Cutting temperature prediction during machining of titanium alloy using DEFORM-3D

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Abstract: 3D simulation of turning process is carried out through Deform-3D software. The workpiece considered for the simulation is Grade 5 of titanium alloy. The dry turning simulation operation is performed with uncoated cutting insert. Optimization of the simulation increases the productivity. Hence, Modeling and simulation closed to the actual cutting process have to be taken in account in terms of the thermal analysis. The 3D simulation is simulated as per the Taguchi L9 orthogonal array. Three cutting parameters is varied at three different level. The cutting temperature data as per the experimental layout are recorded and the effect of cutting parameter on cutting temperature are discussed. Result revealed that increasing in cutting speed the cutting temperature increases.

Keyword: Deform-3D, Cutting temperature, titanium alloy, Process simulation,

Introduction

The turning process is one of the common process which is carried out in most of the industry and it has an uncountable number of applications in almost all the field. In this turning operation mostly the diameter of the cylindrical workpiece is reduced to achieve the desired shape of the component[1].

Many of the researchers had develop a lot of modeling techniques, numerical approaches, finite element methods and empirical method. In current diegetic the simulation analysis of the machining operation is widely used for calculating various types of output responses. [2]. Metal cutting simulation is a complicated and complex because of large deformation in nonlinear process. By help of such simulation techniques the machining operation have develop a potential to improvise the cutting variable and to redesign the cutting tool [3]. Deform-3D software provide a node deleting and generating criteria which lead to development of the new surface after machining and creating of the chip during the simulation process. [4].

In general, all the machining process deals with the heat zone develop during cutting of workpiece with cutting tool. Heat play a major role since is transmitted between the cutting tool and cutting tool. Also, the heat affects the tool chip interface area near to the cutting edge. The heat is transferred in two to three fundamental heat exchange mediums. [5]. The machining simulation of the turning operation need some basic thermal fields and law of continuity represent the beginning of the calculation model. During modeling of the turning operation, the relation between the cutting tool and the workpiece have to be properly defined in terms of both mechanical and thermal aspects. In this paper the cutting temperature is recorded after the simulation is carried out as per the L9 orthogonal layout and the result is being discussed.

3D simulation using Deform-3D

The simulation of the turning operation is done through Deform 3D software.[6] The cutting variable considered for the simulation are cutting speed, feed and depth of cut. The cutting variable are varied with three level. So, if the full phase simulation is the be carried out with all the combination of level and parameter than total 27 simulation has to be conducted. Hence to reduce the simulation time, and number of simulations run the taguchi orthogonal approach is considered. The Taguchi L9 orthogonal is considered and according to the level and cutting parameter of the L9 layout as shown in table 1 the simulation is performed. The cutting variables and levels are cutting speed (A) at 40, 65 and 112 m/min, feed (B) at 0.04, 0.08. and 0.16 mm/rev, the depth of cut

(C) at 0.04, 0.08 and 1.6 mm respectively. Level 1 is lower value, level 2 is medium value and level 3 is higher value.

Table 1 Taguchi L9 layout

Sl no	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The simulation is performed in the Deform-3D software in three steps. The first step is pre-processor in this step the cutting tool, workpiece, cutting parameter, boundary condition and the environmental condition is defined. The second step is simulation in this step the simulation is carried out as per the defined solver. Finally, the third step is post-processor where the result is being depicted and analyze.

In this paper the uncoated cutting insert with the specification of SNMG120408 is design using the 3D modeling software and the design is save in the stereolithography format (.STL). This key file is imported to the Deform3D software as depicted in Figure 1. The material of cutting insert is defined from the material library i.e. tungsten carbide. The workpiece is created inside the Deform-3D workbench and the workpiece material is defined as titanium alloy of grade 5. The boundary condition of the cutting operation is defined inside the workbench. The lower art of the workpiece is fixed. The cutting insert is considered to be rigid body. The linear movement of cutting tool is defined by cutting speed and the motion of workpiece kept constant. The meshing of workpiece and the cutting insert is fixed i.e. 25000[7]. The simulation is carried out and total nine cutting temperature data is recorded as per the Taguchi L9 layout.

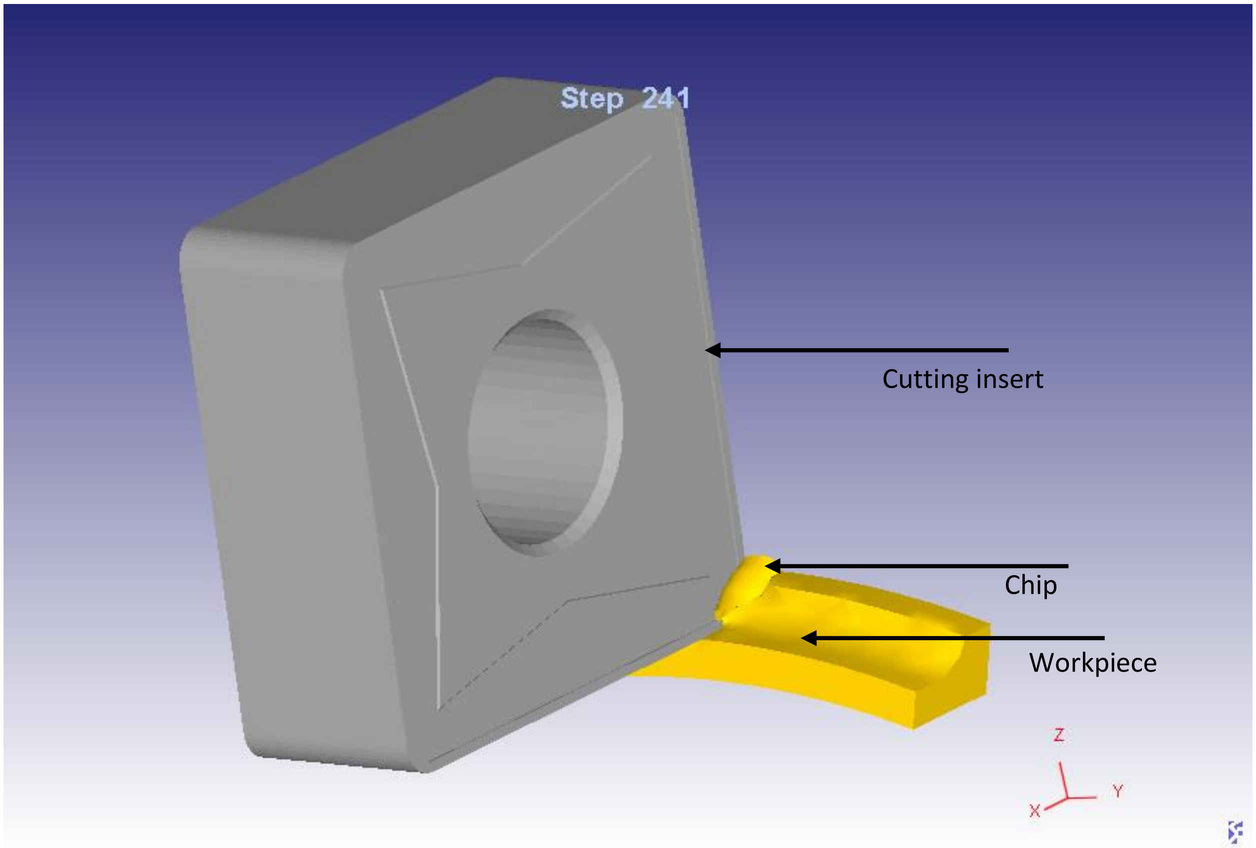

Figure 1 Cutting insert with workpiece

Result and Discussion

All the nine runs are simulated as per the L9 layout[8]. During simulation each run have different cutting speed, feed and depth of cut. The chip is formed in each of the run with Lagrange separation method.

The cutting variable and the cutting variable level are tabulated, the simulation is carried out and the cutting temperature according to each cutting variable and level are show in the Figure 2-11. In the Figures the cutting temperature at each of the different is zone is shown. The temperature distribution as per the cutting time is observed

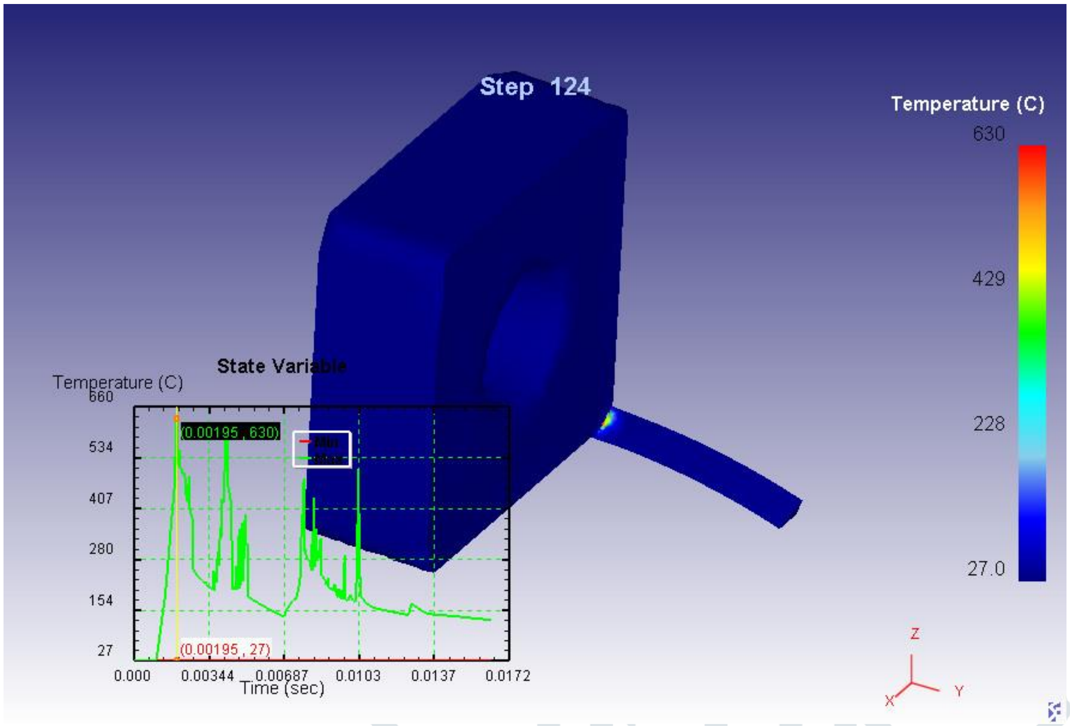

Figure 2 Cutting temperature at A 40 m/min, B 0.04 mm/rev and C at 0.4 mm

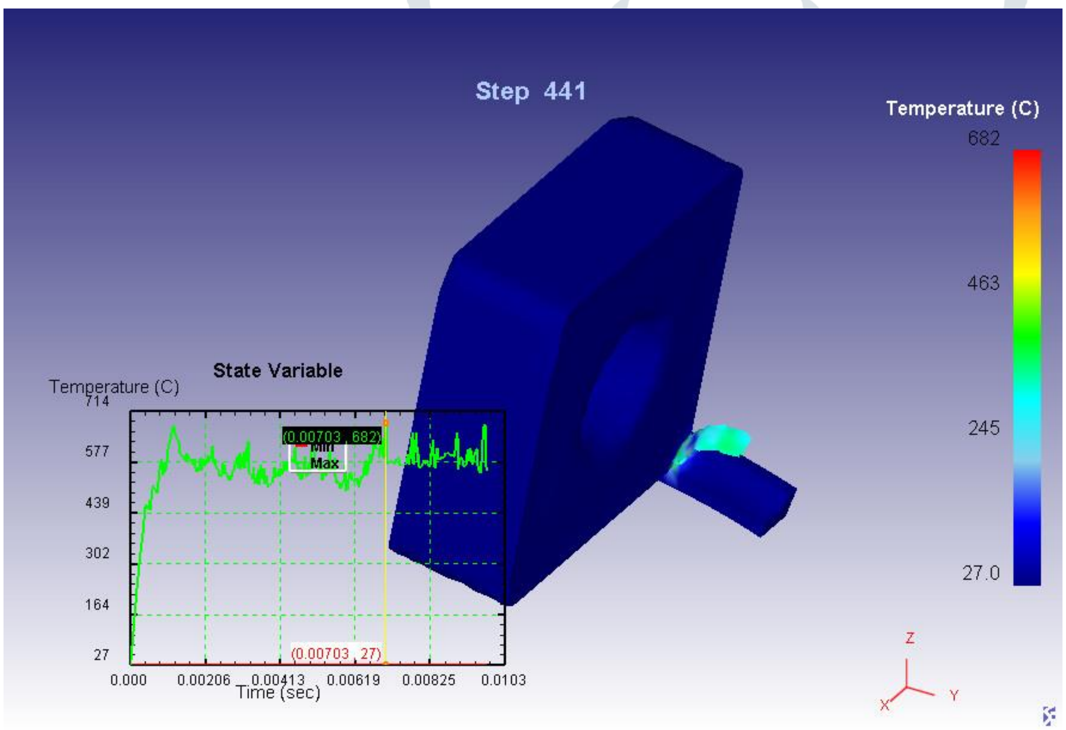

Figure 3 Cutting temperature at A 40 m/min, B 0.08 mm/rev and C at 0.8 mm

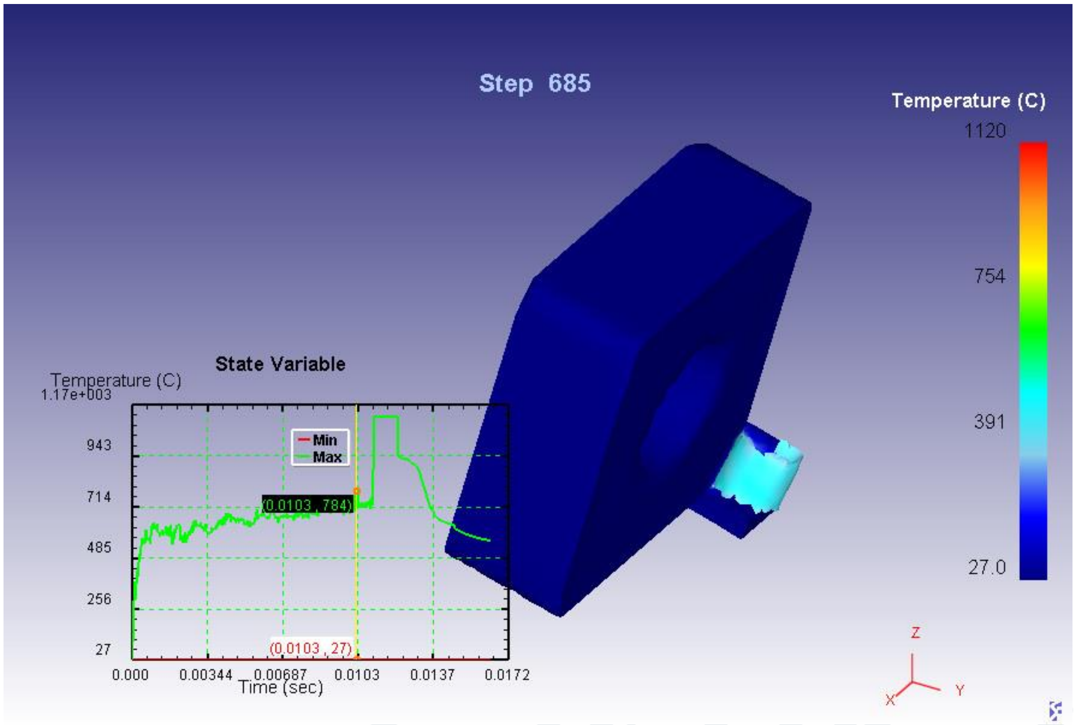

Figure 5 Cutting temperature at A 40 m/min, B 0.16 mm/rev and C at 1.6 mm

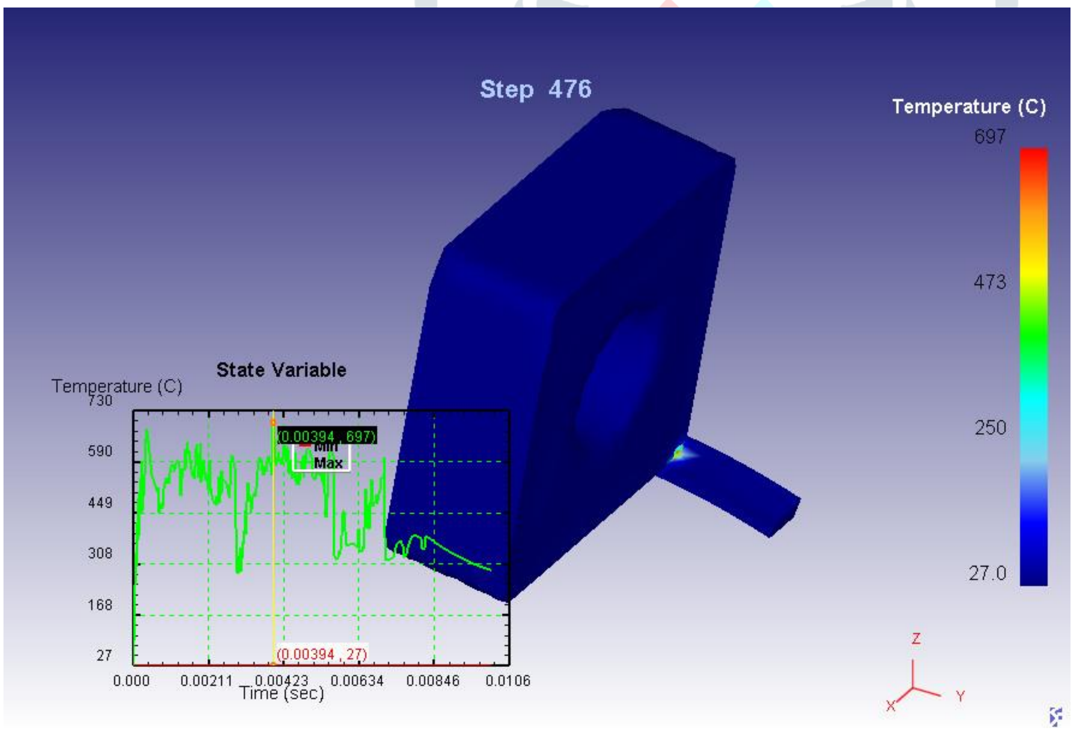

Figure 6 Cutting temperature at A 65 m/min, B 0.04 mm/rev and C at 0.8 mm

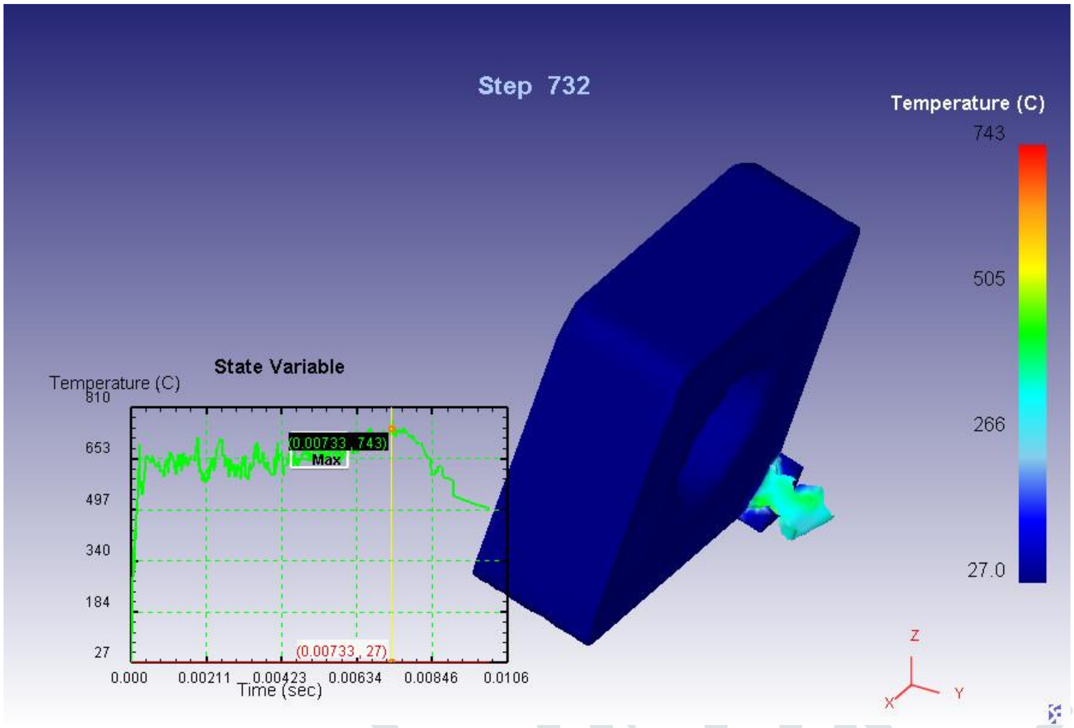

Figure 7 Cutting temperature at A 65 m/min, B 0.08 mm/rev and C at 1.6 mm

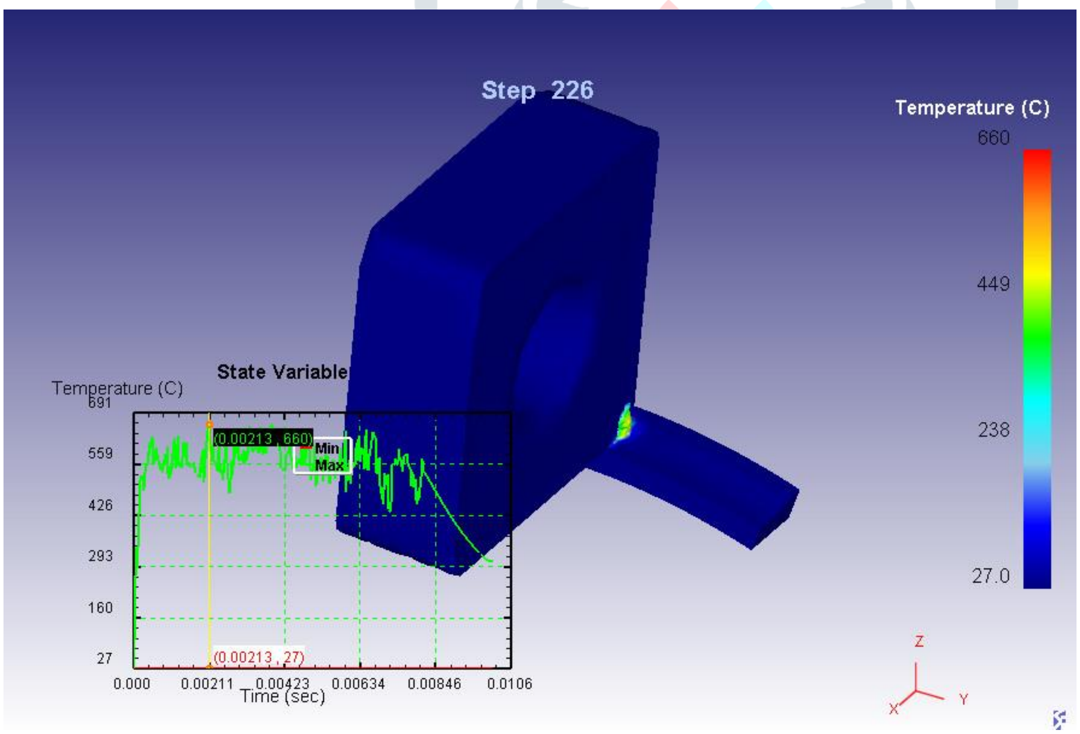

Figure 8 Cutting temperature at A 65 m/min, B 0.16 mm/rev and C at 0.4 mm

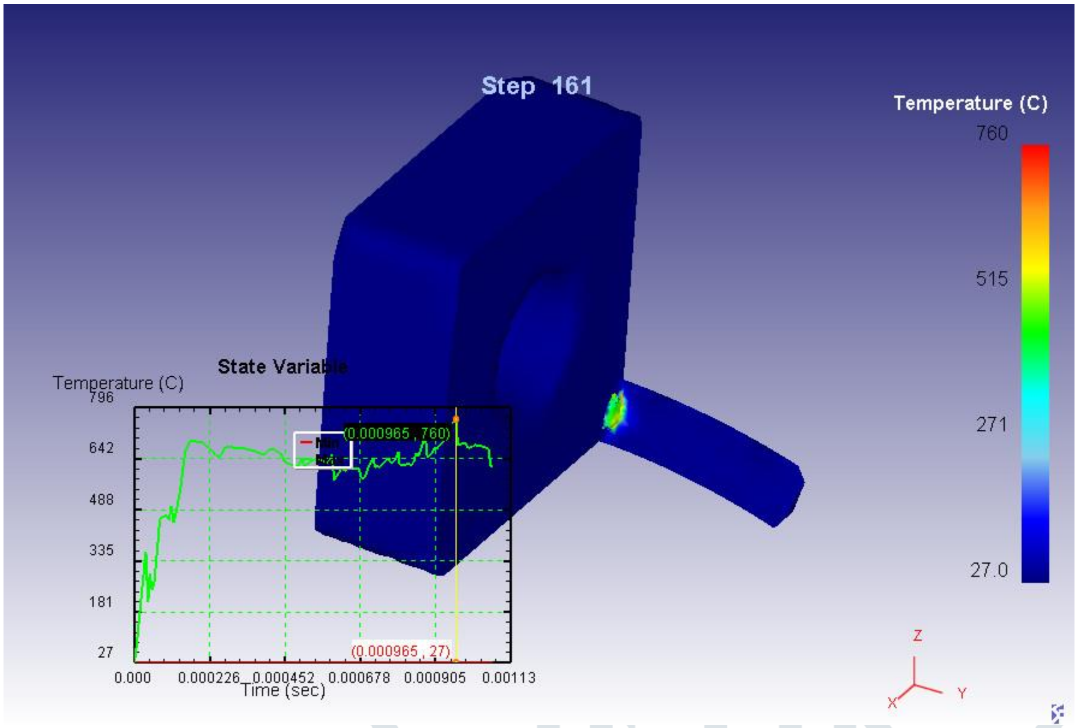

Figure 9 Cutting temperature at A 112 m/min, B 0.04 mm/rev and C at 1.6 mm

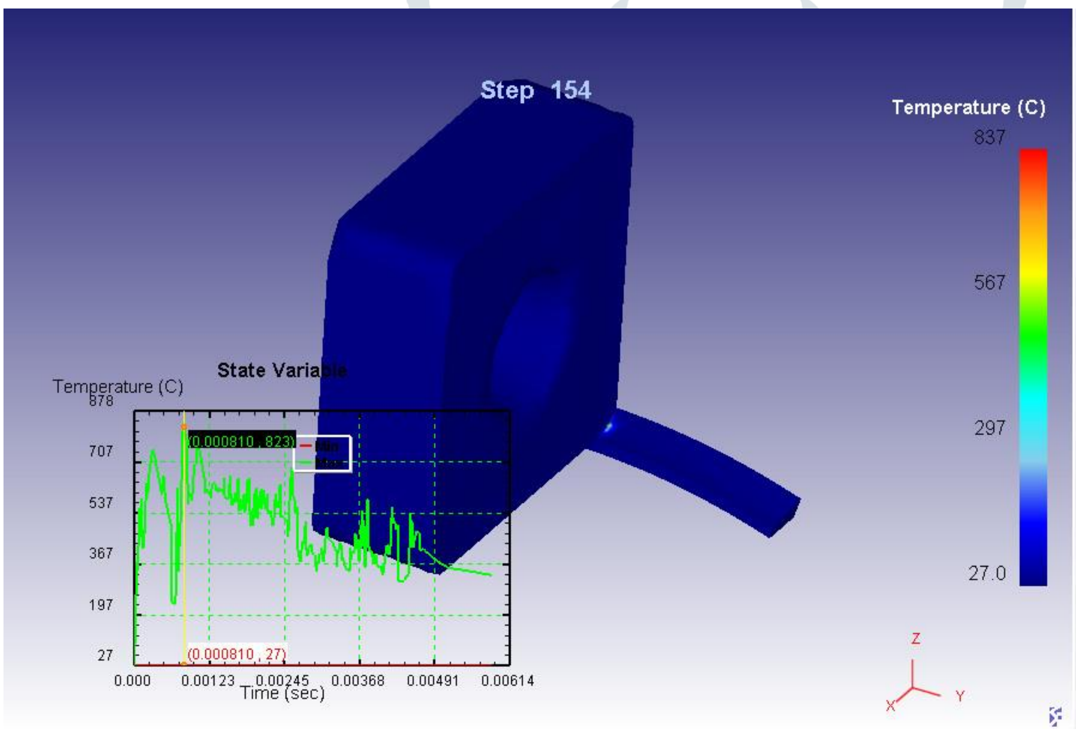

Figure 10 Cutting temperature at A 112 m/min, B 0.08 mm/rev and C at 0.4 mm

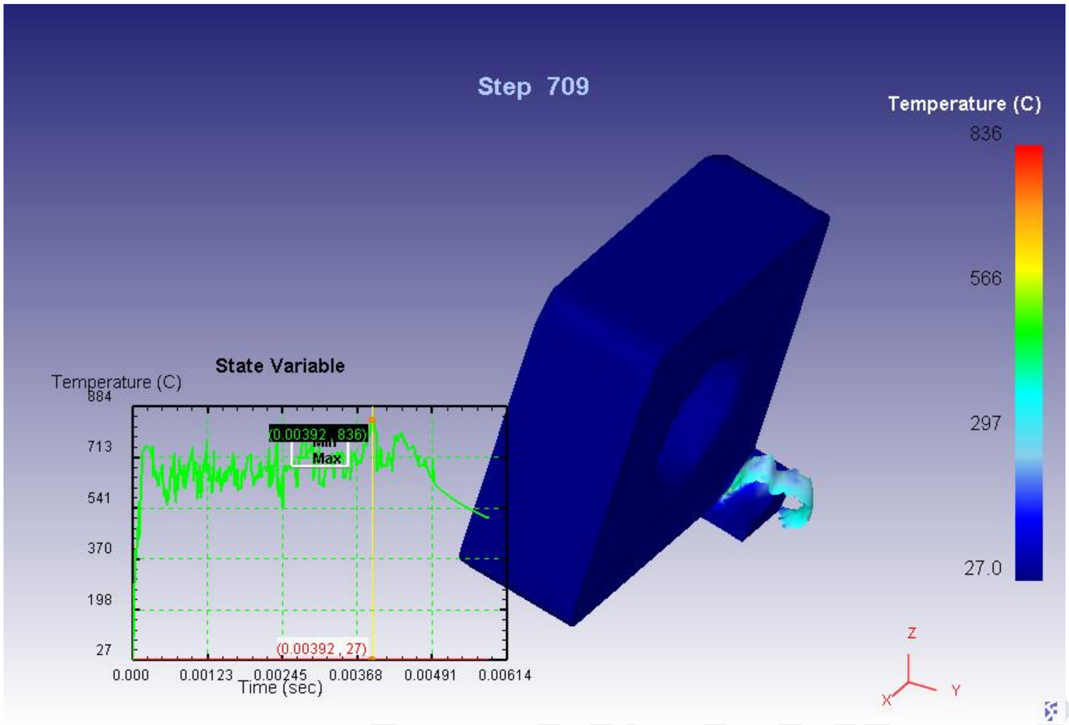

Figure 11 Cutting temperature at A 112 m/min, B 0.16 mm/rev and C at 0.8 mm

It observed form the figure that increase in cutting speed the temperature increases. Cutting temperature also increases with feed. Similarly, with the increase in the depth of cut the cutting temperature increases. As it is well known that, plastic deformation and the acts of friction at the rake and chip surface generate the heat. The shearing occurs which causes the outflow of metal in the rake surface results in severe distortion to the bottom surface of the chip and increases the temperature in the tool chip interface [9]. From the figures it is depicted that maximum temperature appears at contact zone of workpiece tool interface zone. The chip formed due to the shearing action creates the deformation zone which contains high strain rate and strain which increases the temperature. Further chip carries the temperature and due to high speed, the cooling time is very less. The chip rapidly flow over the rake surface generates high friction thus the cutting temperature increases.

Conclusion

The FEM simulation of the machining process is done by using the DEFORM-3D software. To study the generation of cutting temperature while machining the titanium ally of grade 5 with the uncoated tungsten carbide cutting inserts. The result revealed that the maximum temperature appeared when the cutting speed is high.

Acknowledgements

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