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Study on cutting temperature and surface roughness during the turning process of pure titanium

D Panduru, N Craciunoiu, E N Patru, M Bica

Faculty of Mechanics, University of Craiova, Calea Bucuresti, 107, Craiova, Romania

dumitru_panduru23@yahoo.com

Abstract. In this paper some experimental determinations on the temperature and surface roughness during the turning process of pure titanium was conducted, using different cutting parameters (depth of cut, feed and rotational speed). The results are presented as graphical dependencies of temperature and surface roughness as function of cutting parameters also as a screen capture of the values obtained using an adequate technique for temperature of the turning process of pure titanium.

1. Introduction

Pure titanium and its alloys are very use in aeronautical and automotive industries and not only, due to the high strength-weight ratio that is maintained at high temperatures and their very good corrosion resistance.

But, the machining of pure titanium and its alloys is very difficult due to their low thermal conductivity (21 W/mK, for pure titanium, and between 5.5-25 W/mK, depends of temperature, for α, α –β and β-titanium alloys [1]), and as an effect, increasing the tool temperature. On the other hand, the high chemical reactivity can produce adhesion of the chips to the tool and, as a consequence, built-up edge formation. Also, due to the low elastic modulus (116 GPa), the deflection of the workpiece can be produce.

The quality of the material affect the machinability, so that pure titanium and α-titanium alloys assure an very good machinability, while β-titanium alloy is inferior from point of view of machinability.α –β alloy is an intermediate material between and α and β titanium alloys.

From point of view of cutting temperature developed during turning process in [1], the authors based on literature review show that the temperature is mainly influenced by the cutting speed and this influence is not linear.

In [2] study the surface roughness using the S/N ratio, and concluded that the relevant parameter for surface roughnees if the feed rate followed by the cutting speed, while the depth of cut has a minimal effect.

The authors show in [3], after studies on influence of coolant in machinability of titanium alloy (Ti-6Al-4V), that the surface finish increase with the increasing of cutting speed for the machining with or without coolant.

In their work [4**]** the researchers presents, based on literature review, the cases for cutting temperature as function of cutting speed, when two different rotary cutting tools are used, the temperature being lower for rotary insert.

For different titanium alloys, in [5] the authors present the temperature variation for two different cutting speeds and feed rates, and show a clear relationship between the temperature and the machinability. Also due to the low thermal properties of titanium alloys, by increasing the cutting conditions heat generated during machining cannot be dissipated effectively, and is concentrated near the tip of the tool which leads to premature wear of the tool.

In [6], the authors study the dependence of the measured temperature on the emissivity, measured using direct radiometric method for uncoated P10 tungsten carbide inserts, as a function of the surface roughness and the oxidation state.

In order to measuring the temperature during turning process [7], for machining with coated and uncoated tungsten carbide tools a work thermocouple was used, and concluded that the increasing of rake face temperature is due to the increasing the cutting speed and feed rate.

Based on a thermocouple and an infrared sensor-based measurement for dry machining with coated carbide insert of alloy steel, in [8], the authors showed the increasing of temperature with increasing of cutting speed, feed rate and depth of cut. They show that the results obtained can assure the useful data for the optimization of the cutting parameters in orthogonal machining.

The main purpose of this paper is to analyse the temperature and surface roughness, after turning of pure titanium, using different cutting parameters (rotational speed, feed and depth of cut).

2. Experimental setup

2.1 Material and cutting tool

Material used in this study is a pure titanium bar having ϕ50 mm diameter, and prepared for experiments as is shown in figure1. Composition and mechanical characteristics presented in table 1.

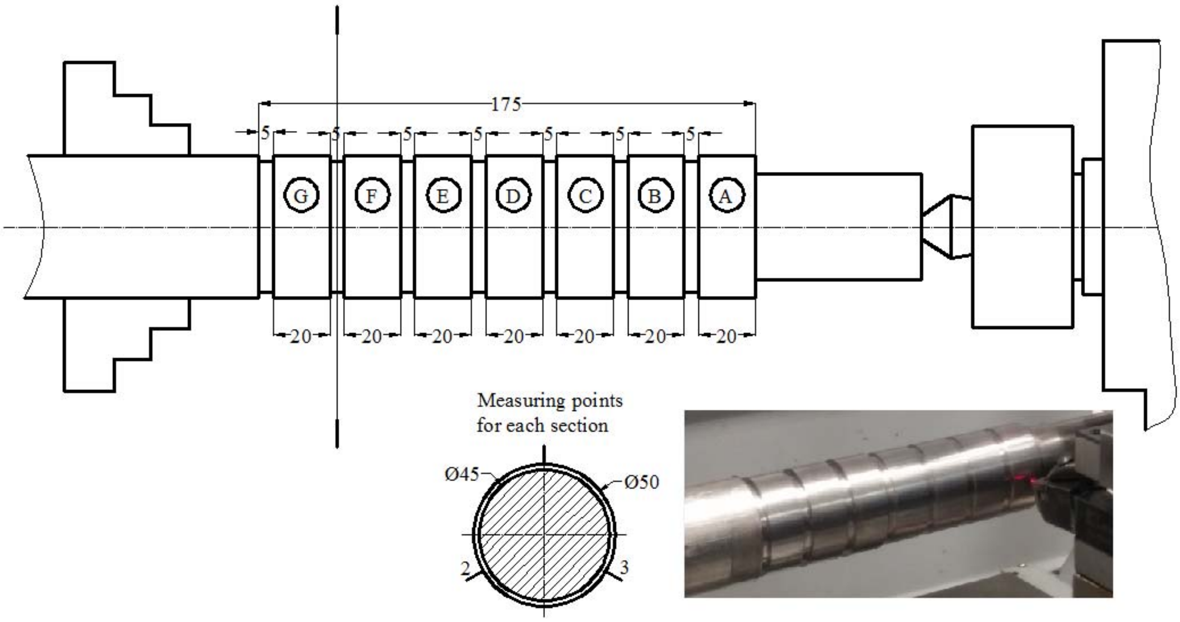

Figure 1. Pure titanium bar use for experiments.

Table 1. Composition and mechanical characteristics material

Material	Quality	Hardness, HRBW	Chemical composition %		
			Ti	C	Fe
Pure Titanium	Grade 2	80	99,67	0,003	0,055

The cutting tool is presented in figure 2. The support for carbide insert is DCLNR2020K12KC04 type with CNMG120408MS ISO type, carbide insert code and KCU10 grade, [9], with a special geometry of the rake face.

2.2 Experimental assembly for temperature measuring

In order to measuring the cutting temperature, in figure 3, an adequate experimental assembly was realized

Figure 2. Cutting tool with the support and carbide inserts type

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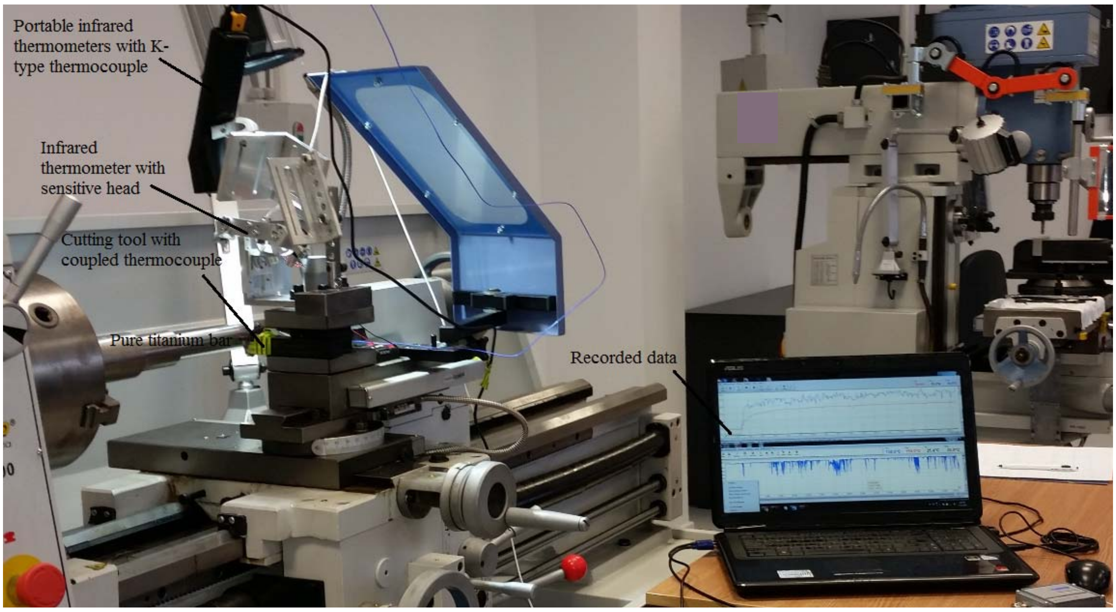

Figure 3. Experimental assembly

The experimental assembly consists in**:**

The portable infrared thermometer, Compact Connect type [10], with the measuring temperature range (-32^{0}C – 760^{0}C), emissivity adjustable between (0.1-1.00), precision ±1% and ratio distance/spot size 20/1, coupled with K-type thermocouple.

In order to measuring the temperature in the same time with portable infrared thermometer, a K-type thermocouple was used. The thermocouple was attached to the tool surface and secured by thermal insulation tapes. The temperature measurement location is specified as in Fig.4. So, a hole with ϕ2 mm diameter was machining in carbide insert (figure 4), using EDM.

2.3 Cutting conditions

Rotational speed, n = variable (n = 490 rpm, n = 700 rpm, n = 1000 rpm), feed rate , f_r = variable (f = 0,09mm/rot, f = 0,18 mm/rot, f = 0,36 mm/rot); depth of cut: a_p = 2 mm, constant for all experiments.

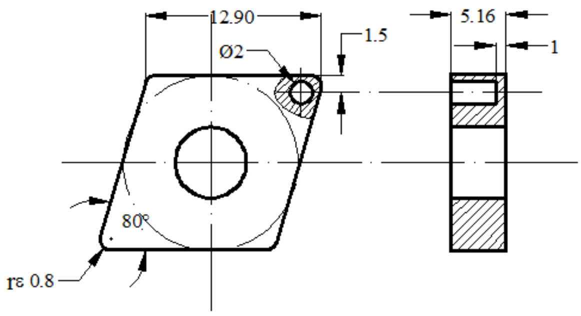

Figure 4. The carbide insert with ϕ2 mm diameter obtained by EDM

2.4. Measuring of the surface roughness

In order to measuring the surface roughness a Portable Surface Roughness Tester - TR200,[11], as it is shown in figure 5.

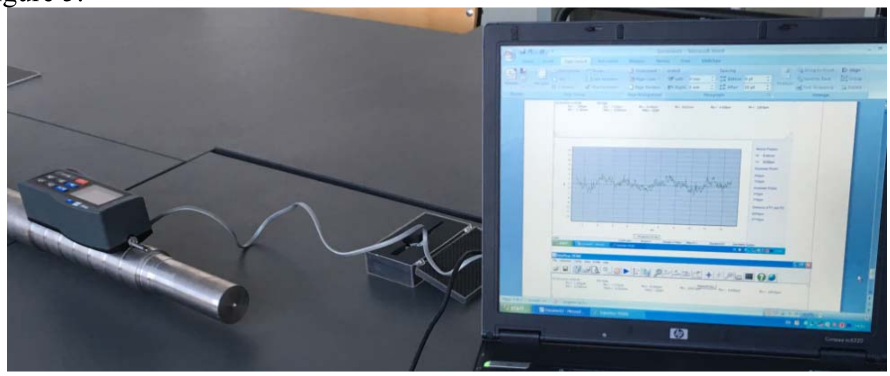

Figure 5. Measuring of the surface roughness

3. Results

3.1 Temperature results

The data were collected using the cutting conditions, portable infrared thermometer and K-type thermocouple, above described. The measured data, using Compact Connect software, are presented in figure 6.

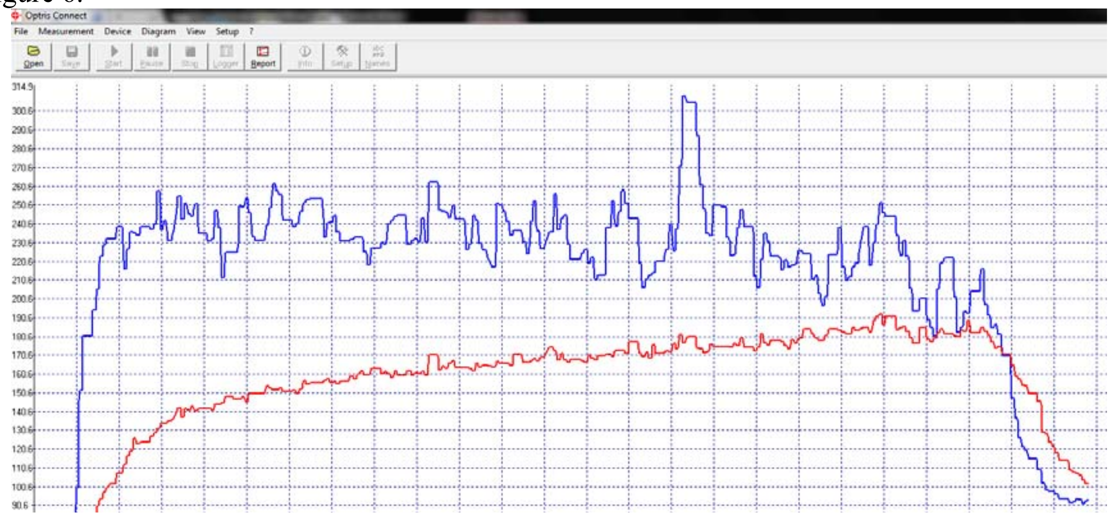

Figure 6. Temperature registered during turning process of pure titanium using both infrared thermometer (blue graph) and K-type thermocouple (red-graph)

For all data collected the graphical dependencies of the temperature as function of feed, for n = 700 rpm, and n = 1000 rpm, was represented, as it shown in figure 7 and figure 8.

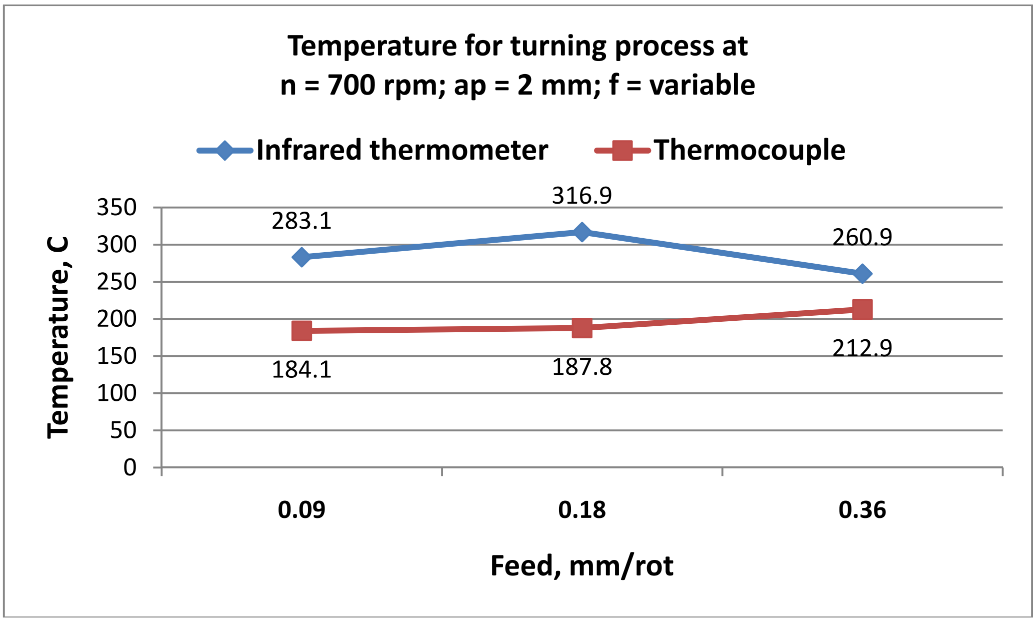

Figure 7. Temperature for turning process of pure titanium,
n = 700 rpm, f = variable, mm/rev; ap = 2 mm

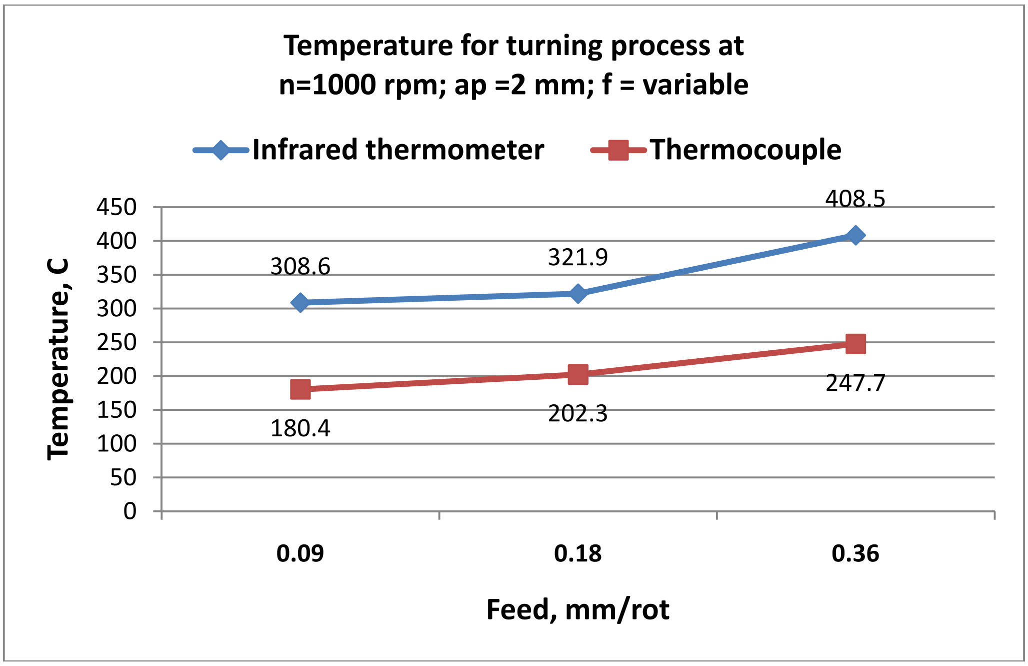

Figure 8. Temperature for turning process of pure titanium,
n = 1000 rpm, f = variable, mm/rev; ap = 2 mm

3.2 The surface roughness results

For each sections of the piece (see figure 1), using the roughness tester TR 200, the roughness parameters was measuring, and the results are presented in figure 9 (for section G), figure 10 (for section C), and figure 11 (for section C).

Using the data collected for turning process, below is represented variation of the surface roughness as function of the feed for rotational speed n = 1000 rpm, and n = 700 rpm (figure 12).

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ISO data:

Ra =	0.915µm	Rq =	1.157µm
Rz =	6.806µm	Rt =	8.007µm
Rp =	3.619µm	Rv =	3.187µm
RS =	0.103mm	RSm =	0.200mm

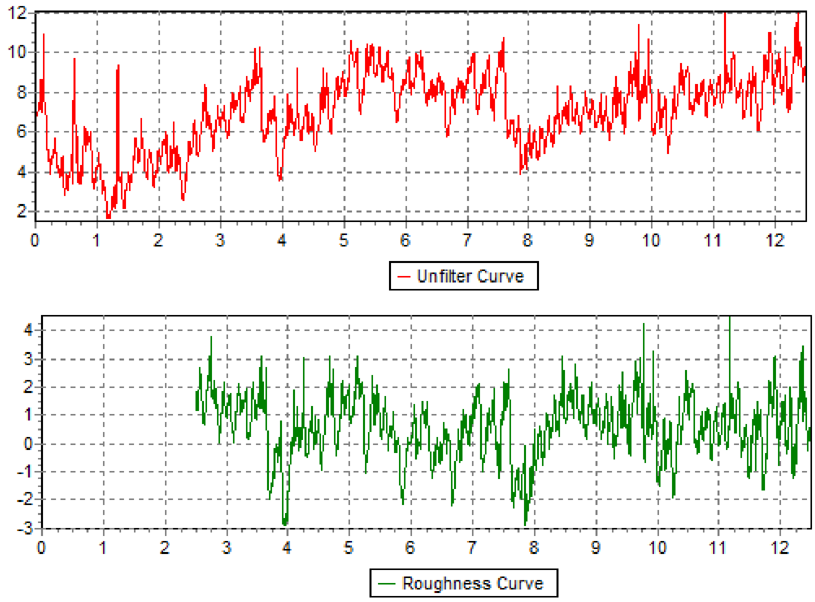

Figure 9. The Surface roughness for the section G
(n = 1000 rpm, f = 0.09 mm/rot, ap = 2 mm)

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ISO data:

Ra =	1.392µm	Rq =	1.879µm
Rz =	11.980µm	Rt =	18.300µm
Rp =	8.366µm	Rv =	3.613µm
RS =	0.286mm	RSm =	0.667mm

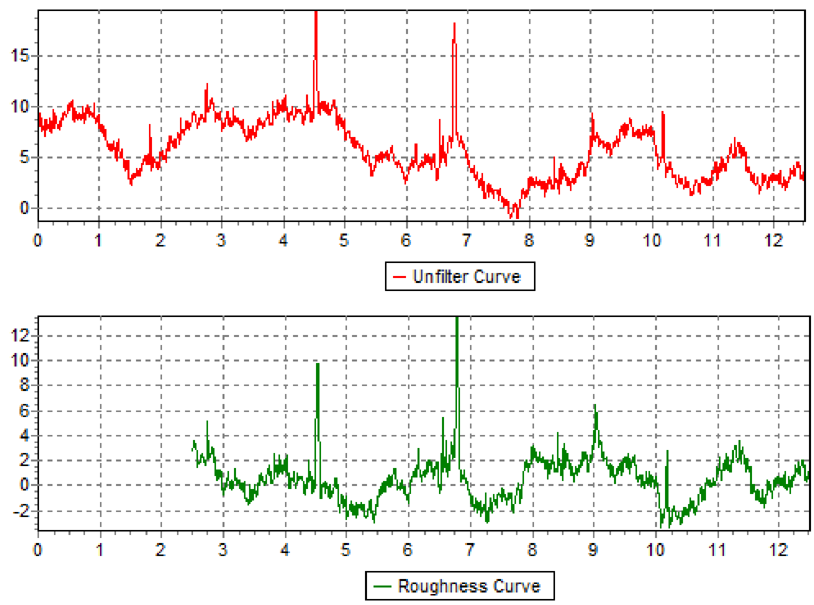

Figure 10. The Surface roughness for the section C
(n= 700 rpm, f = 0,18 mm/rot, ap = 2 mm)

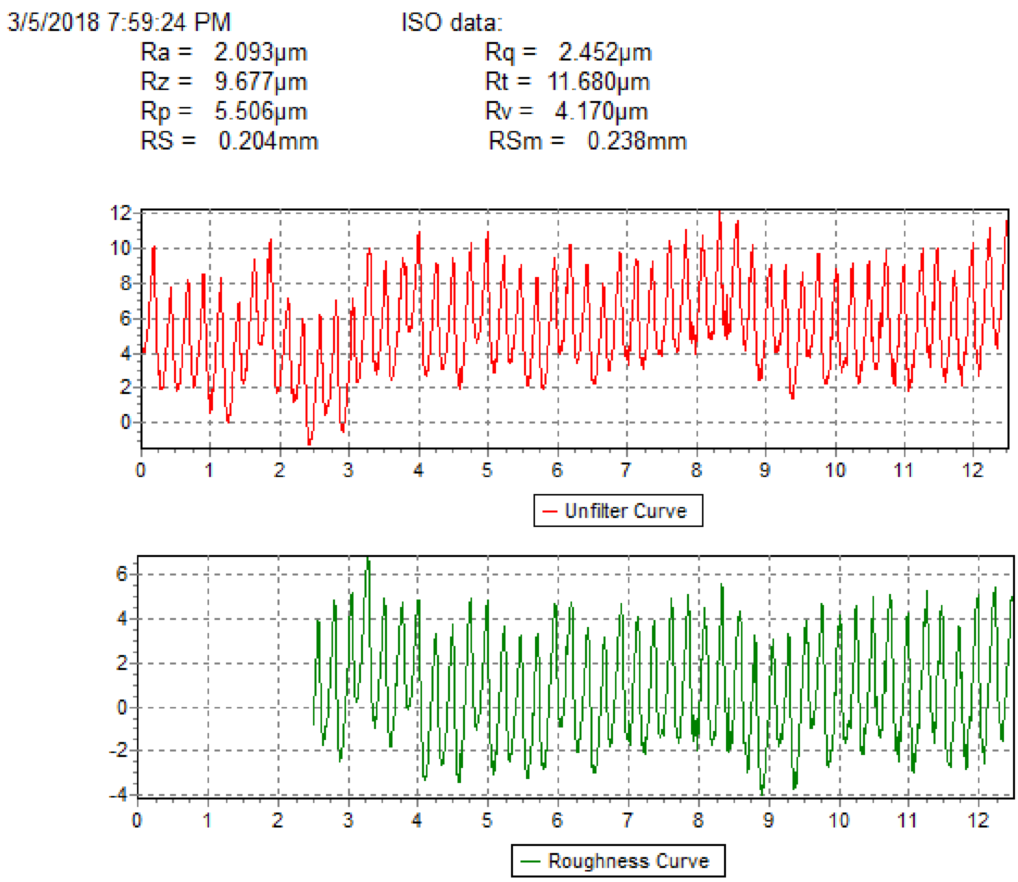

Figure 11. The Surface roughness for the section F
(n= 1000 rpm, f = 0,36 mm/rot, ap = 2 mm)

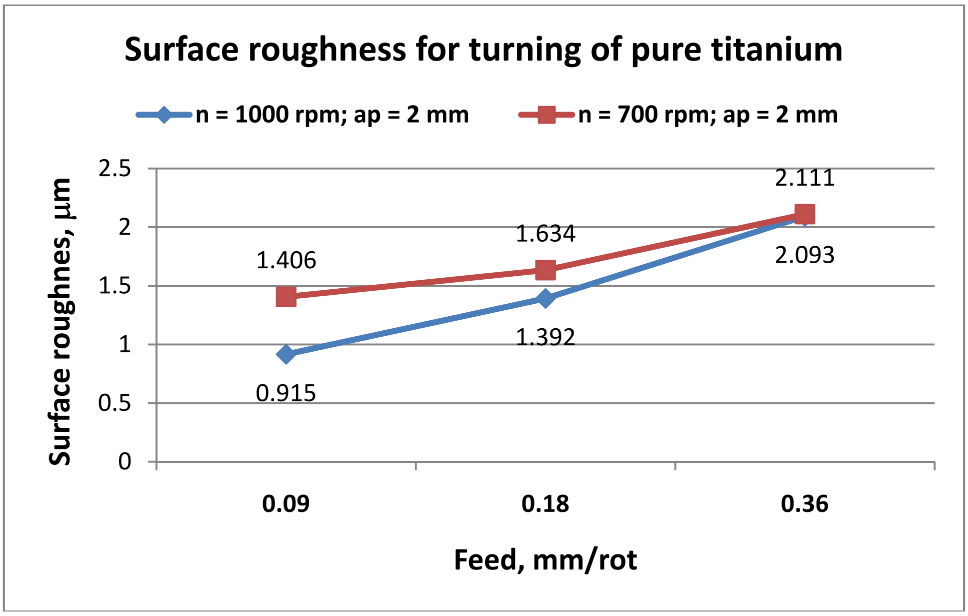

Figure 12. Surface roughness for turning of pure titanium
for different feed and rotational speed

4. Conclusions

The temperature for turning of pure titanium was measured using the both infrared thermometer and K-type thermocouple, figure 6. So, maximum value of the temperature was registred by infrared thermometer, 408.5 ^{0}C, and 247.7 ^{0}C, for K-type thermocouple, at n = 1000 rpm, f = 0,36 mm/rot and

a_p = 2 mm (figure 7 and figure 8). For the both values of the rotational speed (n = 700 rot/min and n = 1000 rpm) the temperature increase with the increasing of the feed value, except, f = 0.18 mm/rot at n = 700 rpm where the temperature value (316.9 ^{0}C) is greater as for f = 0.36 mm/rot (260.9 ^{0}C).

An explanation can be found in the difficulties of cutting process of pure titanium (the chips wrap on the workpiece, buil-up-edge phenomena, thermal expansion etc.) because these phenomena can affect the measuring results.

The surface roughness, figures 9,10, 11 and 12 show the increase of R_a values with the increasing of the feed values (for f = 0.36 mm/rot, R_a = 2.093 µm, at n = 1000 rpm, and R_a = 2.111 µm, at n = 700rpm), but the roughness value decrease with the increasing of rotational speed, figure 12,

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