Optimization of Cutting Parameters by Turning Titanium Material Using CBN Tool

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Abstract: Hard turning is a technique that can be used in the Finishing operations for titanium material (HRC38and above). The introduction of developed CBN cutting tools has made hard turning. This study was undertaken to investigate the performance of finish hard turning of TITANIUM (Ti-6A1-4V, HRC 37- 38). Various cutting speeds:25,45,100,135,150 m/min and various feed rate : 0.05,0.075,0.1,0.125,0.135 mm/rev and depth of cut : 0.08,0.05,0.1,0.125,0.16 mm were employed. Turning was done under wet cutting condition. Cutting forces, surface Roughness and tool life were investigated. The cutting forces, tool life and surface roughness models were developed using the five level full factorial designs. The mathematical models developed are statistically valid and sound, particularly for Fr, Fc, Ft and tool life, surface roughness. Finally the study combined regration analysis (mini-tab), utility concept and RSM method for predicting the optimal Setting. Optimal result was verified through confirmatory test. This indicates Application feasibility of the RSM techniques ::: Optimization and off-line quality control in turning operation.

Keywords: surface roughness, optimization, RSM method, Regret ion analysis

1. INTRODUCTION

Titanium material is a difficult-to-machine material because of its high hardness, low specific heat and tendency to get strain hardened. The life of the cutting tool is shortened due to the tendency of the work material to carry the carbide particles with the outgoing chip at elevated temperature. Titanium material finds its typical applications in the manufacturing of aeronautical and machine tool parts [1]. Because of its wide application Titanium material has been selected as the work material in this work. The recently developed tool materials like CBN tools have improved the productivity levels of difficult-to-machine material [2]. The quality of design can be improved by improving the quality and productivity in companywide activities. They are concerned with quality, product planning, product design and process design [3, 4]. Process modeling and optimization are the two important issues in manufacturing products. A greater attention is given to accuracy and surface roughness of product by the industries. Surface finish and cutting forces has been one of the most important considerations in determining the machinability of materials. Surface roughness and tool life dimensional accuracy are the important factors required to predict machining performances of any machining operations [5]. In order to establish an adequate functional relationship between the responses (Such as Surface Roughness) and cutting parameters, (Cutting Speed, Feed and Depth of Cut), a large number of tests are needed, requiring a separate set of tests for each and every combination of Cutting Tool and work piece material. This increases the total number tests and as a result the experimentation cost also increases. As a group of mathematics and Statistical Technique, response surface methodology is useful for modeling the relationship between the Input parameters (Cutting conditions) and output variables; RSM saves Cost and time by reducing the number of experiments required. Applied response Surface methodology to optimize the surface finish in Turning. Hard turning is a technique that can be used in the Finishing operations for TITANIUM (Ti-6A1-4V, HRC 37 - 38) by using CBN cutting tool. Cutting parameters:

Turning was done under wet cutting condition. Cutting forces, surface Roughness and tool life were investigated. The mathematical models developed are statistically valid and sound, particularly for Fr, Fc, Ft and tool life, surface roughness. These are

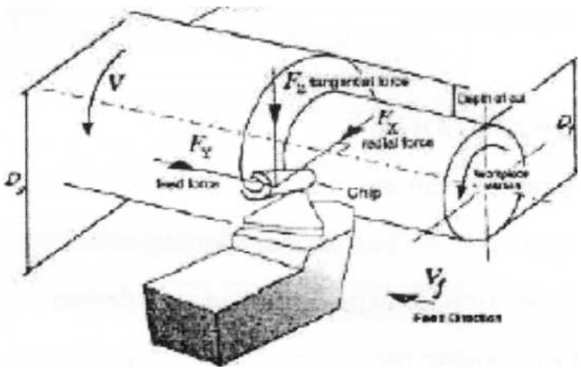


Figure 1: Forces Acting during Turning

verified by the confirmation run experiments and therefore can be used for prediction within the limits of; he factors investigated. Based on this research, hard turning with CBN inserts having conventional geometry performed satisfactory.

Optimization problem which seeks identification of the best process condition or parametric :combination for the said manufacturing process. The present study Applied extended R.S.M method through a case study in straight turning of Titanium bar with CBN tool. The study aimed at evaluating the best process Environment which could simultaneously satisfy requirements of both quality and as well as productivity with special emphasis on increases surface finish of cutting tool. Because increases surface finish of cutting tool, increase in tool.

Cutting speeds: 25, 45,100,135,150 m/min Feed rate: 0.05, 0.075, 0.1, 0.125, 0.135 mm/rev Depth of cut: 0.08, 0.05, 0.1, 0.125, 0.16 mmlife. The predicted optimal setting ensured minimization of surface roughness, the cutting tool life and maximization of cutting forces. In view of the fact, that traditional RSM method can Optimization problem.

Finally the study combined regration analysis (mini-tab), utility concept and RSM method for predicting the optimal Setting. Optimal result was verified through confirmatory test. This indicates Application feasibility of the RSM techniques for Optimization and off-line quality control in turning operation

2. RESEARCH METHODOLOGY

This study was undertaken to evaluate the performance of Cubic boron nitrated cutting tools when turning Titanium (Ti-6A1-4V) at various Cutting conditions in terms of cutting forces and surface finish of the turned part. Experimental design using design of experiment technique was applied to evaluate the cutting force and surface roughness in terms of cutting speed, depth of cut and feed rate. This chapter will also explain the experimental procedure, equipment being used, work piece material Titanium (Ti-6AI-4Y. and cutting tool is Cubic boron nitrated (CBN).

2.1. Equipment for Experiment

2.1.1. Daewoo (Doosan) Puma 300LCNC Lathe

This machine motor horse power is 35 HP (2 speed gear) and the spindle rotation ranges from 3500rpm. Spindle nose A2-8

2.2.2. Work Piece material - Titanium

Titanium is known as a transition metal on the periodic table of denoted by the symbol Ti. It is a Light weight, silver-gray material with an atomic number of 22 and an atomic weight of 47.90. It has a density of 4510 kg/m which is somewhere between the densities of aluminum and stainless steel. It has a melting point of rough!;. 3.032°F (1,667°C) and a boiling point of 5,948°F (3,287 C). It behaves chemically similar to zirconium and silicon. It has excellent corrosion resistance and a high strength to weight ratio.

3. CHEMICAL COMPOSITION OF MATERIAL

N, Nitrogen	0.03 %
C, Carbon	0.08 %
H, Hydrogen	0.0125 %
Fe, Iron	0.25 %
0, Oxygen	0.13 %
Pd, Palladium	–
Al, Aluminum	5.5-6.5 %
Mo, Molybdenum	-
V, Vanadium	3.5-4.5 %
Ni, Nickel	-
Ti, Titanium	Bal

3.1. Phase II SRG-1000 Surface Roughness Tester

This equipment used to measure surface roughness of the work piece machine during experiment. The surface roughness was measured at three locations around work piece circumferences. The value of the surface roughness is the average of three points taken for each measurement.

3.2. Cubic Boron Nitride

Cubic boron nitride (CBN or c-BN) is widely used as an abrasive.[1381] Its usefulness arises from its insolubility in iron, nickel, and related alloys at high temperatures, whereas diamond is soluble in these metals to give carbides. Polycrystalline c-BN (PCBN) abrasives are used for machining steel, Titanium.

A three component dynamometer compromising of basic unit (Kistler, Type 9265B) and a screwed on working adapter in a form of a tool holder for turning. (Kistler, Type 9441 B) Hisomet II tool marker's microscope is used for measured by flank wear has been considered as the criteria for tool failure. For design the tool life of the CBN tool.

3.3. Image Analyzing Software of ANOVA (Mini tab) Version 14

Design and optimization of experiment software. Response surface mythology (RSM) is used for analysis of optimal result.

4. EXPERIMENTAL RESULTS AND DISCUSSION

Conventional DCMT 070204 insert which is Cubic boron nitride (CBN) was used in the machining study to finish turn Titanium with a hardness ranging from HRC 37 to 38. Cutting forces that can be resolved into three components: Cutting force (Fc),

Radial force (Fr),

Feed force (Ff),

Surface roughness,

Tool life.

4.1. Cutting Conditions

For this experiment, five level full factorial arrangements were used in the experiment. Cutting speed and feed rate were varied in this experiment.

Level's	*Cutting Velocity S (m/min)- Xi*	*Feed Rate V(mm/rev) -X_2*	*Depth of Cut DOC (mm)-X_3*
1	35	0.05	0.08
2	45	0.075	0.05
3	100	0.1	0.1
4	135	0.125	0.125
5	150	0.135	0.16

5. CODING IDENTIFICATION FOR TURNING USING CBN TOOL

Level's	*Lowest*	*low*	*center*	*high*	*Highest*
Coding	-1.41	-1	0	1	1.41

5. OPTIMIZATION OF CUTTING PARAMETERS BY TURNING

Level's	*Lowest*	*low*	*center*	*high*	*Highest*
Cutting speed S (m/min) -Xi	35	45	100	135	150
Feed Rate V(mnVrev) -X_2	0.05	0.075	0.1	0.125	0.135
Depth of Cut DOC (mm) -X_3	0.08	0.05	0.1	0.125	0.16

5.1. Cutting Forces

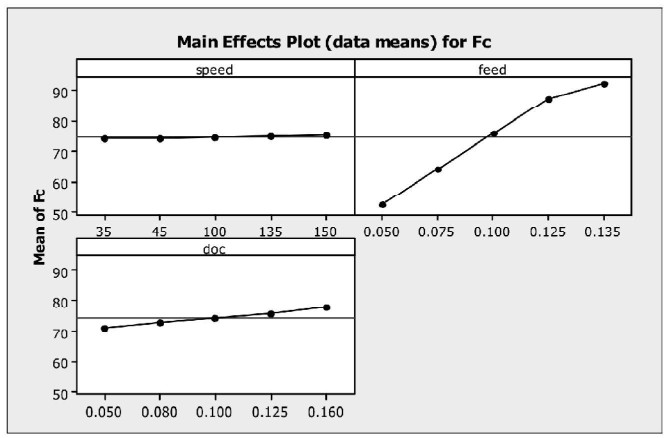
The experiment was conducted with the objective of determining the main cutting forces and surface roughness when using CBN cutting tool when turning Titanium with a hardness range of 37 to 38 HRC. The cutting forces generated in metal cutting have a direct influence on heat generation, tool wear or failure, quality of machined surface and accuracy of the Work piece. The forces acting on tool are an important aspect of machining, where for those concerned with the manufacture of machine tools, knowledge of the forces is needed for the estimation of power requirements and for the design of machine tool elements, tool holders and fixtures, thereby ensuring they are adequately rigid and free from vibration. Force measurement in metal cutting is an essential requirement as it is related to machine part design, tool design, power consumptions, vibrations, part accuracy and other influential factors. By measuring the cutting force one is able to understand the cutting mechanism such as the effects of cutting variables on the cutting force, the machinability of the work piece, the process of chip formation, chatter and tool wear. It has been observed that the force values obtained by engineering calculations contain some errors when compared with experimental measurements. The cutting force even in steady state conditions is affected by many parameters and the variation of cutting force with time has a peculiar characteristic. The need for measurement of all cutting force component arises from many factors, but probably the most important is the need for correlation with the progress of tool wear. If this can be obtained, it will be possible to achieve tool wear monitoring in turning based on force variation. The cutting parameters such as cutting speed, feed rate and depth of cut often present a deviation from the calculated values. For this purpose, many dynamometers have been developed. In these dynamometers, cutting force measurement is mainly based on elastic deformation of the materials Cutting forces can be resolved into three components which are radial thrust force (Fr), feed force *(Ff)* and tangential cutting force *(Ft)*. Usualh the tangential cutting force is the largest of the three components, though in finish turning the radial thrust force is often larger, while the feed force is minimal. According to Xioali Li (2005), the cutting force is one of the most important characteristic variables to be monitored in the cutting processes, because the change of cutting force is directly related to the cutting conditions. In particular, real-time and online information c: the cutting force is very useful for the tool wear redactions, breakage detection, and othe: malfunction inspections. Many companies, such as the Kistler Instruments Limited, have developed a series of apparatus to measure the cutting force in turning, milling, drilling, an: so forth. This series of apparatus can be used to measure the cutting force accurately. Som; researchers, therefore, have developed various monitoring systems for the cutting proces; using the measured cutting forces.

5.2. Experimental Designs in Coding of Level and Cutting Force's

Sl. No.	*Coding of level's*			*Fc*	*Fr*	*Ff*
	X_1	X_2	X_3			
1	-1.41	-1.41	-1.41	50.6	76.8	35.2
2	-1.41	-1	-1	60.4	116.5	47
3	-1.41	0	0	75.2	193	65
4	-1.41	1	1	88.5	257.6	81
5	-1.41	1.41	1.41	95.2	295	88.6
6	-1	-1.41	-1	49	63	34
7	-1	-1	0	64	140	50.9
8	-1	0	1	77	204	67
9	-1	1	1.41	90	274	84
10	-1	1.41	-1.41	90.01	258	85
11	0	-1.41	0	52	85	42
12	0	-1	1	65.2	150	57
13	0	0	1.41	80	220	74
14	0	1	-1.41	86	236.7	83.7
15	0	1.41	-1	88.8	244	87
16	1	-1.41	1	54	96	46
17	1	-1	1.41	68	165	62
18	1	0	-1.41	75	182	72
19	1	1	-1	84	222	85
20	1	1.41	0	92	266	93
21	1.41	-1.41	1.41	56	112	50
22	1.41	-1.41	-1.41	63	129	60
23	1.41	0	-1.41	73.01	169	71
24	1.41	1	0	88	244	89
25	1.41	1.41	1	94	278	96

5.3. Radial Force (Fr)

The radial force, Fr acts in the radial direction and tends to push the tool Away from the work piece. It is the largest among the cutting force components and is sensitive to the changes in cutting speed, doc and feed in this experiment. The three cutting force components and is most sensitive to the changes of cutting edge geometry and tool wear.



Regression Analysis

Fr versus SPEED(S), FEED (V), DEPTH OF CUT (DOC)

The regression equation is:

Fr = - 66.5 - 0.0132 speed + 2138 feed + 459 doc

The relationship between radial force, Fr when different cutting speed, feed and depth of cut are used. From Figure it can be seen that Fr increase with the increase in cutting speed and increase with the increase in feed and increases in depth of cut.

5.4. Tangential Force (or) Cutting Force (Fc)

The tangential force, Fc acts downward on the tool tip and therefore tends to deflect the tool downward.

Regression Analysis: Fc versus SPEED, FEED, DEPTH OF CUT

The regression equation is

Fc = 22.1 + 0.00699 speed + 465 feed + 62.8 doc

1. The feed rate increases, the section of sheared chip increases and then cutting force can increases.
2. cutting forces is very affected by the feed rate, then feed force and lastly radial force
3. increase in cutting speed generally leads in the cutting forces
4. the depth of cut increase the depth of cut is gradually increases

5.5. Feed Forces (Ff)

The feed force, Ff acts in the longitudinal direction. This force is called the Feed force because it is in the feed direction. Normally the feed force is the most minimal of all the forces. The horizontal axis of the graphs represents the cutting speed and feed and the vertical axis gives the values of the Ff. The Ff is the lowest among the measured force components. In addition, the trend observed where the feed force increase as the speed increase but it increase as the feed increase.

Regression Analysis: Ff versus SPEED, FEED, DEPTH OF CUT The regression equation is Ff = - 1.22 + 0.0835 speed + 572 feed + 60.4 doc

1. When cutting speed increases the feed force gradually is increases
2. Feed rate increases then the feed force can be increases
3. Depth of cut increases the feed force can be increases

5.6. Tool Life

Flank wear has been considered as the criteria for tool failure and the wear was measured under a Hisomet II Tool maker's microscope. Tool life experiments were stopped when an average flank wear achieved exceeded 0.3mm.

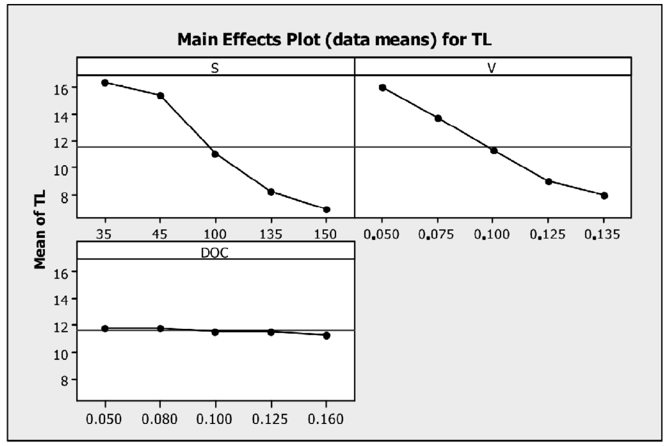
ANOVA is used to verify and validate

Regression Analysis: TL versus S, V, DOC

The regression equation is

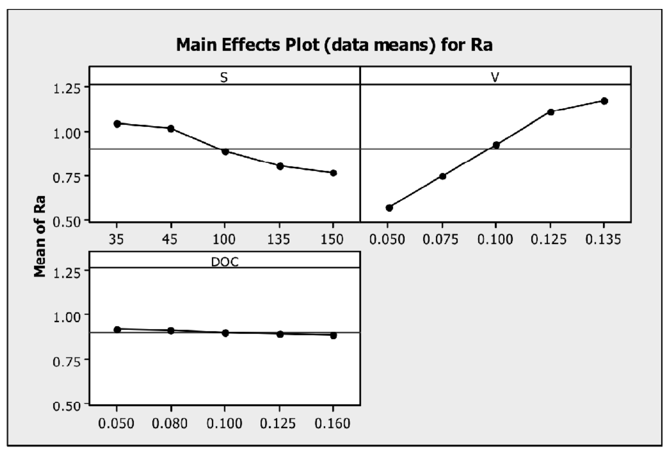
TL = 28.7 - 0.0809 S - 94.1 V - 4.69 DOC

- The tool life decreases with increase of the cutting speed, feed and depth of cut.
- The cutting speed has most dominant effect on tool life, followed by the feed and depth of cut.



5.7. Surface Roughness

Regression Analysis: Ra versus SPEED, FEED, DEPTH OF CUT The regression equation is Ra = 0.459 - 0.00236 SPEED + 7.14 FEED - 0.298 DEPTH OF CUT



1. The increase in cutting speed improves the machined surface quality.
2. When the feed rate can be increases the quality of the surface roughness decreases.

CONCLUSIONS

1. It can be concluded that cutting speed, feed rate and axial depth play a major role in deciding the surface roughness on the work material.

2. Increase in cutting speed will reduce the surface roughness; lower surface roughness is always preferred.
3. Increase in feed increases the heat generation and hence the tool wear, which results in higher surface roughness. The increase in feed also increase the chatter, and it produces incomplete machining of work piece, which leads to higher surface roughness.
4. Increase in depth of cut will be slightly reducing the surface roughness; lower surface roughness is always prefers.
5. The Optimum parameters observed in this study is cutting speed 150m/min, depth of cut 0.0.16mm and feed 0.05mm/rev.
6. Application of RSM has been recommended to eliminate response correlation by converting correlated responses into uncorrelated quality indices called principal components which have been as treated as response variables for optimization.
7. R. S. M. has been proved as a good method in designing the experiments, modeling the models and optimizing the cutting parameters in Turning of Titanium using CBN tool inserts under wet conditions.
8. R. S. M. combined with the factorial design of experiment is found to be a successful technique to perform trend analysis of surface roughness with respect to various combinations of design variables (cutting speed, feed rate, and depth of cut).
9. Cutting speed, feed rate have a major impact on surface roughness.Smouther surface will be produced when machined with a higher cutting speed, smaller feed rate. Depth of cut has a significant impact on surface roughness only in an interaction.
10. In case CBN tools, the effect of feed on tool life is much more pronounced than the effect of speed. The magnitude of the feed exponent is found to be greater than the cutting speed exponent.
11. The cutting force increases when the speed is increased, whilst it increases when the feed or depth of cut is increased.
12. Tangential cutting force is very sensitive to the variation of cutting depth Surface rough and tool life is very sensitive to the variation of feed rate.

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