Experimental Investigation of different variables while turning on Ti-6Al-4V using DEFORM-3D

Amit Sharma [a], C S Kalra [b], and Rohit Rampal [c]

[a]M-Tech student, SUSCET, Tangori, PTU

[b]Assistant professor, SUSCET, Tangori, PTU

[c] Assistant professor, SUSCET, Tangori, PTU

Abstract

Turning is one of the most widely used manufacturing techniques for producing a circular shape from irregular shape in the industry and there are lots of studies to investigate on this process. Predictions of important process variables of turning such as temperature, cutting forces and stress distributions play significant role on designing turning process parameter and optimizing cutting conditions. At this point of view, finite element modelling and simulation becomes main tool for saving time, no material waste, accurate and less costly. With finite element method, the important turning variables can be predicted without doing any machining of workpiece. This paper covers a study on modelling and simulation of turning by finite element method. For this purpose, turning simulations of Ti-6Al-4V are performed and model used in simulations is validated. The FEM used to analyze cutting stress, strain, damage and temperature of workpiece in turning.

Key words: Ti-6Al-4V, Turning, Deform-3D, Tungsten Carbide.

1. INTRODUCTION

Turning is a machining process to produce round parts by a single point cutting tool on lathe machine. The primary motion in turning is the rotation of the work piece which is hold in chucks, and the secondary motion is the feed motion of tool. The tool is feed either linearly in the direction parallel to the axis of rotation is named feed motion or perpendicular to the axis of rotation is named depth of cut. The process is used to produce straight, conical, tapered, curved, or grooved work pieces such as shafts, spindles, rods, pins etc.

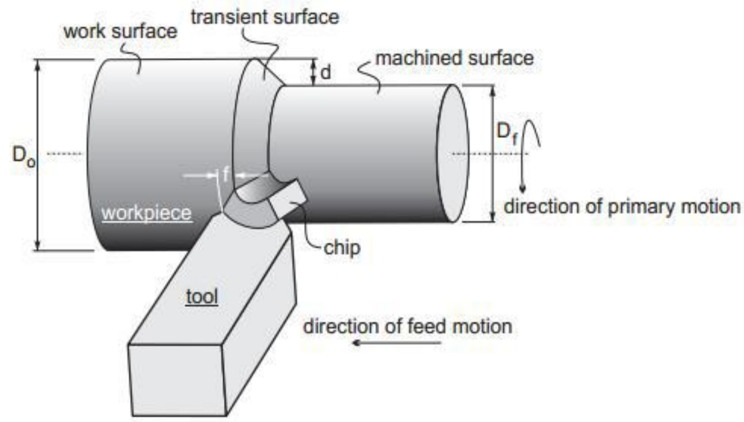

Fig 1: Schematic diagram of turning operation (Hafr-Al-Batin Community College, Hand-out)

DEFORM-3D is a Finite Element Method (FEM) based tool on process simulation system designed to analyze machining processes used by manufacturing industries. By simulating manufacturing processes on a computer by DEFORM-3D, these are following advantages:

- Reduce the need for shop floor trials and redesign of tooling.
- Improve tool and die design to reduce overall costs of products.
- A better tool geometry is easily design, which can help to reduce the thrust force (B.Padma Raju and M.Kumara Swamy 2012).
- Shorten lead time in bringing a new product to market.
- Software has extensive material library (Corina Constantin et al.)

2. TURNING SIMULATION USING DEFROM-3D

Turning modelling procedures in DEFROM-3D software enable to study the process response for any change in process conditions. The effect of process parameters i.e. cutting speed, feed rate and depth of cut on the process response i.e. cutting forces, temperatures or stress etc can be study by it. For turning of work piece, the relationship with insert to the analysis domain is shown in Fig 2.

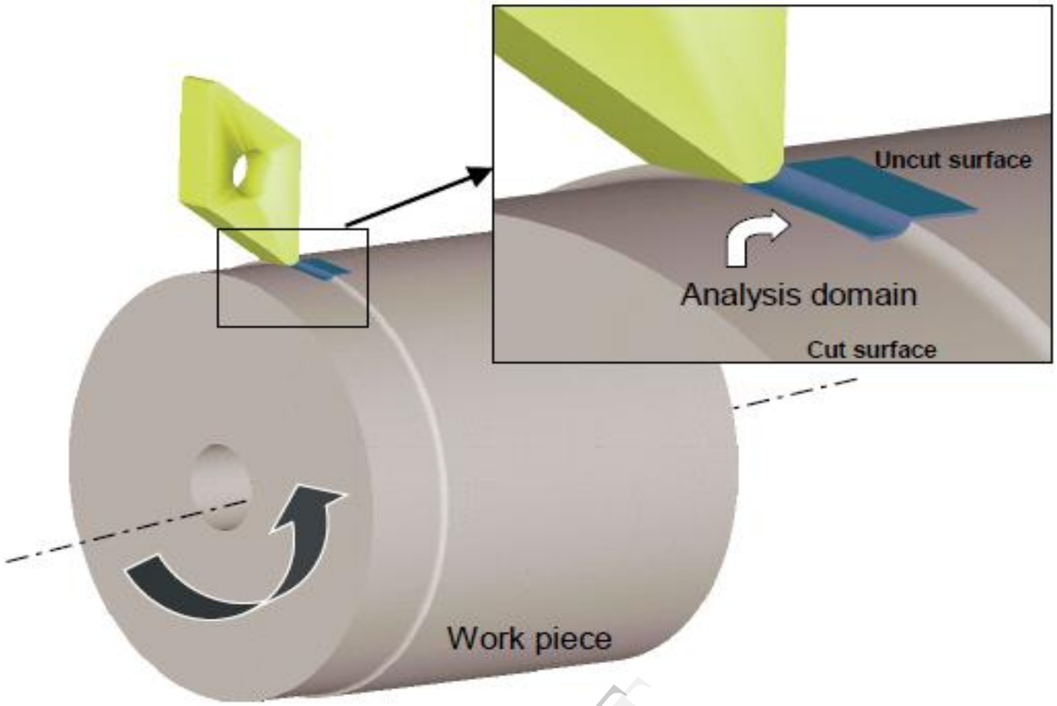

Fig 2: Basic components of Turning and its relationship (Deform-3D User's Manual)

Experiments will be conduct based on Taguchi's method with three factors at three levels each for turning simulation of Ti-6Al-4V material on DEFROM-3D to analyze the temperature. The factors will be study and their levels chosen are detailed in the Table 1.

Table 1: Turning Parameters and Their Levels (Satyanarayana Kosaraju et al. 2012)

Sr. No.	Parameter	Level		
		1	2	3
1	Cutting Speed (m/min)	45	60	75
2	Feed Rate (mm/rev)	0.25	0.30	0.35
3	Depth of Cut (mm)	0.5	1.0	1.5

Put the dimensions and materials in a pre-processor for creating work piece and tool, the data required like processing conditions of turning to analyze the simulation of temperature. A simulation engine is analyzing the results by numerical calculations.

After completing the simulation in simulation engine, displaying the results graphically in a post-processor at each position of both work piece and tool interface as shown in Fig 3.

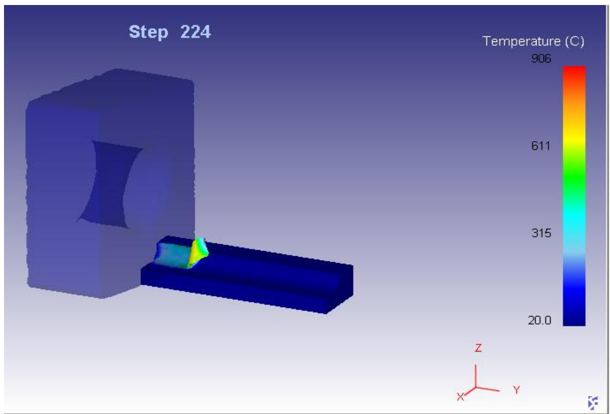

Fig. 3: Temperature Simulation Results of work piece and tool interface

Fig 4 shows the graph of generated temperature at every point of work piece by turning simulation. At step 224 the simulation temperature is 812 ^{0}C.

Fig. 4: Generation of results in form of Graphs

3. RESULTS AND DISCUSSION

The results of temperatures which were measured after all the nine experiments perform in DEFORM-3D. Now, after analyzing the experimental data from the test, the data is feed into the Minitab software for finding the optimum value from the parameters being taken in this experimentation. The S/N ratio and the mean values were calculated by putting the values of Temperature in Minitab software. The results of temperatures are shown in Table 2.

Table 2: Results of Temperature by Simulation

S.No	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Simulation Temperature (^{0}C)
1.	45	0.25	0.5	631
2.	45	0.30	1.0	645
3.	45	0.35	1.5	668
4.	60	0.25	1.0	739
5.	60	0.30	1.5	732
6.	60	0.35	0.5	729
7.	75	0.25	1.5	814
8.	75	0.30	0.5	769
9.	75	0.35	1.0	764

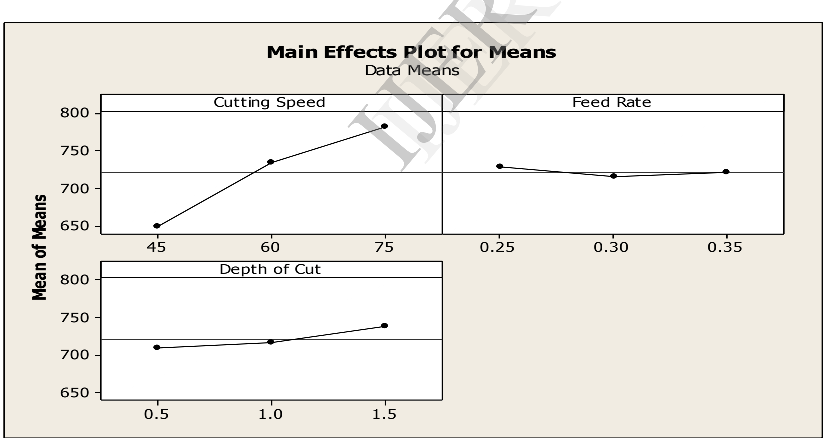

Fig 5: Showing the effect of turning Parameters on Mean Temperature

Fig 5 shows effect of various turning parameters on the mean of temperature plotted utilizing the DEFORM results obtained. From the figure, it is observed that the mean value of temperature is increase by increasing the cutting speed from 45 to 60 and 60 to 75 m/min. The mean of temperature is slightly decrease by increasing the value of feed rate from 0.25 to 0.30 mm/rev and after that if increase the feed rate from 0.30 to 0.35 mm/rev the temperature is slightly increase. It is observed that the mean value of temperature is increase by increasing the depth of cut from 0.5 to 1 and 1 to 1.5 mm.

4. CONCLUSIONS

In this thesis work, a thermo-mechanical model of turning with continuous chip formation is presented with help of DEFORM. The developed model is able to predict temperature distributions. Followings are conclusion from analysis;

1. The mean value of temperature is smaller for of 45 m/min cutting speed which is 648^0c.
2. It is observed that the mean value of temperature is smaller for 0.30 mm/rev of feed rate which is around 715.3^0c.
3. It is observed that the mean value of temperature is smaller for 0.5 mm of depth of cut which is 709.6^0c.
4. For Ti-6Al-4V materials the optimum machining condition for achieving minimum temperature (θ) was obtained as $v_1f_2d_1$ i.e. cutting speed (45 m/min), feed rate (0.30 mm/rev), and depth of cut (0.5 mm).

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