Aspects Regarding the Specific Energy and Temperature in Turning of Pure Titanium

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Abstract: *Pure titanium and their alloys are very used in aeronautical and automotive industry, but also in medicine and other domains, especially due to their high specific strength (strength/density) and excellent corrosion resistance, low conductibility etc., but, in terms of machinability, these materials are very difficult to cut especially due to the low conductibility. As results, a surface quality of the machined parts can be affected.*
In this paper, in order to appreciate the machinability of these materials the temperature and specific energy are analyze, using different cutting tools (uncoated carbide and ceramics inserts) and different value of the cutting parameters.
All the results are graphically representations and discussion and conclusion about the factors influence are presented.

Keywords: C*eramics inserts, Pure titanium, Specific energy, Temperature, uncoated inserts carbide*

1 INTRODUCTION

Titanium and its alloys are some of the most used materials and recommended in many fields, automotive especially, due to their mechanical and physical properties, but, in the same time, can be considered very difficult materials from point of view of machining, especially due to their low thermal conductivity. For this reason, the heat accumulation rise in the primary shear zone, and as effect, is affected tool life, surface quality and dimensional accuracy, [5].

Also, commercially pure titanium and titanium alloy Ti6Al4V, are used for aerospace industry, [3], mainly for airframe and engines parts.

From point of view of temperature, in [1] are analysed the performance of two types of inserts, ceramic and CBN, in turning of a titanium alloy, while in [7], is analysed the influence of the tool tip temperature on the wear for ceramic inserts, having different hardness.

In [9] the authors used simulations tool to obtain the temperature at tool-chip interface in orthogonal turning process.

In [11] the authors compare the temperature during turning process using the measured temperature with the one obtained by simulation for turning with coated carbide inserts,

Researches on the cutting temperature, for coated and uncoated inserts are done, also, in [4] and [10]. So, in [4], in order to obtain the useful data for optimization of cutting parameters, based on the two methods, with thermocouple and infrared based sensors, for coated carbide, as tool, they found that the increase of temperature is due to the increasing of speed, feed and depth of cut, while in [10] the authors, using coated and uncoated carbides tool, proceed to measure the turning temperature on the rake face using work thermocouple, and show that the increasing of the temperature is due to the increasing the cutting speed and feed rate.

2. HEAT IN CUTTING PROCESS

As it is known, generally, the cutting heat is transferred to the chip, tool, workpiece material, and environment, in approximate value presented in fig. 1. The cutting heat is generated due to the elasto-plastic deformations in the primary deformation zone, A (shear plane) and due to plastic deformation in secondary zone, B, (friction between chip and rake face of the tool), and friction in tertiary zone, C (flank face and work piece surface)

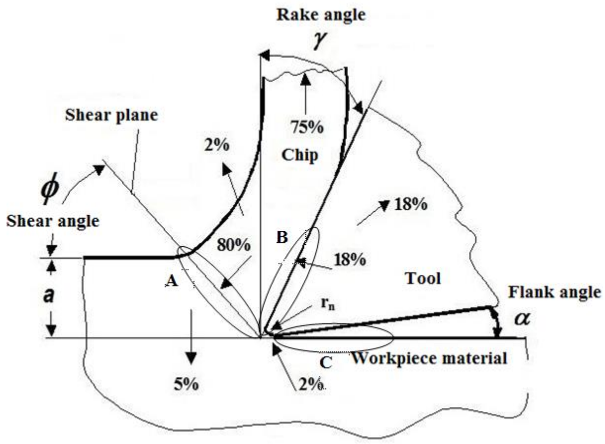

Fig. 1. Distribution of the cutting heat, as results of the cutting process

The deformations in the cutting area can be seen in fig. 2, as effect of simulation for turning process of pure titanium.

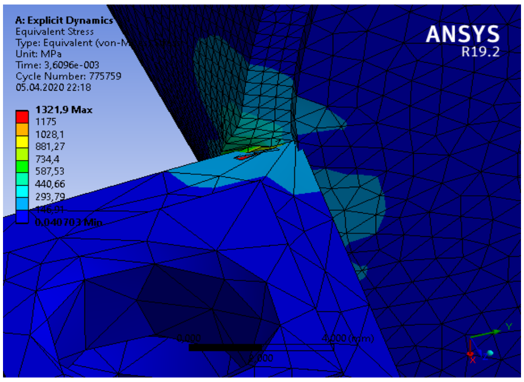

Fig. 2. Equivalent stress in cutting area for turning of pure titanium

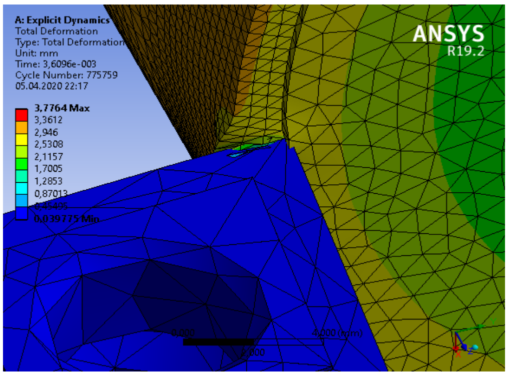

Fig. 3. Total deformation in cutting area for turning of pure titanium

3.MATERIALS AND EXPERIMENTAL CONDITIONS

Experimental instalation is presented in Fig. 4, is attached on a lathe with digital readout, and consists in a noncontact infrared thermometer, pure titanium workpiece, with ϕ45 mm, diameter, cutting tool, and three K-type Thermocouples.

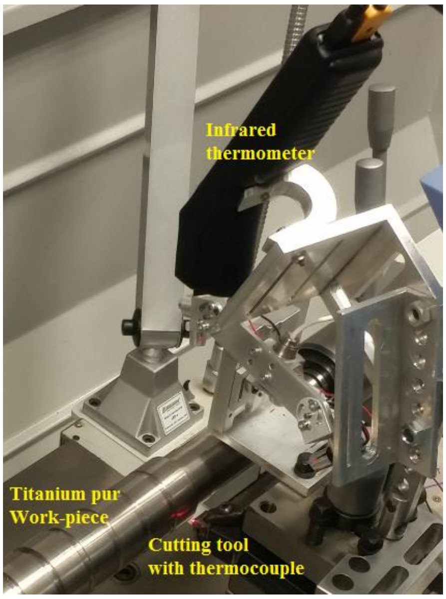

Fig. 4 Experimental installation

In order to compare the temperature during turning process of pure titanium, just the measuring values for temperature with infrared thermometer, are presented.

So, in this study two cutting tools was used: a single point tool, with carbide insert KCU10 grade, code CNMG 12 04 08 MS, support insert, cod CNMG 432MS, all assembled on a toolholder DCLNR 2020K12KCO 4, and a single point tool with ceramics insert, KYS25, grade, CNGA 120408E, suport insert DCLNR2020K12KCO4 NA7, [12].

In order to measure the temperature with infrared thermometer, closer to tip of tool, a hole with ϕ2 mm diameter and depth 4 mm was machining, just for carbide inserts, using EDM, a non-conventional technique, fig. 5.

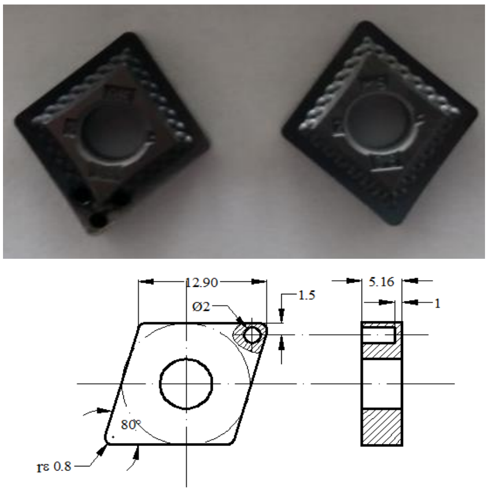

Fig. 5. Carbide insert with the holes for instaling of the thermocouples

From point of view of physical properties of the pure titanium, grad 2, these are presented in Table 1.

Table 1.Physical properties of pure titanium, grade 2

Material	Hardness, HRBW	Physical properties		
		Thermal conductivity λ, w/m·K	Specific heat, c, J/Kg·C	Density ρ Kg/m^3
Pure Titanium Grade 2	80	171	473	4.5

In order to control the experiments , the piece was pre-machined in seven parts, as is presented in the above fig. 6, [6].

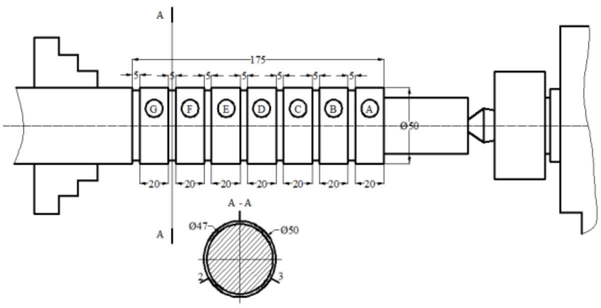

Fig. 6. Pure titanium bar pre-machinend before the experiments

Measuring of the cutting temperature for turning with cemented and ceramics insert was done using an infrared thermometer, Optris MS Pro, having the measuring range -32°C to 760°C, and ± 1% or ± 1°C (20...760°C), measuring precision, and ratio D/S- 40 :1 (distance from sensor to measured object), fig. 7, [13].

3. RESULTS

3.1. Graphical representations of collected data

The data was saved as ".dat" files, and then was transferred to Excel program.

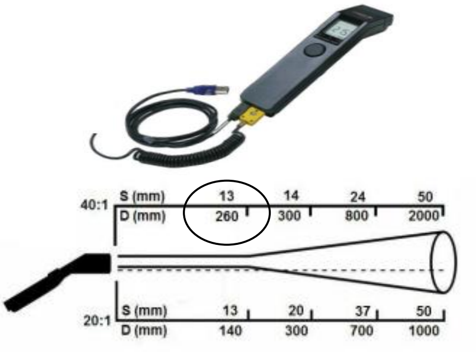

Fig. 7. Infrared Thermometer with the ratio D/S- 40:1

Here are presented these graphical representations for the both studied cases (turning with cemented carbide and ceramics inserts) for three different cutting speed , fig. 8 to fig. 13.

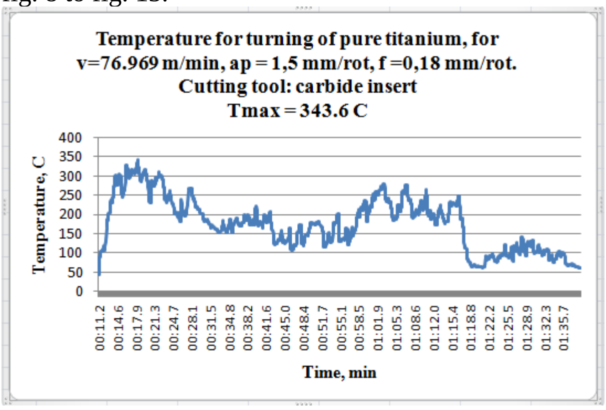

Fig. 8. Temperature for turning of pure titanium, for: v=76.969 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot. Cutting tool: carbide insert

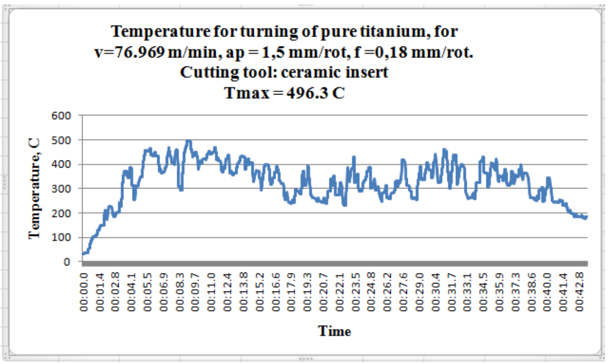

Fig. 9. Temperature for turning of pure titanium, for: v=76.969 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot. Cutting tool: ceramic insert

Examples of temperatures registered with three thermocouples are presented in fig. 14 and fig. 15.

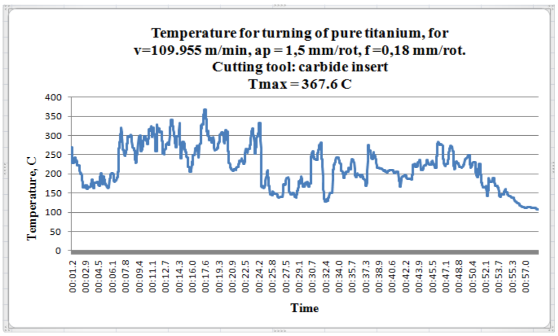

Fig. 10. Temperature for turning of pure titanium, for: v=109.955 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot. Cutting tool: carbide insert

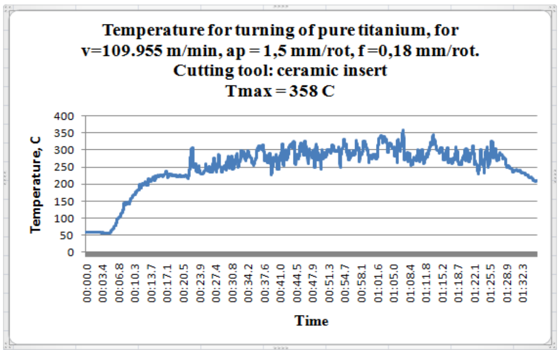

Fig. 11. Temperature for turning of pure titanium, for:v=109.955 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot.Cutting tool: ceramic insert

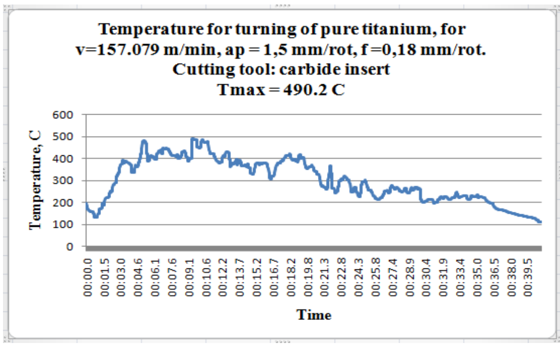

Fig. 12. Temperature for turning of pure titanium, for:v=157.079 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot.Cutting tool: carbide insert

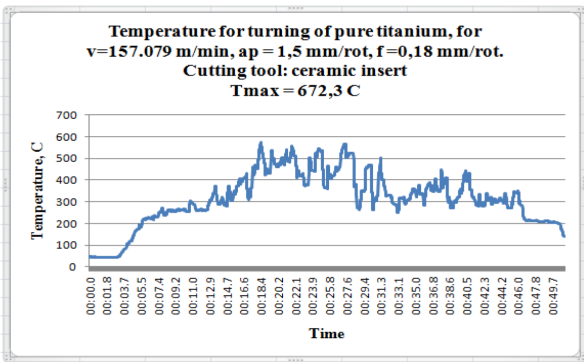

Fig. 13. Temperature for turning of pure titanium, for: v=157.079 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot. Cutting tool: ceramic insert

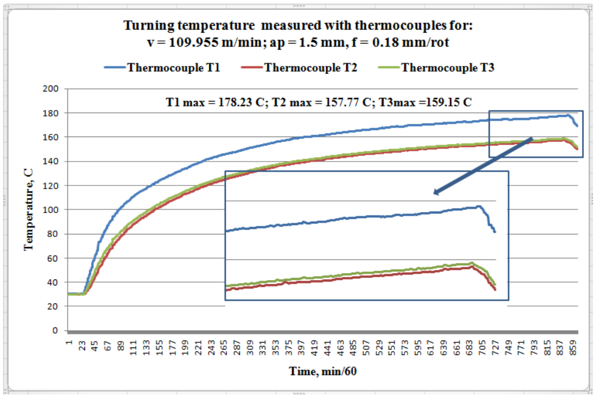

Fig. 14. Temperature measured with three thermocouples, for: v=109.955 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot. Cutting tool: carbide insert

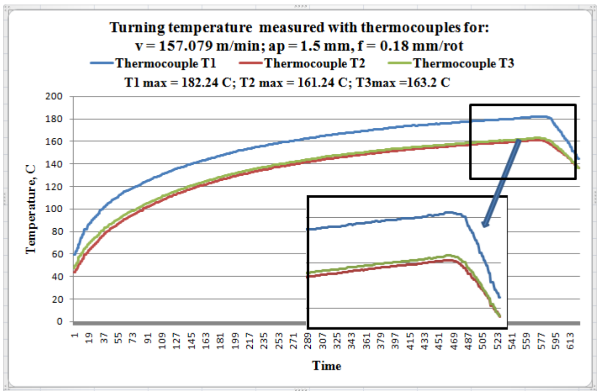

Fig. 15. Temperature measured with three thermocouples, for: v=157.079 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot. Cutting tool: carbide insert

3.2. Specific energy

Using the graphical representations and values of the two components of cutting forces, fig. 16, and, also, the values of cutting speed used in experiments and cutting time, it was possible to calculate the values of specific energy, using the relation (1), [8]:

$$U = \frac{v}{V_{rem}} \int_0^{t_c} \sqrt{F_a^2 + F_p^2}\, dt \qquad (1)$$

where:
v – cutting speed;
V_{rem} – the chips volume removed;
t_c – turning process time;
F_a and F_p represent the axial and radial force.

The graphical representations of the axial and radial components of the cutting force, as results of simulation, are presented in fig. 16.

Synthetically, the results obtained for turning temperature and specific energy are presented in Table 2.

4. CONCLUSIONS

In order to measure temperature an adequated instalation is used, including here an infrared thermometer, Optris MS Pro, cutting tool by carbide and ceramics insert, and a K-type thermocouple.

In this paper, in order to appreciate the machinability of these materials the temperature and specific energy are analyzed, using different cutting tools (uncoated carbide and ceramics inserts) and different value of the cutting parameters,

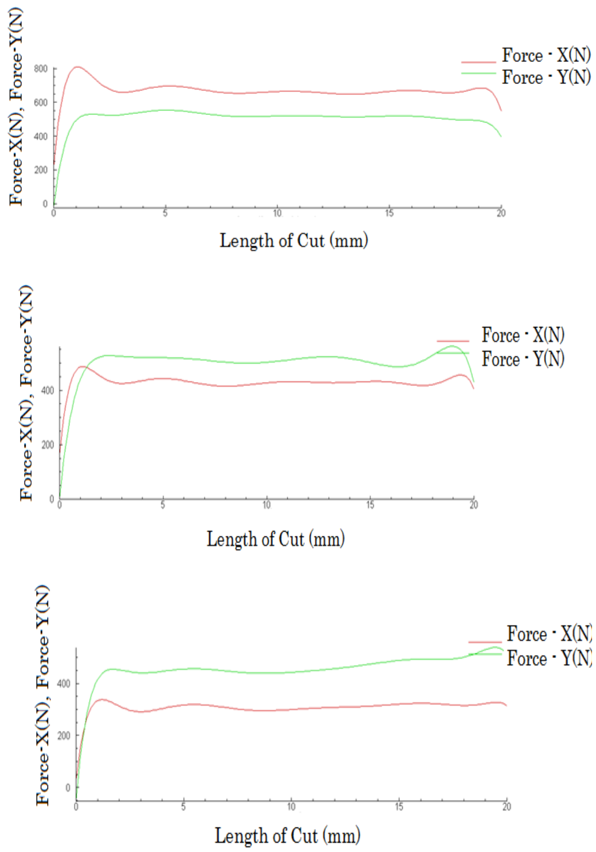

Fig. 16. Graphical representations of the axial and radial components

Table 2. Values for *turning temperature and specific energy*

Cutting speed, v, in m/min					
76.969		109.955		157.079	
Maximum values of the temperature, °C					
Car.I	Cer.I	Car.I	Cer.I	Car.I	Cer.I
343.6	496.3	358	367.6	490	672.3
Values of the specific energy, J/mm^3					
2.06		1.402		1.092	
Obs.: Car.I – carbide insert; Cer. I – ceramic insert					

Temperature was found to be greater for turning with ceramics inserts than carbide insert. The greater was 672,3 C for turning with ceramic insert for v=157.079 m/min, ap = 1,5 mm/rot, f =0,18 mm/rot , fig. 15, and 490,2 C, in the same conditions, for carbide insert, fig. 14, closer as it is indicated in literature.

For temperature registered with the three thermocouple the greatest value was 182.24°C corespond to the cutting speed, v=157.079 m/min, and for the thermocouple instaled near the tip of carbide insert, for the other two, the values are closer, as is presented in fig. 16 and fig. 17.

Is necessary the next observation: all the experiments was done keeping the depth of cut and feed, constant.

From point of view of specific energy for turning process of pure titanium, was calculated as function of cutting speed, volume of chips removed and two components of cutting forces (active and passive components) as it is result from turning simulation, and the values obtained, U = (1.092 – 2.06) J/mm^3, this value is closer as it is indicate in literature, (1,8-2) J/mm^3, [2]. The specific energy was determinate, just, for carbide insert.

Maybe more experimentation are necessary to decrease the range, and to have a certain value for specific energy.

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