International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.3, pp 137-142, 2017

Modeling and Simulation of Drilling Process in Ti-6Al-4V, Al6061 Using Deform-3D Software

Pravin Pawar[1]*, Raj Ballav[2], Amaresh Kumar[2]

[1]Ph.D. Research Scholar, Department of Manufacturing Engineering, National Institute of Technology, Jamshedpur, India, 831014
[2]Associate Professor, Department of Manufacturing Engineering, National Institute of Technology, Jamshedpur, India, 831014

Abstract : The drilling is an important process for the manufacturing of any products. In the present work the drilling process is carried out by finite element modeling and simulated with the help of DEFORM-3D software. The diamond drill bit tool is used for drilling of Ti-6Al-4V and Al6061 alloy material. The titanium alloy which is widely used in the field of biomedical applications, whereas the Al6061 aluminum alloy is mostly applicable in automotive and aerospace industries. The geometrical shape and input process conditions are same for both materials. According to the simulated results, it is observed that the Ti-6Al-4V material shows the maximum effective stress and temperature during the drilling process than Al6061 material, which may possibly be an effect of physical properties of Ti-6Al-4V material.
Keywords: Drilling Process, Ti-6Al-4V, Al6061 Deform-3D Software.

1. Introduction

Titanium alloy has biocompatibility properties due to which it is used in biomedical applications such as artificial hip joints, cardiac valve prostheses, artificial knee joints, bone plates, screws for fracture fixation, dental implants, dental crowns, dental bridges[1]. The aluminum alloy also has a variety of applications i.e. the pressure vessels, cooking utensils, construction of machines, structures and appliances, automotive industry and aerospace industry[2]. The titanium alloy and aluminum alloy, both materials have the wide range of applications, hence there is the requirement of different machining process which can be applied to these materials for the production of various products. The drilling process is mostly used for making a hole in the materials. It is one of the important and the final step in the manufacturing of mechanical components. In advancement, the drilling process has a touch of different simulated software which will help to predict the various parameters related to this process. The AdvantEdge software is used to predict the thrust force, torque, deformation, drills temperatures and stresses of Ti-6Al-4V using a spiral point drill[3]. Similarly, the effect of high ultra cutting speeds on the residual stress in the drilling of the Ti-6Al-4V alloy also obtained by using numerical methodology[4]. For the drilling of the aluminum, the workpiece is analyzed by diamond coated carbide drills, whereas uncoated carbide tools were used for drilling of Ti-6Al-4V titanium alloy, which is resulted into the influence of cutting speed and feed rate on burr size, hole diameter[5]. The investigated force and deformation of structural steel broach tool was applied to titanium alloy, aluminum alloy, copper alloy, magnesium alloy by using ANSYS software. According to them, maximum stress was occurred on the titanium alloy[6].

In the present study the drilling process is analyzed by using DEFORM-3D Software which is an extremely effective in a wide range of research institutes and industrial applications[7]. The diamond drill is used as a tool to drill the titanium alloy and aluminum alloy in cylindrical shape.

2. Finite Element Method and Simulation Model

The finite element method analysis was executed by DEFORM-3D software. It is developed by SFTC (Columbus, OH)[8], The FEM analyses in DEFORM-3D having three steps: preprocessor, simulation and post processor (Deform 3D-V6.1, User's Manual). In the pre-processor, the original data for modeling and simulation should be set[9]. In this work, the FEM code is created based on Lagrangian incremental computational routine. The study shows drilling of cylindrical shape titanium alloy and aluminum alloy using a diamond drill bit. The tool and Workpiece are modeled as plastic geometry shape and figure 1 presents the meshed model of tool and workpiece. In this geometry model drill tool having elements of 8780 and nodes of 2365 and Workpiece having elements of 46394 and nodes of 10364. The material properties of diamond, titanium alloy and aluminum alloy are shown in table1.

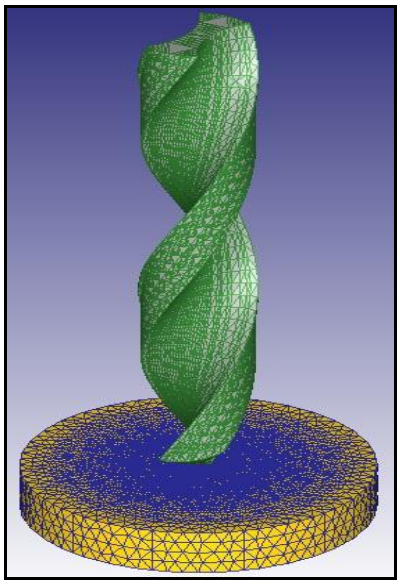

Figure 1. Deformed Meshed model for the drilling process simulation

Table1: Materials Properties

No.	Materials	Density (g/cm^3)	Young's Modulus (GPa)	Poisson's Ratio	Shear Modulus (GPa)	Yield Strength
1	Diamond	3.50	1050	0.10-0.29	478.0	60 GPa
2	Al6061	2.7	68.9	0.33	26.00	276 MPa
3	Ti-6Al-4V	4.42	110	0.31	40.00	950 MPa

3. Workpiece materials and Cutting Tool Parameters

In this FEM analysis diamond drill tool material is used for making a drill in the cylindrical shape in Ti-6Al-4V and Al 6061 alloy material. The cutting speeds 1000 mm/sec and the feed rate of 0.5 mm/rev were applied as machining parameters in the simulated drilling process. The tool wears calculations using equations 1 empirical Usui model. Table 2 shows the input of cutting parameters and simulation values for drilling operations.

$$W = \int apVe^{\frac{-b}{T}}\, dt \quad \text{_____ (1)}$$

P= interface pressure, V= sliding velocity

T= interface temperature (in degrees)
Dt= time increment
a,b = experimentally calibrated coefficients, a= 1e-5, b=1000

Table 2: Geometrical, Input and Simulated parameters

Main Category	Sub Category	Values
Cutting Parameters		
	Cutting Speed	1000 mm/sec
	Feed Rate	0.5 mm/rev
	Temperature	20 c
	Convection coefficient	0.02 N/sec/mm/C
Tool Workpiece Parameters		
	Shear friction Factor	0.6
	Heat transfer coefficient	45 N/sec/mm/C
Drill Geometry Parameters		
	Drill bit diameters	10mm
	Number of flutes (cutting edges)	2
	Drill radius	5 mm
	Web thickness	1.8mm
	Helix angle	30 deg
	Point angle	118 deg
	Margin	0.4 mm
	Clearance	0.2 mm
Workpiece geometry Parameters		
	Diameter	30mm
	Thickness	5mm
Simulations Steps		
	Number of simulation steps	1000
	Step increment	25
	Drill depth	2.5 mm

4. Results and Discussion

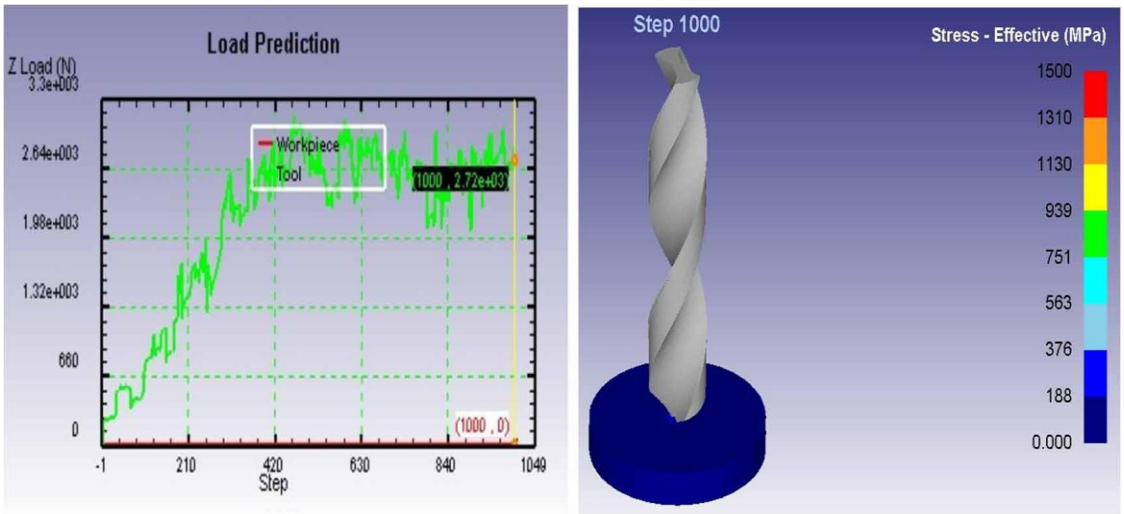

Figure 2 Load Predictions and

Figure 2 shows Ti-6Al-4V titanium alloy load prediction of the drilling process at 1000 simulation step interval. The maximum load occurred was $2.72e^{+3}$ and maximum effective stress obtained 1500 at 1000 simulation steps interval. There is no any deformation between drill tip point and Workpiece surface during drilling operation because of materials physical properties. The figure 3 shows that the total displacement obtained during drilling operation which is maximum up to 8.91mm and temperature occurred during drilling of Ti-6Al-4V titanium alloy material is about 618˚C and it shows very less deformation which indicates that the temperature generates between tool and workpiece deformed area.

Effective Stress in Drilling Operations of TI-6Al-4V Material

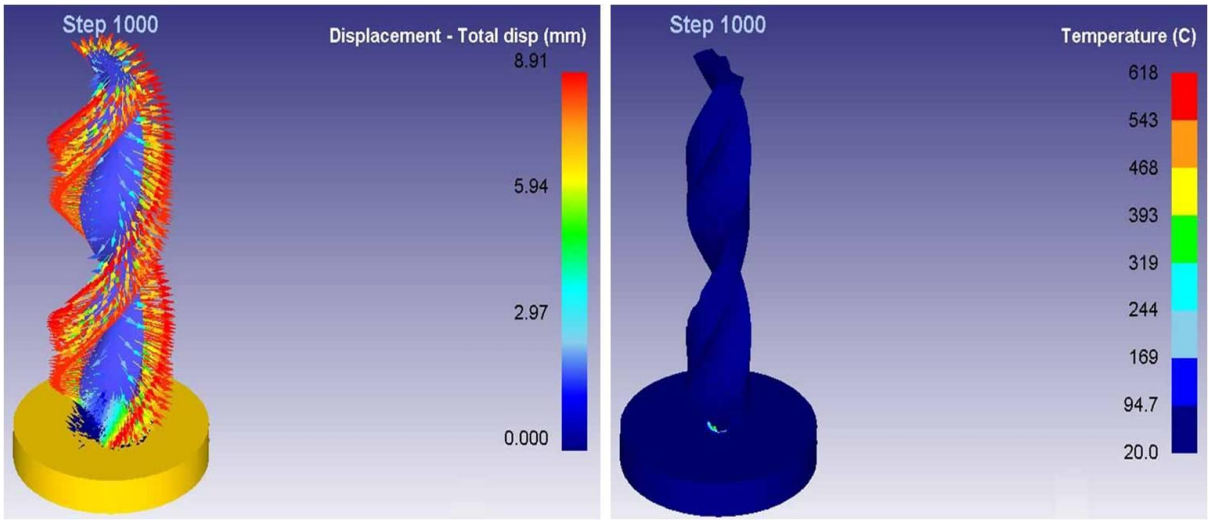

Figure 3 Total Displacements and Temperature in Drilling Operations of TI-6Al-4V Material.

Figure 4 shows a load prediction of the Al6061 aluminum alloy during the drilling process at 1000 simulation step interval. The maximum load occurred was 1.83e+3 and maximum effective stress obtained 739 at 1000 simulation steps interval. The deformation was observed between drill tip point and Workpiece surface during drilling operation because of physical properties material. The figure 5 show, the total displacement obtained during a drilling operation and it is maximum up to 8.91mm and temperature occurred during drilling of Al6061 aluminum alloy material is about 260 C and its shows very less deformation which indicate that the temperature generates between tool and workpiece deformed area.

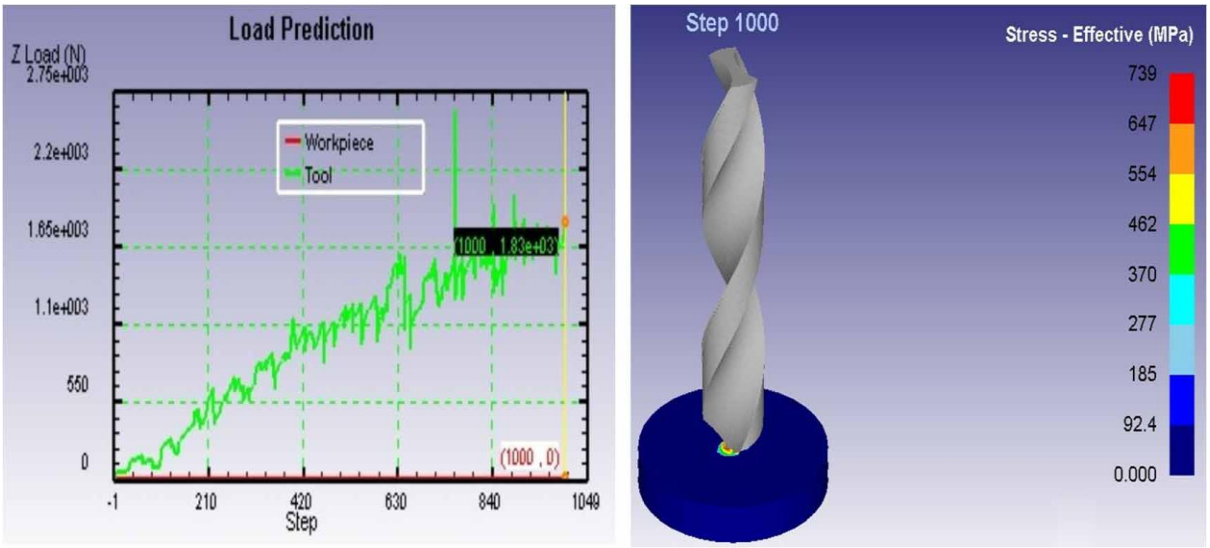

Figure 4 Load Predictions and Effective Stress in Drilling Operations of Al6061Material

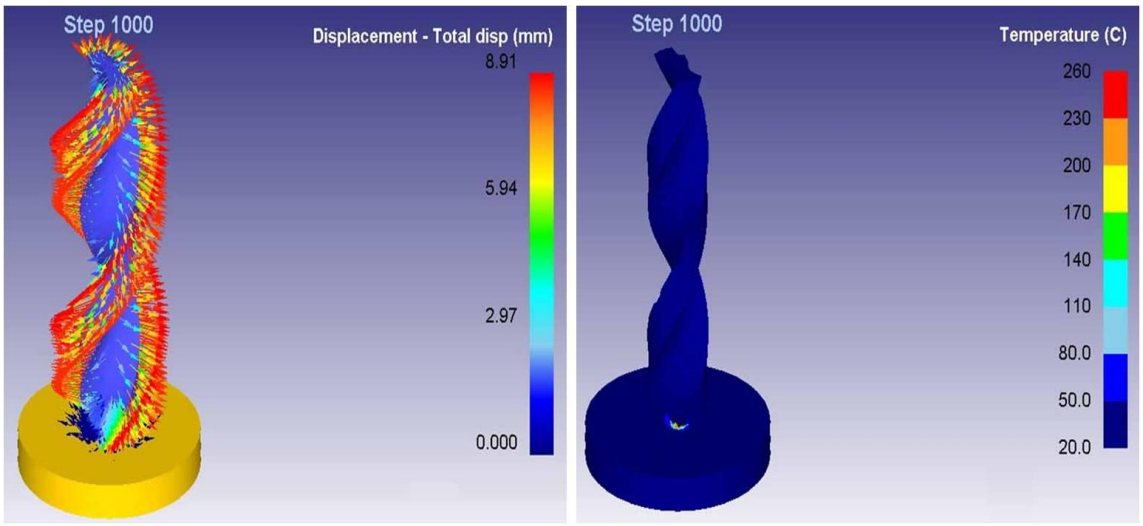

Figure 5 Total Displacements and Temperature in Drilling Operations of Al6061 Material.

Figure 6 shows effective stress versus materials and temperature versus materials. The effective stress, as well as temperature, is occurred maximum in Ti-6Al-4V titanium alloy material in a drilling process as compared to Al6061 aluminum alloy material due to its physical and mechanical properties of materials.

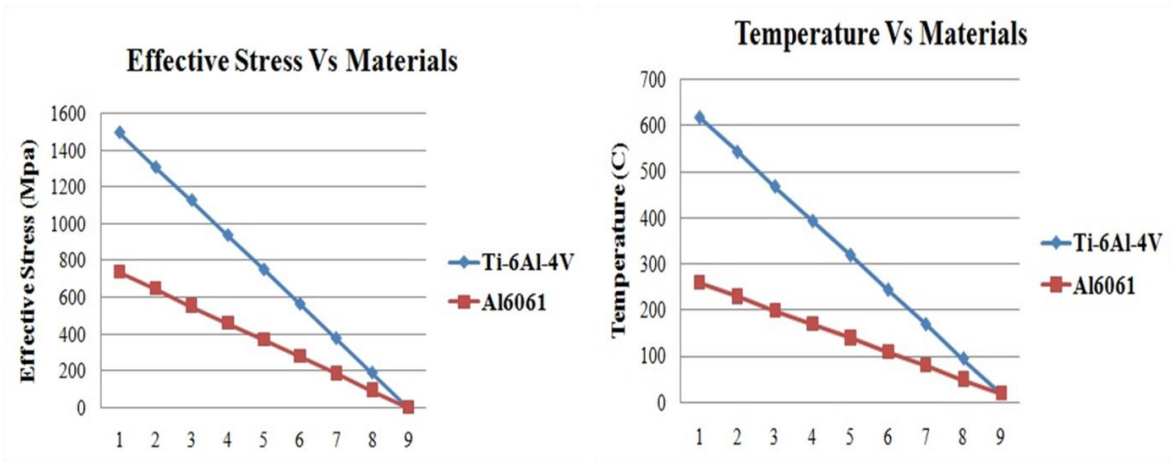

Figure 6 Graph of Effective stress Vs Materials and Graph of Temperature Vs Materials.

5. Conclusion

This paper proposed finite element method analysis of diamond tool drilling process applied on Ti-6Al-4V titanium alloy and Al6061 aluminum alloy material. The DEFORM-3D software is used for modeling and simulation of the drilling process to estimate stress and temperature occurred during this process.

From this analysis, it is concluded that maximum effective stress of 1500 Mpa and maximum temperature of 618˚C occurred in Ti-6Al-4V titanium alloy than that of Al6061 aluminum alloy material because of its physical and mechanical properties.

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