Analysis of Turning Process of Pure Titanium Using Finite Element Method

Dumitru Panduru(✉), Marin Bica, Nicolae Craciunoiu, Ionut Geonea, and Emil Nicusor Patru

Faculty of Mechanics, University of Craiova, 200512 Craiova, Romania
dumitru_panduru23@yahoo.com

Abstract. In this paper finite element analysis is applied to evaluate the results regarding the stress and deformation during the turning process of the commercially pure titanium. The results are a very important task to appreciate the state of the piece, from point of view of stress and deformations, during the machining process.

In order to perform this analysis, a 3D model of the assembly is developed, with respect to the real dimensions for each of the components, part and tool, respectively. Then, the 3D model was transferred to the finite element analysis software, where, starting with the input data, meaning the mechanical properties of the pure titanium, the appropriate mesh and loading applied, but also interactions between the bodies, the results of the analysis, were obtained. For 3D model and finite element analysis, the dedicated software is used.

Keywords: Pure titanium · 3D model · Finite element analysis · Stress · Deformations

1 Introduction

In the last year, the tendencies are to used titanium and its alloys, on the large scale, in the automotive industry, not only for exhaust pipes and mufflers, but also for engine valves, both intake and exhaust valves, especially due to their advantages: wear resistance, high fatigue strength and high heat resistance, [1].

The same properties recommend, also, commercially pure titanium and titanium alloy Ti6Al4V for the aerospace industry, [2], mainly used for airframe and engines parts.

From point of view of machining of pure titanium, it can appreciate, that for these materials is a very difficult process, of especially due to the low thermal conductivity, [3]. On the other point of view, the high chemical reactivity can produce adhesion of the chips to the tool and, as a consequence, built-up edge formation. Also, the low elastic modulus, can negatively affect the deflection of the workpiece.

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Furthermore, pure titanium and its alloys are considered with a poor machinability. For this reason, many machining operations of titanium, like drilling and turning in many cases cannot be performed on the CNC machining center or automated machines, especially due to the formation of a long chips which is wrapped on the tool.

The finite element method is a well-known method used in the simulation of the cutting processes, and is a very used tool to estimate the temperature, forces, vibration tool wear, chips formation process, stress and deformations, and not only, based on input data (cutting materials, cutting tools, cutting parameters - speed, feed, depth of cut).

For this reason, many researchers treat in their papers aspects regarding for this estimations, using adequate programs that involve finite element method, [4–7], for titanium, titanium alloys, carbide alloys or other different materials.

The advantage of this method is that, essentially, reduces the costs involved by experimental installations (cutting tool, work-piece, the tool used for collecting data and measurements, machine tools etc.).

In this paper, starting with the mechanical properties of pure titanium and cutting parameters used for the turning process (speed, feed and depth of cut), the stress and deformations are analyzed using finite element method.

First the assembly tool and work-piece were modeled in Solid Works, with respect to all the dimensional data about this component of the assembly.

2 Analysis Details

2.1 Work-Piece and Tool Materials

The materials used in the present analysis, are, for work-piece, commercially pure titanium, with the mechanical properties and chemical composition, present in Table 1, and, for cutting tool, carbide alloy, with the mechanical properties, presented in Table 2.

Table 1. Mechanical properties and chemical composition of pure titanium

Material	**Mechanical properties**	**Chemical composition**		
Commercially Pure titanium, Grade 2	Hardness, HRBW	C, %	Fe, %	Ti, %
	80	0.03	0.055	99.67

Table 2. Mechanical and physical properties for carbide alloy

Ultimate strength, Rm, MPa	Young's modulus, E, GPa	Poisson's ratio	Density, Kg/m^3	Thermal expansion	Heat Capacity, c
2600	800	0.22	14500	5.4	220

2.2 Assembly Workpiece-Tool

As it is presented in the previous section, first the assembly workpiece-tool, presented in real shape in Fig. 1, was developed in a dedicated program for solid modeling, SolidWorks, and then was exported in Ansys Explicit Dynamics, Fig. 2, *a* and *b*.

Then, in order to perform the finite element analysis, Ansys Explicit Dynamics was used, following the well-known steps: material properties both for tool and workpiece, defining the coordinated system, interaction between the bodies, with specifying a friction coefficient, having the value of 0.25.

After the meshing defining, Fig. 3, *a* and *b,* all the analysis results were obtained,

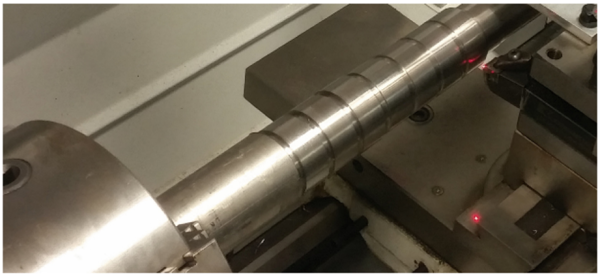

Fig. 1. Assembly work-piece and tool with carbide alloy

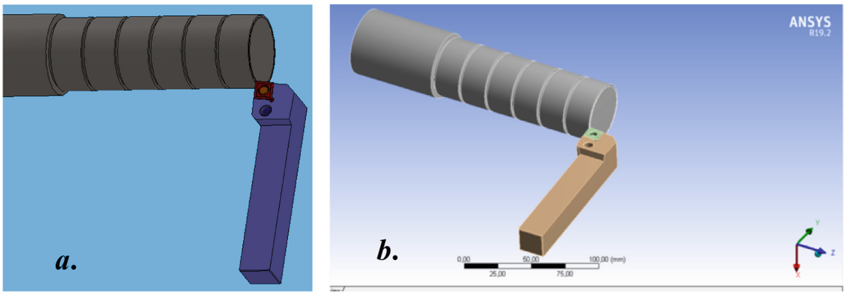

Fig. 2. 3D model for assembly workpiece-tool: *a.* developed in SolidWorks: *b.* exported in Ansys Workbench.

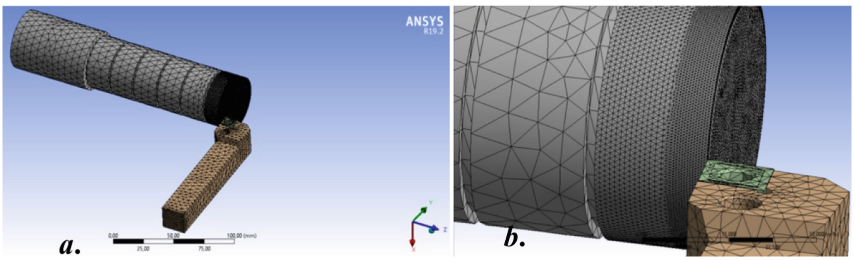

Fig. 3. Defining of the mesh, *a*, and corresponding detail for the cutting zone, *b*

3 Results

So, as the results, first, regarding to the total deformation, are presented in Fig. 4, *a* and *b,* having the maximum value of 3.7764·10^{-3} mm*,* and then, the equivalent Von Misses stress, having the maximum value of 1023.7 MPa, is presented in Fig. 5, *a* and *b.*

Shear elastic strain, having the value of 0,080746 mm/mm is presented in Fig. 6, *a* and equivalent elastic strain, with the value of 2,1224 ·10^{-6} mm/mm in Fig. 6, *b*.

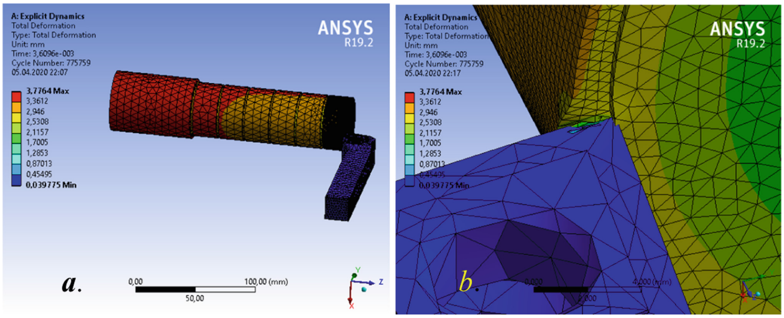

Fig. 4. Total deformation in the cutting zone with the value of 3,7764·10^{-3} mm, *a*, and detail, *b*

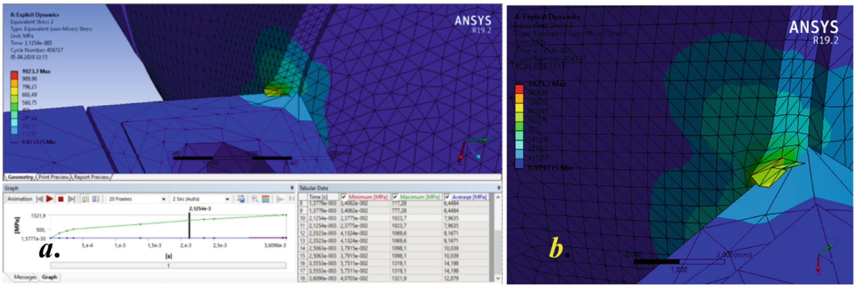

Fig. 5. Equivalent Von Misses stress, *a*, with the detail, *b*.

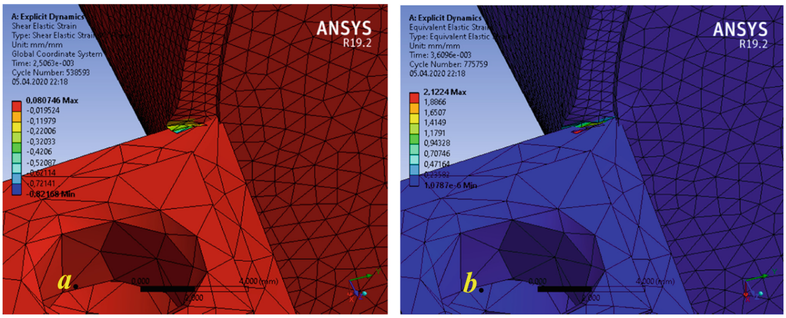

Fig. 6. Shear elastic strain, *a* and equivalent elastic strain, *b*.

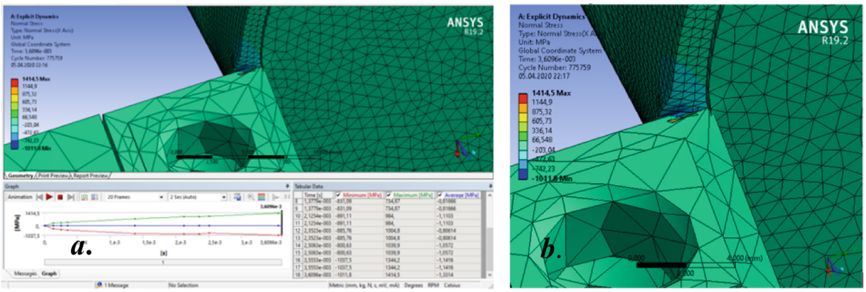

Fig. 7. Normal stress (X axis), *a* and corresponding detail, *b*

Normal stress, in X direction, with the value of 1414.5 MPa, with the corresponding detail is presented in Fig. 7, *a* and *b*.

4 Conclusions

In order to estimate the stress and deformation, for turning operation of pure titanium, using a tool, made from carbide alloy, in this paper the finite element analysis method is applied. First, the model was developed in Solid Works, and then exported in Ansys Explicit Dynamics.

After define of the input data, material for cutting tool, for the workpiece, with their mechanical properties, cutting parameters, meshing etc., the results of analysis was obtained, presented in Fig. 4 to Fig. 7, for total deformation in the cutting zone, equivalent Von Misses stress, shear elastic strain, and normal stress (X axis), respectively.

The values obtained, show the normal values, for the stress, deformations and strains under the admissible values.

So, for equivalent Von Misses stress, the maximum value is 1023.7 MPa, Fig. 5, for the normal stress the maximum value obtained is 1414.5 MPa, Fig. 7.

Also, for total deformation in the cutting area has the value of $3{,}7764 \cdot 10^{-3}$ mm, Fig. 4, while for shear elastic strain, Fig. 6, the maximum value obtained is 0,080746 mm/mm.

The results presented in this paper are for turning of pure titanium, grad 2. In order to have more results and to compare them, our intention is to continue the analysis, also, for titanium alloys.

Also, it can remark the fact that this analysis is very useful to identify several future researches regarding the other phenomena, as it is the temperature during turning of pure titanium, using the finite element simulation tools, and compare these values with the experimental values.

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