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Experimental Investigation in Turning Wrought Alloy (VT-20)

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***Abstract:* -- Turning operation is one of the most basic machining processes. That is, the part is rotated while a single point cutting tool is moved parallel to the axis of rotation. Hard turning is becoming more popular for machining hardened steels as it has several benefits over grinding. The hard Turning process is defined as machining metals with the hardness greater than 45 HRC. CNMG 120408 is the dominant tool material for hard turning applications due to its high hardness, high wear resistance, and high thermal stability. The temperature generated in hard turning is Substantially higher when compared to conventional machining as the cutting speeds employed in hard turning are higher and dry cutting environment is usually employed.[1] Hard turning is a high-speed machining phenomenon with surface speeds going normally as high as 250 m/min, sometimes even more than this. So the machine tool capabilities should include high machine tool rigidity, high surface speed, and constant surface speed for a profile to be finished and high accuracy with a required surface finish.[2].**

I. INTRODUCTION

1.1 TURNING

Turning operation is one of the most basic machining processes. That is, the part is rotated while a single point cutting tool is moved parallel to the axis of rotation. Hard turning is becoming More popular for machining hardened steels as it has several benefits over grinding. The hard Turning process is defined as machining metals with hardness greater than 45 HRC. CNMG 120408 is the dominant tool material for hard turning applications due to its high hardness, high wear resistance, and high thermal stability. The temperature generated in hard turning is Substantially higher when compared to conventional machining as the cutting speeds employed in hard turning are higher and dry cutting environment is usually employed.[1]

Hard turning is a high speed machining phenomenon with surface speeds going normally as high as 250 m/min, some-times even more than this. So the machine tool capabilities should include high machine tool rigidity, high surface speed, and constant surface speed for profile to be finished and high accuracy with required surface finish.[2]

1.2 CNMG 120408 KCU25 Insert

CNMG 120408 KCU25 is the material with outstanding mechanical properties such as extreme Hardness, high Young's modulus, low coefficient of friction, and superior wear resistance. An Advance PVD grade with hard AlTiN coating and fine-grain unalloyed substrate. The new and improved coating improves edge stability with wide rage speed and feed capabilities

CNMG 120408 KCU25 provides extreme resistance to deformation and wear at high temperatures typically an order of magnitude better than the nearest carbide or ceramic materials. [3]

1.2 Introduction of Titanium VT 20

Titanium wrought alloy (VT-20) has high degree of hardness with compressive strength and abrasion resistance. Its hardness is greater than that of steel, so that it does not make noticeable changes at high temperatures.

1. Titanium alloys such as BT20 are extensively used in the aerospace industry, especially in the high temperature flow area of engines, because of their excellent strength at elevated temperatures and corrosion resistance.
2. Titanium has emerged as wonder metal that justifies its choice for wide variety of applications including jewelers, bicycle frames, missiles, airplanes, and helicopter.
3. Titanium alloys are also finding their applications in submarines, automobiles.
4. Titanium alloys are also been used in medical field in surgical instruments and also in bone implants due to high strength to weight ratio and its biological compatibility.

1.2.1 Properties of Titanium wrought alloy (VT-20):
Standard Chemical Composition:

Table 1.1 Std. chemical composition of Titanium wrought alloy (VT-20)

	Fe	C	Si	Mo	V	N	Ti	Zr	O	H	Al	Impurity
Max%	0.025	0.1	0.15	0.5-2	0.8-2.5	0.05	85.15-91.4	1.5-2.5	0.15	0.015	5.5-7	Other 0.3

1.2.2 Mechanical Properties:

Table 1.2 Properties of Titanium wrought alloy (VT-20)

Density	4.65 g/cc
Mechanical:	
Modulus of Elasticity	106 GPa
Hardness	45 HRc
Tensile Strength	1240 MPa
Yield Strength	1200 MPa
Shear modulus	41 GPa
Shear strength	760 MPa
Thermal and Electrical:	
Thermal conductivity	7.80 W/m-K
Specific heat	0.525 J/g^{0}c
Electrical resistivity	0.000150 ohm-cm

II. EXPERIMENTAL SETUP

2.1 Introduction:

The experimental work was carried out on a High speed precision CNC lathe CTX 400E having 50 to 4000 RPM speed range, Fig 5.1 Shows the detail setup. The turning operation is done on Titanium wrought alloy (VT-20). The Inserts were of geometry CNMG 120408 KCU25 grade. The turning operation is carried out in wet environment i.e. with coolant. [4]

Figure No.2.1 Setup for Turning

2.2 Lathe-

Experiments are carried out on the High speed precision CNC lathe CTX 400E model having 16KW power. The machine is known for its very good process capability for precision turning. The machine has very wide range of speeds from 50 to 4000 rpm and feeds from 0.01 to 3.0 mm/rev.

2.3 Work Piece - The turning operation is done on Titanium wrought alloy (VT-20) of outer Dia. 148 inner Dia. 123 and 25 mm thick. The material is hardened to 45±2 HRC. Hardening make outer layer of work piece hard and wear resistant but impact resisting property is still present inside the work material.

2.4 Cutting inserts:

The cutting insert is a removable type and offered four working edges which are mounted on tool holder. Its standard designation is CNMG 120408 KCU25, where CNMG is ISO form, 12-edge length, 04-insert thickness & 08-Corner radius and it is manufactured by Kennametal Company.

2.5 Tool Holder:

Tool holder is codified as PCLNL 20x20 M12 with a common active part tool geometry described as:

Table 2.1. Specification of tool holder PCLNL 20x20 M12

Particulars	Value
Rectangular shank	20 x 20 mm
Tool Cutting Edge Angle	95 deg.
Tool Lead Angle	-5 deg.
Minimum Overhang	27.2 mm
Functional Length	150 mm
Functional Width	25 mm
Functional Height	25 mm

2.7 Tool post - To mount the tool holder which is to be used is fixed on the turret. This special tool is rigidly mounted on turret and transfer all the forces generated during cutting action through tool holder to the turret.

2.8 Surface Roughness Tester:

To measure the surface roughness of machined work piece the surface tester of Surtronic S128 series is used. The S128 Series can evaluate 10 kinds of roughness parameters conforming to the latest ISO, DIN, and ANSI standards, as well as to JIS standards.

B. DESIGN OF EXPERIMENTS

2.9 Introduction:

Design of Experiment (DOE) is an efficient experiment planning process that allows the data obtained to be analyzed, valid conclusions to be drawn and objectives to be set. There are two aspects of any experimental problem, the design of experiment & statistical analysis. Experimental

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design involves planning experiments to obtain the maximum amount of information from available resources.

DOE is used to determine the appropriate number of tests and the experimental conditions necessary to obtain the desired goal of analysing which factor of the process influences the response variables. The most common design consists of running the test with all the possible combinations of variables at predetermined levels. [5]

2.10 Taguchi Method

Genichi Taguchi, a Japanese engineer, proposed several approaches to experimental designs that are called "Taguchi Methods". These methods utilize two, three, and mixed-level designs. Taguchi method is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment. Taguchi approach to design of experiments is easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. Taguchi method is especially suitable for industrial use, but can also be used for scientific research.

2.11 Input Process Parameters:

The input process parameters selected are speed, feed and depth of cut. The Ranges of speed, feed and depth of cut are decided on the basis of machine capability, literature review and tool manufactures recommendations.

Table 2.1 Levels and values of Input parameters

Parameters	Level	Values
Cutting Speed (v) m/min	3	250,300,350
Feed (f) mm/rev	3	0.15,0.2,0.25
DoC (d) mm	3	0.5,1,1.5

2.12OutputProcessParameters:

The output parameters selected are Surface Roughness & Tool wear rate.

2.13 Selection of Orthogonal Matrix Experiment:

The total degrees-of-freedom (DOFs) for experiments is calculated first to select an appropriate orthogonal array for the experiment. The Cutting Speed, feed, depth of cut are the three factors and each factor has three levels considered for experiments. With three factors at three levels, the total DOFs is 7 [= 1+ 3 x (3-l)]. The Cutting Speed, feed, depth of cut are the three factors and each factor has three levels considered for experiments. With four factors at three levels, the total DOFs is 9 [= 1+ 4 x (3-l)]. In the present study, the interaction between the machining parameters is neglected. From the value of DOFs, it is concluded that at least seven and nine experiments are to be conducted to estimate the effects of each machining parameters. After knowing the value of total DOFs, the next step is to select an appropriate orthogonal array. The standard orthogonal array which has at least three numbers of columns at three levels is selected for the experiments. Hence, the selected standard orthogonal array is L9 for both the cases. It has four three-level columns and nine rows. Each machining parameter can be assigned to a column and nine machining-parameter combinations are available in L9 orthogonal array matrix experiment. Therefore, only nine experiments are required to be conducted as per L9 orthogonal array to study the effects of machining parameters on Surface Roughness and Tool wear rate. Since the L9 orthogonal array has four columns, one column of the array is left empty; it counts for the error of experiments and orthogonally is not lost by letting one column of the array remain empty. [6]

2.14 Selection of levels for input parameters:

Factors are selected from the study of literature survey i.e. by analysing the effect of parameters on Surface roughness and Tool wear rate. Levels of factors are decided after conducting some pilot study where experiments has been done for varying speed, feed and DOC.

Table No. 2.2 Input Parameters- Levels

Factor → / Level ↓	Cutting Speed (m/min)	Feed (mm)	Depth of cut (mm)	Coding
High	350	1.5	0.25	+1
Medium	300	1	0.2	0
Low	250	0.5	0.15	-1

Table No. 2.3L9 OA factor column assignment used for Experimentation

Run	Actual Values			Coded values		
	Feed	Speed	DOC	Feed	Speed	DOC
1	0.15	250	0.5	1	1	1
2	0.2	250	1	2	1	2
3	0.25	250	1.5	3	1	3
4	0.2	300	0.5	2	2	1
5	0.25	300	1	3	2	2
6	0.15	300	1.5	1	2	3
7	0.25	350	0.5	3	3	1
8	0.15	350	1	1	3	2
9	0.2	350	1.5	2	3	3

Table No. 2.4ObservationaldataforRa and TWR.

Run	INPUT PARAMTERS						OUTPUT PARAMETERS	
	Actual Values			Coded values			Ra (μm)	TWR (gm./min)
	Feed (mm/rev)	Speed (m/min)	DOC (mm)	Feed (mm/rev)	Speed (m/min)	DOC (mm)		
1	0.15	250	0.5	1	1	1	0.423	0.0770
2	0.2	250	1	2	1	2	0.435	0.1610
3	0.25	250	1.5	3	1	3	0.437	0.1270
4	0.2	300	0.5	2	2	1	0.269	0.1380
5	0.25	300	1	3	2	2	0.328	0.1690
6	0.15	300	1.5	1	2	3	0.439	0.2130
7	0.25	350	0.5	3	3	1	0.194	0.1950
8	0.15	350	1	1	3	2	0.275	0.2730
9	0.2	350	1.5	2	3	3	0.475	0.3590

III. CONCLUSION'S

Based on the results of the experiments and statistical analysis carried upon, the following general conclusions can be drawn. An approximate value of surface roughness (Ra) and Tool wear rate in case of hard turning process can be evaluated by the following equation.

• Ra = 0.679 - 0.00117 SPEED + 0.155 DOC - 0.593 FEED
• TWR = - 0.320 + 0.00154 SPEED + 0.0963 DOC - 0.240 FEED

Effect of cutting parameters on Surface Roughness-

• At lower feed, surface roughness decreases with increase in cutting speed up to some stage then it goes on increasing.
• Surface roughness found to be highest at higher feed and higher depth of cut.

Effect of cutting conditions on Tool Wear Rate-
• At higher DOC, Tool wear increases with increase in cutting speed.
• At lower DOC, Tool wear increases with increase in feed as well as speed.

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