3 X0.8)/ (0.4X200 X1800)

Ks=1150N

Feed = 250mm/min, Depth of cut – 0.5mm

Ks = **(**4.65×60 X 10^3 X0.8)/ (0.5X250 X1800)

Ks=992N

Feed = 300mm/min, Depth of cut – 0.6 mm

Ks = **(**4.65×60 X 10^3 X0.8)/(0.6X300 X1800)

Ks=688N

2. SPEED – 1200rpm

Feed = 200mm/min, Depth of Cut – 0.4mm

Cutting Force

Ne = (Depth X Feed X Cutting Speed X Ks) / (60 X 10^3 X Coefficient of Efficiency)

Ne = 4.65KW

Ks = (Ne X 60 X 10^3 X Coefficient of Efficiency)/ (Depth X Feed X Cutting Speed)

Coefficient of Efficiency = 0.8

Ks = **(**4.65×60 X 10^3 X0.8)/ (0.4X200 X1200)

Ks=550N

Feed = 250mm/min, Depth of cut – 0.5mm

Ks = **(**$4.65\times60 \text{ X } 10^3$ X0.8)/ (0.5X250 X1200)

Ks=375N

Feed = 300mm/min, Depth of cut – 0.6mm

Ks = **(**$4.65\times60 \text{ X } 10^3$ X0.8)/(0.6X300 X1200)

Ks=270N

3. SPEED – 600rpm

Feed = 200mm/min, Depth of cut – 0.4mm

Ks = **(**$4.65\times60 \text{ X } 10^3$ X0.8)/(0.4X200X600)

Ks=465.2N

Feed = 250mm/min, Depth of cut – 0.5mm

Ks = **(**$4.65\times60 \text{ X } 10^3$ X0.8)/(0.5X250 X600)

Ks=297.6N

Feed = 200mm/min, Depth of cut – 0.6mm

Ks = **(**$4.65\times60 \text{ X } 10^3$ X0.8)/(0.6X200 X600)

Ks=200.1N

3.4 Structural analysis

FORCE -1150N

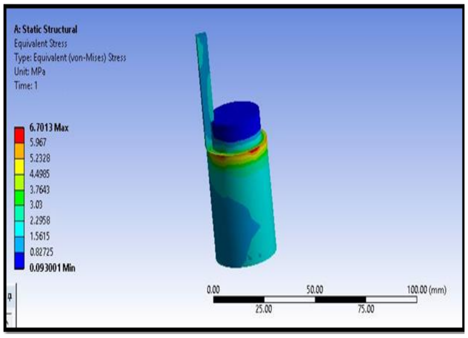


Fig 3.4 total deformation

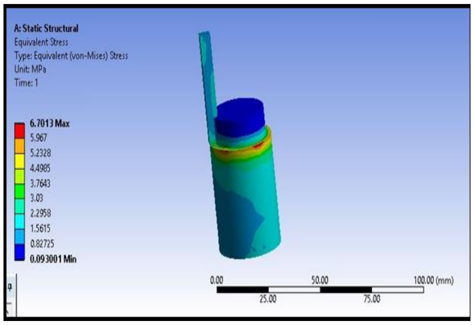


Fig 3.5 stress

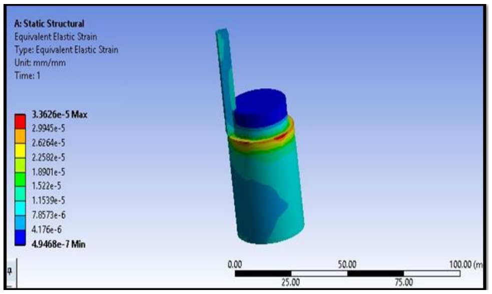


Fig 3.6 strain

3.5 Introductions to cutting forces and surface finish

Knowing the magnitude of the cutting forces in the turning process as function of the parameters and conditions of treatment is necessary for determining of cutting tool strength, cutting edge wearing, limit of the maximum load of the cutting machine and forecasting the expected results of the processing. In particular, during machining with high cutting speed, using modern materials and modern cutting machines imposes the necessity of studying physical phenomena in the cutting process and their mathematical modeling.

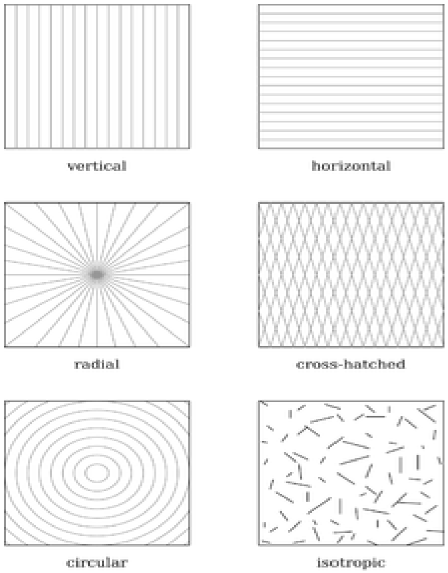


Fig 3.7 Examples of various lay patterns

3.6 Surface roughness

Surface roughness commonly shortened to *roughness*, is a measure of the finely spaced surface irregularities. In engineering, this is what is usually meant by "surface finish".

3.7 Waviness

Waviness is the measure of surface irregularities with spacing greater than that of surface roughness. These usually occur due to warping, vibrations, or deflection during machining.

3.8 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

Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 3 (2024)

FEED – 200mm/min, 250mm/min, 300mm/min

CUTTING SPEED – 600rpm, 1200rpm, 1800rpm,

DEPTH OF CUT – 0.4mm, 0.5mm, 0.6mm

3.9 EXPERIMENTAL PHOTOS

Fig 3.8 CNC machine

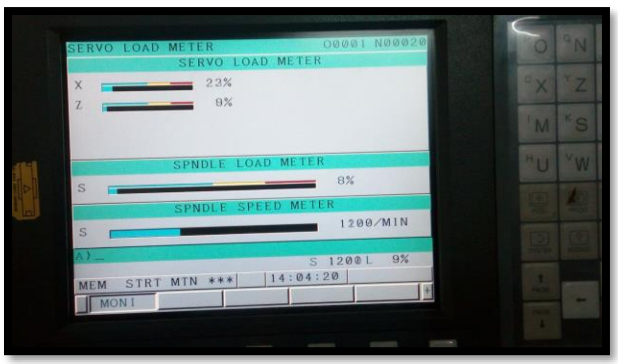


Fig 3.9 servo load meter

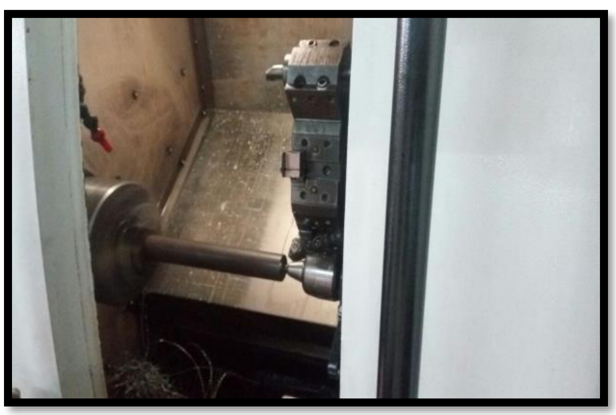


Fig 3.10 tool adjusting

Fig 3.11 work piece

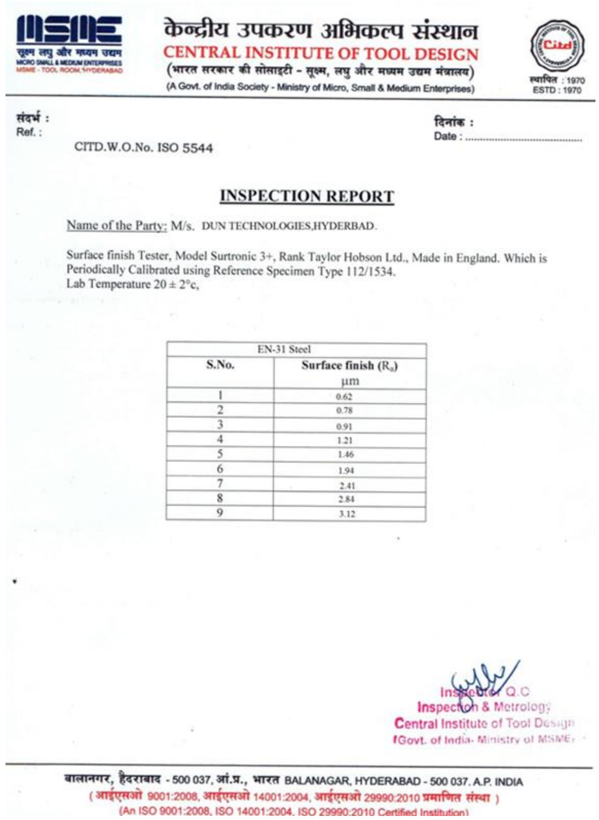
4. Results

PROCESS PARAMETERS	LE VEL1	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
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

4.1 Surface finish value

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)	Surface finish (R_a) µm
1	600	200	0.4	0.62
2	600	250	0.5	0.78
3	600	300	0.6	0.91
4	1200	200	0.4	1.21
5	1200	250	0.5	1.46
6	1200	300	0.6	1.94
7	1800	200	0.4	2.41
8	1800	250	0.5	2.84
9	1800	300	0.6	3.12



केन्द्रीय उपकरण अभिकल्प संस्थान
CENTRAL INSTITUTE OF TOOL DESIGN
(भारत सरकार की सोसाइटी - सूक्ष्म, लघु और मध्यम उद्यम मंत्रालय)
(A Govt. of India Society - Ministry of Micro, Small & Medium Enterprises)

स्थापित : 1970
ESTD : 1970

संदर्भ :
Ref. :
CITD.W.O.No. ISO 5544

दिनांक :
Date : ....

INSPECTION REPORT

Name of the Party: M/s. DUN TECHNOLOGIES,HYDERBAD.

Surface finish Tester, Model Surtronic 3+, Rank Taylor Hobson Ltd., Made in England. Which is Periodically Calibrated using Reference Specimen Type 112/1534.
Lab Temperature 20 ± 2°c,

EN-31 Steel	
S.No.	**Surface finish (R_a) µm**
1	0.62
2	0.78
3	0.91
4	1.21
5	1.46
6	1.94
7	2.41
8	2.84
9	3.12

Inspector Q.C
Inspection & Metrology
Central Institute of Tool Design
(Govt. of India- Ministry of MSME)

बालानगर, हैदराबाद - 500 037, आं.प्र., भारत BALANAGAR, HYDERABAD - 500 037. A.P. INDIA
(आईएसओ 9001:2008, आईएसओ 14001:2004, आईएसओ 29990:2010 प्रमाणित संस्था)
(An ISO 9001:2008, ISO 14001:2004, ISO 29990:2010 Certified Institution)

4.2 Introduction to taguchi technique

- Taguchi defines Quality Level of a product as the Total Loss incurred by society due to failure of a product to perform as desired when it deviates from the delivered target performance levels.
- This includes costs associated with poor performance, operating costs (which changes as a product ages) and any added expenses due to harmful side effects of the product in use.

4.3 Taguchi Methods

- Help companies to perform the Quality Fix!
- Quality problems are due to Noises in the product or process system
- Noise is any undesirable effect that increases variability
- Conduct extensive Problem Analyses
- Employ Inter-disciplinary Teams
- Perform Designed Experimental Analyses
- Evaluate Experiments using ANOVA and Signal-to noise techniques

4.4 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 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.

4.5 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 and depth of cut (BXC), cutting speed and depth of cut (AXC).

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

4.5 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

4.6 Observations

The following are the observations made by running the experiments. The cutting forces are measured using dynamometer

4.7 Cutting forces, surface finish

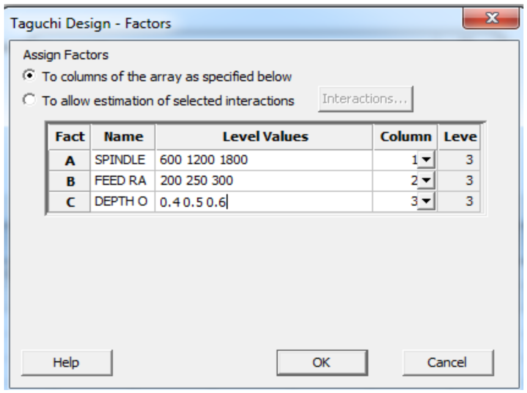
Surface finish (R_a) µm
0.62
0.78
0.91
1.21
1.46
1.94
2.41
2.84

4.8 Optimization of surface finishes using Minitab software

4.8.1Design of Orthogonal Array

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

4.8.2 Factors



4.8.3 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

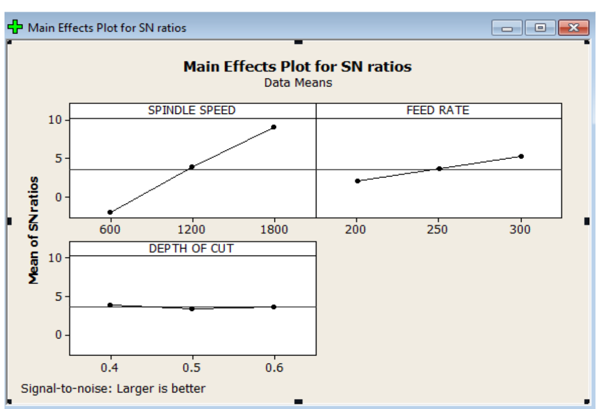
Worksheet 1 ***

↓	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

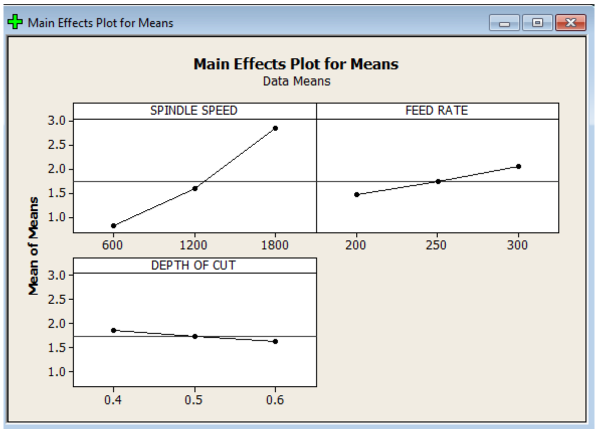
Worksheet 1 ***

↓	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	1.95612	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

4.8.4 Mean effective plot



4.8.4 Effect of turning parameters on force for Means



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 analysed using Ansys. 3D modeling is done in Pro/Engineer.

By observing the analysis results, the stress values are less than the yield stress values.

References

1. Using the Response Surface Method to Optimize the Turning Process of AISI 12L14 Steel
2. Optimization of Process Parameters of Turning Parts: A Taguchi Approach by Neeraj Sharma, Renu Sharma
3. The Effect of Tool Construction and Cutting Parameters on Surface Roughness and Vibration in Turning of AISI 1045 Steel Using Taguchi Method by Rogov Vladimir Aleksandrovich, Ghorbani Siamak
4. Parametric investigation of turning process on mild steel aisi 1018 material by J. M. Gadhiya, P. J. Patel
5. Evaluation and Optimization of Machining Parameter for turning of EN 8 steel by Vikas B. Magdum, Vinayak R. Naik
6. Analyses of surface roughness by turning process using Taguchi method by S. Thamizhmanii, S. Saparudin, S. Hasan
7. Application of Taguchi Method for Optimizing Turning Process by the effects of Machining Parameters by Krishankant, Jatin Taneja, Mohit Bector, Rajesh Kumar

8. Multi-Objective Optimization of the Cutting Forces in Turning Operations Using the Grey-Based Taguchi Method by Yigit

9. Experimental investigation of Material removal rate in CNC turning using Taguchi method by Kamal, Anish and M.P.Garg

10. Optimization of Cutting Parameters of Composite Materials using Genetic Algorithm by Dhavamani and Alwarsamy