Optimization of Turning Process Parameter of Ti6Al4V using PVD Coated Insert on CNC Machine

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Abstract— This investigation considers a correlation of results got by PVD covered carbide wet turning of titanium alloy grade 5 which is otherwise called Ti6Al4V. Titanium alloys has numerous applications, for example, aviation segments, restorative surgical parts and so on because of their properties, for example, high strength to weight proportion, warm treatable and better erosion protection. In this trial, turning of titanium compound was completed utilizing diverse cutting parameters like speed, feed and depth of cut on CNC machine. Experimentation depended on Taguchi's L9 orthogonal cluster delivered by Minitab 16. Toward the end, Surface roughness was measured for combination of parameters and optimum parameters can be selected.

Key words: Titanium alloy, PVD Coated, Taguchi method, CNC turning, DOE

I. Introduction

In recent years, Because of the extreme working environment of aviation engines the improvement of aircraft engines has been done which depends on the properties of materials. Among all the choices, titanium alloy has become one of the most favorable materials in the aerospace industry. It has very high strength-to-weight ratio which makes titanium alloy a lightweight material with high strength. In addition to that it has high strength at elevated temperatures, a property that enables it to stand the aircraft engine environment. However, titanium is classified as a difficult-to-cut material because of its several inherent properties like its low thermal conductivity increases the temperature at the tool and work-piece interface, which affects tool performance dramatically. The second, its high chemical reactivity causes problems of material bonding and chip evacuation, which commonly leads to severe tool failure. Finally, its high strength at elevated temperatures, although it has been mentioned above as one advantage, requires extremely large cutting forces and power, which leads to several difficulties during the machining process. Thus, the machining of titanium alloy has become an important issue in both industrial and academic field.

Turning is considered a critical process not only because it can remove the unwanted part of materials efficiently, but also because it can create almost all kinds of contour surfaces smoothly. However it is a cutting process with varying chip load, forces and heat generation. Along the turning tool edges, the rake and clearance angles vary with respect to the distance from the milling tool tip. Therefore, the analysis of turning process and turning tool performance is always a big challenge.

Turning titanium alloys has drawn attention because the material is difficult to cut or the available speed is low. A large amount of heat generated during the cutting process conducts to the tool instead of the chips or work-piece due to the low thermal conductivity of titanium alloys. The high temperature in the tool degrades the tool properties and results in thermal stress and causes excessive damage to the tool. Experimental approach is still the dominant method to investigate the tool performance in titanium turning process numerous studies focused on testing for different cutting conditions

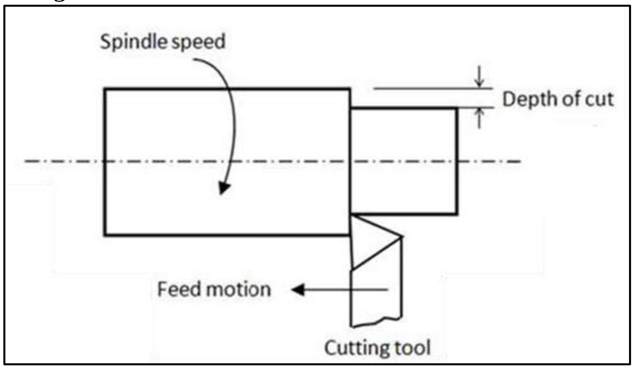

Fig. 1: Turning Process

II. CNC turning process

Turning is defined as the process of removing material from the outer diameter of the work-piece. In this process, the single point cutting tool is moving parallel to rotating axis with a certain velocity. It is used to produces work-pieces with conical, curved, or grooved shapes.

The Automatic turning process is carried out on CNC Lathe machine. The cutting parameters of the operation include the speed, feed and depth of cut. The selection of these parameters influences cutting forces, power consumption, and surface roughness of the work-piece and cutting tool life. Cutting parameters are usually selected based on the work-piece material, tool material, and tool geometry. Optimization of cutting conditions will minimize the machining cost and improve the quality of the product.

Figure 2 shows the three forces acting on the cutting tool in the turning process. The cutting force (Fc) is main force in the turning process and it acts downward on the cutting tool. The thrust force (Ft) or feed force acts in the direction of the feed motion of the cutting tool. The radial force (Fr) acts in the radial direction

Deiab et al. proposed use of vegetable oil as a machining lubricant in both MQL and MQCL configuration. It was found to be a more sustainable alternative to synthetic cooling in terms of tool wear. [1]

Chauhan et al. found that higher cutting speed results in shorter tool life. But at higher feed rate and depth of cut, effect of cutting speed is less significant. This was due to fracture failure and was more important than gradual wear when high feed rate and high depth of cut were applied. [2]

Akhyar et al. concluded that pattern of tool life progression was rapidly increase at the initial stage. It was due to small contact area between the cutting tool and the work piece. At the first step of machining, the chip welded at the cutting edge but some chip removed away from the cutting edge. Wear mechanism produced were abrasive wear, adhesive, flaking, chipping at the cutting edge and coating delamination. [3]

Patil. et al. conducted experimental work of turning on titanium alloy with different cutting parameters like cutting speed, feed and depth of cut has been carried out. Experimentation was carried out using Taguchi's L9 orthogonal array. Surface roughness was measured for each experimentation. Parameters were optimized and analysis of variance (ANOVA) was carried out. The assessment gave that, when compared to uncoated carbide inserts, the coated carbide inserts shows significantly improved surface roughness. [4]

Pawar et al. concluded that higher compressive residual stresses are induced when the highest cutting speed, and lowest federate and moderate depth of cut. These machining conditions promote mechanically dominated deformation during machining. [5]

III. EXPERIMENTATION

A. *Machine Tool:*

The CNC turner is use for performing operation with the selected parameters by manual part programming.

B. *Test Specimen Material:*

The material chosen for this experiment was Titanium alloy Grade 5 (Ti6Al4V). The chosen titanium alloy had chemical composition & mechanical property as shown in Table 1 & Table 2 which was based on the data provided by the supplier of material.

ELEMENTS	PERCENTAGE (%)
Aluminium (Al)	6.20
Vanadium (V)	3.98
Iron (Fe)	0.20
Tin (Sn)	0.001
Molybdenum (Mo)	0.010
Carbon (C)	0.040
Silicon (Si)	0.018
Nickle (Ni)	0.038
Copper (Cu)	0.001
Chromium (Cr)	0.086
Titanium (Ti)	88.70

Table 1: Chemical composition of Titanium alloy Gr.5

MECHANICAL PROPERTY	VALUE
UTS (MPa)	1025.787
ELONGATION (%)	15.5
MODULUS OF ELASTICITY (GPa)	114
YIELD STRENGTH (MPa)	830
HARDNESS (HRC)	36

Table 2: Mechanical property of Titanium alloy Gr.5 C

C. *Cutting Inserts:*

In this experiment the type of cutting tool was PVD coated carbide tool. ISO designation of PVD coated tool insert was TNMG 160404 HS PC8110.The PVD coated tool inserts used in experiment is shown below in Fig. 3.

Fig. 3: PVD coated carbide insert

D. *Experimental Procedure:*

The turning operations were carried out at fixed cutting conditions based on Taguchi DOE with fresh tool inserts mentioned above. The cutting test run was periodically interrupted due to change in cutting parameter.

E. *Surface Roughness Measurement:*

The surface roughness of the machined surface was measured at different locations by the tester finally the average value was recorded which was displayed on screen of surface roughness tester as shown in fig.4.

Fig. 4: Surface roughness tester showing Ra Value

IV. METHODOLOGY

Using the tool insert manufacturer's guidelines, a cutting range was according to the different values of the feed rate, depth of cut and the work-piece type. The cutting parameters levels were selected based on tool material and work-piece material and by studying different research papers. The experiments are carried out in wet cutting conditions. Cutting conditions is selected using Taguchi based design of experiments. Three levels and three parameters are selected for experimentation. Using Minitab 16 L9 orthogonal array is created. These levels and parameters are as shown in Table 3.

Cutting Parameter	Unit	Level		
		I	II	III
Cutting speed (v)	m/min	85	95	105
Feed rate (f)	mm/rev	0.10	0.15	0.20
Depth of cut (d)	mm	0.5	1.0	1.5

Table 3: Cutting process variables and their levels

V. RESULT & DISCUSSIONS

After measuring the value of surface roughness produced by PVD coated carbide insert following table 4 was made to analyze the optimum set.

Sr. No.	Control factor			PVD coated Tool Surface Roughness Ra (μm)
	Speed	Feed	Depth of cut	
1	85	0.10	0.5	0.603
2	85	0.15	1.0	1.013
3	85	0.20	1.5	1.595
4	95	0.10	1.0	0.766
5	95	0.15	1.5	1.715
6	95	0.20	0.5	1.901
7	105	0.10	1.5	0.685
8	105	0.15	0.5	1.082
9	105	0.20	1.0	1.366

Table 4: Observation table for PVD coated insert

Main effect plots show the variation of individual response with the inputs; speed, feed rate and depth of cut separately. The main effect plot for surface roughness for PVD coated carbide tool insert is shown in Fig. 5. In this plots, the X-axis shows the value of each process parameters at three level and Y-axis the response value which means surface roughness. To get optimum value of process parameter the main effect plots are drawn which gives low surface roughness. The results show that with the increase in cutting speed there is a continuous decrease in surface roughness and then value of surface roughness sudden increases and it again decrease with increase of speed. On the other hand, as the feed increases the surface roughness increases. However, with the increase in depth of cut there is initially an increase in surface roughness followed by decrease of surface roughness with increase of depth of cut. Low value of surface roughness was obtained at cutting speed of 105 m/min, Feed of 0.10 mm/rev and DOC of 1 mm.

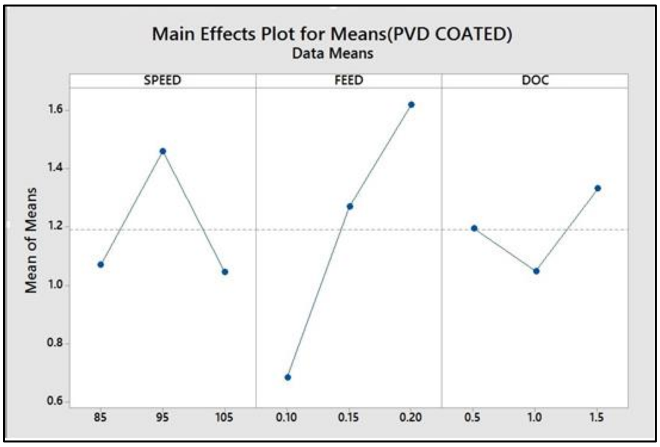

Fig. 5: Main effect plot for Means for PVD coated tool insert

VI. CONCLUSION

In this experimental work, a study for the surface roughness concerning the turning of Ti-6Al-4V alloy is carried out using PVD coated and uncoated carbide inserts. From the experimental results & main effect plot for further details for optimization, it was observed that:

The optimum set for surface roughness is 105 m/min, Feed of 0.10 mm/rev and DOC of 1 mm. so optimum value of surface roughness will be achieved at this set.

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