Bone drilling and temperature measurement

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UTP Intern

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the requirement for

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MECHANICAL ENGINEERING INTERNSHIP

My supervisor Dr Turnad Lenggo Ginta

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Thanks to Dr. Adam Umar Alkali who helped me a lot during all this project, always listening and gave me good advice.

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I spent 2 years in Le Creusot University, I was very lucky to find amazing teachers always listening and ready to help.

Thanks to Clarisse Aref and Tazim Abdallah my neighbor in UTP and my friend’s trip. I hope to see them in France.

I would be eternally grateful to my parents who always have me encourage and help to catch every opportunity I have had in my life. For this I am sincerely grateful.

I spent 3 amazing month in Malaysia a beautiful country with welcoming and wonderful people thank you so much everyone for all of this.

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ABSTRACT

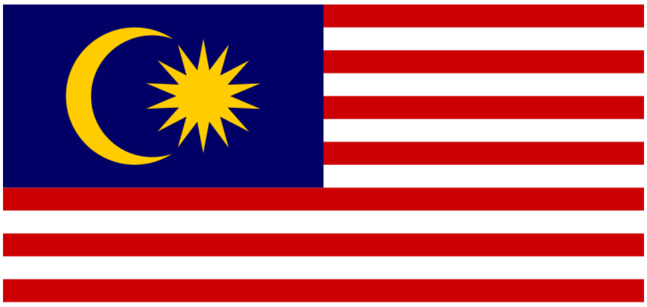
For my final years in Electrical and Industrial Data Processing I have to do an internship in a company or in a foreign country to complete the diploma.
I chose to do my internship in Malaysia, in Universiti Teknologi Petronas.

I wanted to go in a foreign country because I was thinking that it could be a great opportunity to improve myself in English and discover a new country with a different culture.

My project is to measure the temperature during bone drilling for medical application. And control what parameters influence the increasing of the bone temperature.

During this internship I did show autonomy, by performing each step of this project since buying the bone, the samples preparation, the analysis of the results and it is interpretation.

A.Malaysia



Malaysia is a constitutional monarchy with an elected king every 5 years among the 9 rulers of the Federation.

Actually the head of the state is **Mr. Yang di Pertuan Agong Abdul Halim Mu'adzam Shah** with as for Prime Minister **Mr. Najib Tun Abdul Razak.**

The capital city of Malaysia is Kuala Lumpur, with the famous twin tour of Petronas.

Malaysia is a Southest Asia country, it shares land borders with Brunei, Thailand, Indonesia. Also connected to Singapore by two bridges crossing the Strait of Johor.

It offer various culture with a majority of Muslim people but also Christians and Hindu people.

Malaysia is a wonderful country with beautiful island like Pulau Perhentian, Pulau Langkawi, Pulau Tioman. The beautiful landscape is no shortage of either variety: dense jungles, mountain peaks and lush tropical forests with abundant fauna and flora.

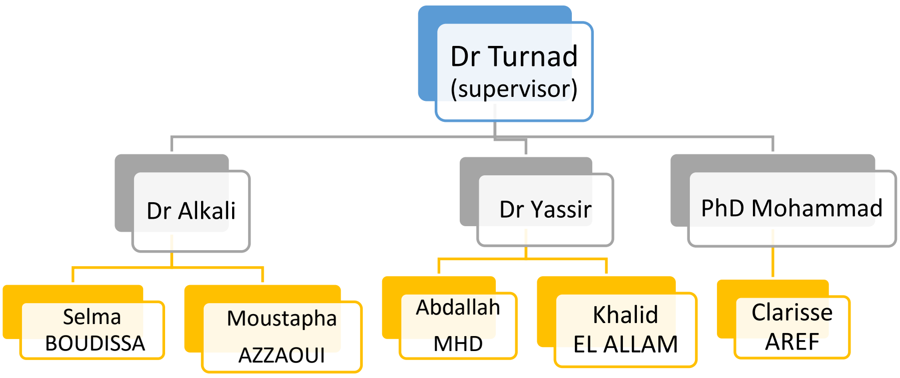
B.UNIVERSITI TEKNOLOGI PETRONAS

Universiti Teknologi Petronas: Chancelor complex

The Universiti Teknologi Petronas is a Malaysian private University founded on January, 10 1997. The campus is built on 400 hectares in the city of Seri Iskandar in the state Perak one of the big state in Malaysia.

It welcome Malaysian students and count many exchange program with foreign students from different country. The campus is organize with different block of laboratory with different department like: mechanical engineering, electrical engineering, chemical engineering…

During my internship, I work in the Mechanical Engineering Department with as supervisor Dr Turnad Lenggo Ginta a Senior Lecturer of Mechanical Engineering Department in UTP.



Hierarchy of the people I work during this internship, in yellow color the intern from France, in grey color the Doctor and PhD student which we have to work with.

List of figures

CHAPTER 1

Introduction

1.1 Background of study

Bone drilling is use for surgery application for correcting fracture and attaching prosthetics. It is important to control the temperature of the bone during drilling because if the temperature exceed 47°C, it can cause irreversible damage to the patient in terms of bone necrosis [1].

There is lot of parameters which influence the increase of temperature like during bone drilling. This include:

- Drill bit size
- Feed rate
- Spindle speed
- Bone hardness

However, until now to measure the temperature there are two prominent methods available. These are, application of thermocouple and the thermal image camera [2]. However, the application of using the thermal image camera is prone to difficulties and inefficiency to capture the temperature beneath the surface of the bone.

In this study, bone drilling was carried out drill using Mazak CNC milling machine which restricts the possibility of incorporating the thermal image camera to capture the temperature of the bone during the drilling process because of the design for safety attributed to the machine. In that case, the use of thermocouple sensors is the prove to be the most viable and effective method for this investigation. With this method, A K-type insulated thermocouple sensors attached to data logger was placed and bedded inside two pre-drilled holes off-setted at 4mm apart from the intended region to be drilled. The insulated thermocouple sensors have been carefully glued and initial reading are monitored before the drill process start.

1.2 Problem statement

Many problems are encountered during drilling bone in orthopedic which result to surgical tragedy. Bone necrosis is widely reported to be as a result of temperature induced during drilling of bones. The maximum temperature at the drill region need to be control in order to ensure minimal heat generation. Bone drilling process using controlled temperature measurement can be study to avoid the tendency to bone necrosis. This principal concern have the area of investigation for this study with the following objectives.

1.3 Objective

1- To study the effect of different machining parameters during bone drilling in order to gain control on the temperature induced.

2- To study the application of temperature measurement using thermocouple sensors to capture the temperature induced during bone drilling.

3- To study the influence of drilling parameters on surface roughness of the bone.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

There exist two types of bone, namely ; the cortical bone which is basically in form of the outer hard layer and a spongy layer called cancellous bone which is a an inner layer of the bone (Figure 2.1). The cortical bone is covered by a tough layer of called periosteum. Most of the inside of a bone is hollow and contains bone marrow. The inner surface of the bone is also lined with a similar cell layer with osteogenic properties called endosteum [3]. Both types of the bone are susceptible to fracture as a result of accident or otherwise. Such predicament necessitate methods of repair and reconstruction of the bone structure. One dominant method to achieve this is by drilling the bone such that separate parts can be effectively repaired. One of the major set back encounter during drilling is the hole accuracy and heat generation [3]. It is significant for the integrity of the bone and implants materials to experienced minimal heat generated during the drilling process. One aspect that have continue to receive attention is the controll of the temperature distribution during the drilling process. Sevaral studies have investigated the effect of drilling process on bone to temperature rise and its consequences to thermal injury.

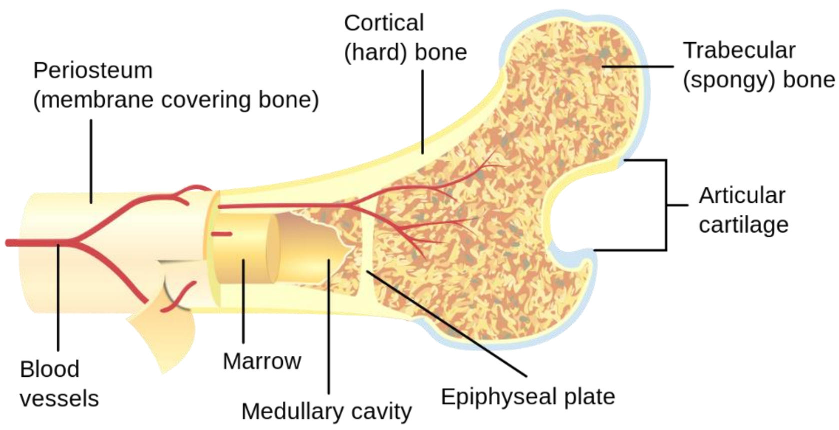


Figure 2.1: Human bone structure

2.2 Heat generation during drilling

In orthopaedic and dental practices use of drilling process for producing holes is common. The heat is produced during bone drilling because of the plastic deformation of the chips and the friction between the bone and the drill. This heat is a significant problem because the bone is very sensitive to increase in temperature which can cause its thermal necrosis [4]. Various researches have shown the influence of many parameters on the increase of temperature [4].

2.3 Bone drilling parameters

Factors	**Levels**		
	Low(-1)	Center(0)	High(1)
Drill Bit Size (mm)	4 mm		
Cutting Speed (rpm)	400	500	600
Feed rate (mm/min)	80	100	120

Figure 2.2: Parameters used durind bone drilling experiments in this internship

The temperature generated during the bone drilling depends upon various parameters such as drill diameter, feed rate, cutting speed ect. In this project, the parameters used are those in the Figure 2.2.

Influence of drill diameter on increase in bone temperature is significant. Drill diameter increases energy transfer to the bone causing temperature rise. This is due to friction because of the contact surface between the drill and the bone [5].

Feed rate is another influencial parameters with dual importance, this parameters can cause the increasing of the temperature but depend of the time of drilling which depend of the thickness of the bone. The unit is mm/min, this parameters represents the forward speed of the drill bit during the bone drilling.

Cutting speed it’s the speed difference between the cutting tool and the surface of the workpiece it is operating on. The unit is revolution per minute (rpm)

CHAPTER 3

METHODOLOGY

Experimental Method:

In order to meet the set set objectives of this study, the effect of drilling parameters in terms of feed rates and spindle speed are studied with respect to temperature rise. A series of other test have been conducted to study the effect of the drilling parameters on surface roughness and surface integrity on the bone so as to investigate their relation to temperature rise. The experiment is conducted according to the work flow chart given below.

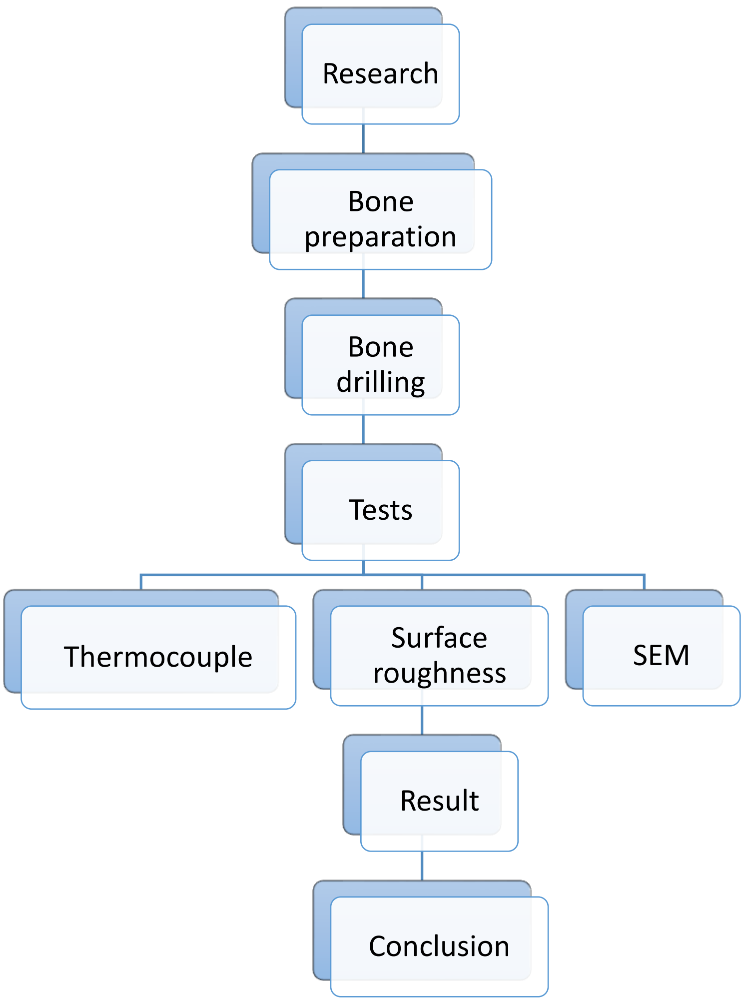


Figure 3.1: Flow chart of the project

3.1 Preparation of the bone

Tibia cow bone have been collected from one animal fresh bone within 24 hours of their removal as shown in Figure 2, from a local abattoir . The femur bone have been effectively frozen to -10^{0}C and stored in a refrigerator until required for the test. This proceedure was apprehended in hillery and Shuaib [3]. The tibia section of the bone was chosen as a suitable long bone for drilling.

Figure 3.2: Fresh cow tibia bones

Steps:

1- Remove all the meat without removing the bone marrow

2- Cut the end of the bone

Figure 3.2 shows how the thickness of the tibia bone is measured and the bone is cut and prepared into specimens ranging from 4 to 5 mm thickness. The bone is cut into 9 samples of 5 cm as shown in Figure 3.4. The samples are there after wrapped stored in the freezer. During the storage process the specimen are sealed in a waterproof cover in order to prevent the any tendency for absorption.

Figure 3.3: Cutting the extremities of the bone

Figure 3.4: Bone samples of 5 cm

The following steps have been carefully observed accordingly.

1- Let 2-3 hours in the room temperature before start drilling

2- After drilling recover the chips for the analysis

3- Remove the bone marrow

4- Cut the bone in the middle of the hole for the roughness test

5- Isolate the holes for the SEM test, made smaller samples

3.2 Thermocouple

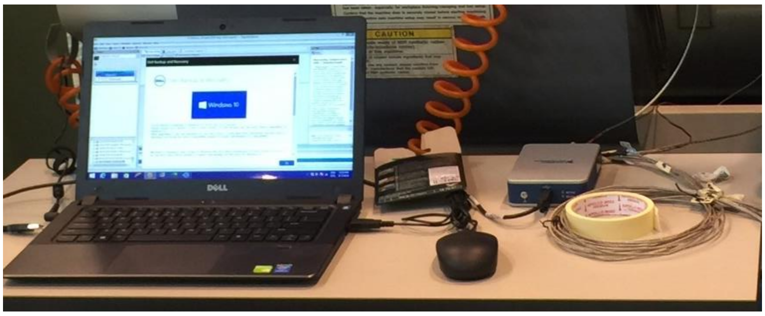


Figure 3.5: Thermocouple NI cDAQ-9171

Definition:

Is an electrical device consisting of two different conductors forming electrical junctions at differing temperatures. A thermocouples produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature.

Principle:

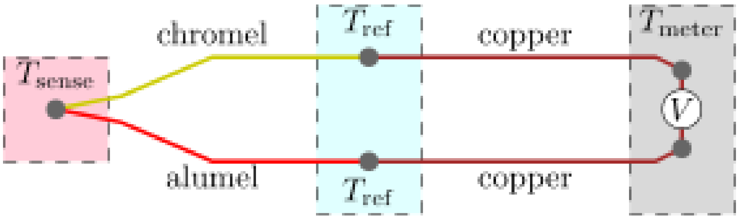


Figure 3.6: Thermocouple mecanism

In 1821, the German physicist Thomas Johann Seebeck discovered that when different metals are joined at the ends and there is a temperature difference between the joints a magnetic field is observed. Refers to an electromotive force whenever there is a temperature gradient in a conductive material.

Use the voltage generated at a single junction of two different wire is what is of interest as this can be used to measure temperature at very high and very low temperature.

Specifications:

Operating Temperature	-40 °C to 70 °C
Form Factor	Compact DAQ, Ethernet, USB, Wireless
Voltage Range	-80 mV to 80 mV

3.3 Mazak Machine

Figure 3.7: Mazak machine VARIAXIS-6305X

<u>Specifications:</u>

Capacity	Maximum Swing: 730mm/ 28.74 in
	Maximum Machining Diameter: 730mm/28.74in
	Maximum Machining Length: 600mm/19.69 in
Turning	Chuck Size: 616 mm/ 21 in
Spindle	Maximum Speed: 1100 rpm
	Motor Output (30 min rating): 19 kW / 24.8 hp
Milling	Magazine Capacity: 30
Spindle	Maximum Speed: 18000 rpm
	Motor Output (30 minute rating): 30 kW / 40.0 hp
Feed Axes	Travel (X Axis): 630 mm / 24.80 in
	Travel (Y Axis): 765 mm/ 30.12 in
	Travel (Z Axis): 600 mm / 23.62 in

<u>Characteristics:</u>

Tool drilling	30 type of tools in the same time
Material	HSS: High Spindle Steel
of the drill bit	
Table tilts up	150°
Table rotates up	360°

3.4 Roughness machine

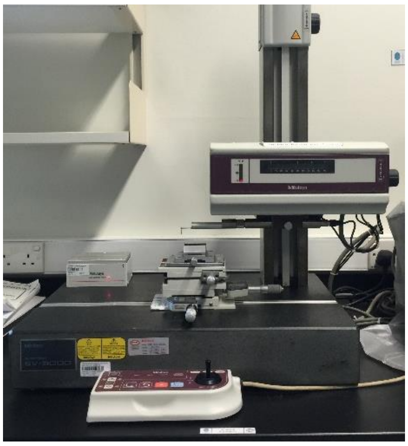


Figure 3.8: Roughness test SV-3000

Definition:

Surface roughness is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough, if they are small the surface is smooth. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces.

Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion.

Specifications:

Z2 axis vertical travel	500mm
Measuring range	200mm
Measuring speed	0.02-2mm/s
Detector range	800µm / 0.01µm, 80µm / 0.001µm, 8µm / 0.0001µm
Traverse straightness	0.5µm / 200mm
Measuring Force	4mN
Stylus tip radius	Diamond, 90° / 5µmR
Scalees	ABSOLUTE Linear encoder
Drive speed	0-80mm/s

3.5 Scanning Electron Microscope

Figure 3.9: SEM machine

Imaging Specifications:

Images MODES		
	Light optical	Magnification range: 20 – 120x
	Electron optical	Magnification range: 80 – 100,000x
		Digital zoom max.12x
DIGITAL IMAGE DETECTION		
	Light optical	Color navigation camera
	Electron optical	High-sensitivity backscattered electron detector (compositional and topographical modes)
IMAGE FORMATS		JPEG,TIFF,BMP
IMAGE RESOLUTION OPTIONS		456 x 456, 684 x 684, 1024 x 1024 and 2048 x 2048 pixels
DATA STORAGE		USB flash drive
		Network
		Pro Suite PC
SAMPLE STAGE		Computer-controlled motorized X and Y
SAMPLE SIZE		32 mm (Ø); 100 mm (h)
SAMPLE LOADING TIME		
	Ligh optical	< 5 s
	Electron optical	< 30 s

Definition:

A Scanning Electron Microscope is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons.
The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition.
The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image.

Principles and capacities

The types of signals produced by an SEM include secondary electrons, reflected or back-scattered electrons (BSE), photons of characteristics X-rays and light, absorbed current and transmitted electrons.

Sample preparation

Figure 3.10: Specimen stub

All samples must be of an appropriate size to fit in the specimen chamber and are generally mounted rigidly on a specimen holder called a specimen stub (Figure 3.10). Several models of SEM can examine any part of 6-inch (15cm) semiconductor wafer and some can tilt an object of that size to 45°.
For conventional imaging in the SEM, specimens must be electrically conductive, at least at the surface, and electrically grounded to prevent the accumulation of electrostatic charge.

3.6 Energy Dispersive Spectroscopy

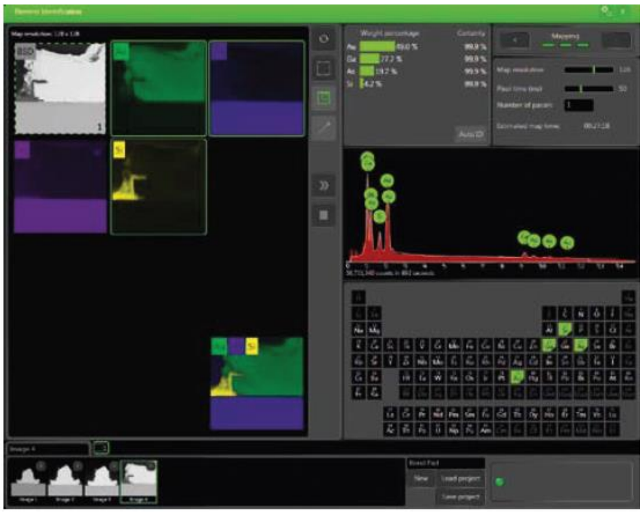


Figure 3.11: EDS result, analysis of the elements present inside the bone

The element identification software package allows the user to identify any hidden elements within the sample via the spot mode analysis.

This analyze identify the major inorganic element in a material.

This instrument is one of the detectors on our SEM. The sample is placed under vaccum and excited to a higher energy state with an eletron beam. As each element falls back down to its original energy state it emits X-ray energy at different wavelenghts for each element.

EDS analyis is very good at determining what elements are present in samples which are as small as one micrometer (40 micro-inches).

Results are plotted with X-ray wavelength on the X-axis and intensity on the Y-axis with each peak labeled with its corresponding element.

<u>EDS Specifications</u>

DETECTOR TYPE	Silicon Drift Detector, Thermoelectrically cooled (LN_2 free)
Detector active Area	25 mm^2
X-ray window	Ultra-thin Silicon Nitride (Si_3N_4) window
Energy resolution	Mn Kα ≤ 140 eV
Processing capabilities	Multi-channel analyzer with 2048 channels at 10 eV/ch
Hardware integration	Fully embedded
SOFTWARE	Integrated in Phenom Pro Suite
	Integrated column and stage control
	Iterative strip peak deconvolution
	Confidence of analysis indicator

CHAPTER 4: RESULTS & DISCUSSION

4.1 Temperature analysis

The maximum temperature is 31.64°C when the parameters is feed rate at 80 mm/min and cutting speed at 500 rpm.

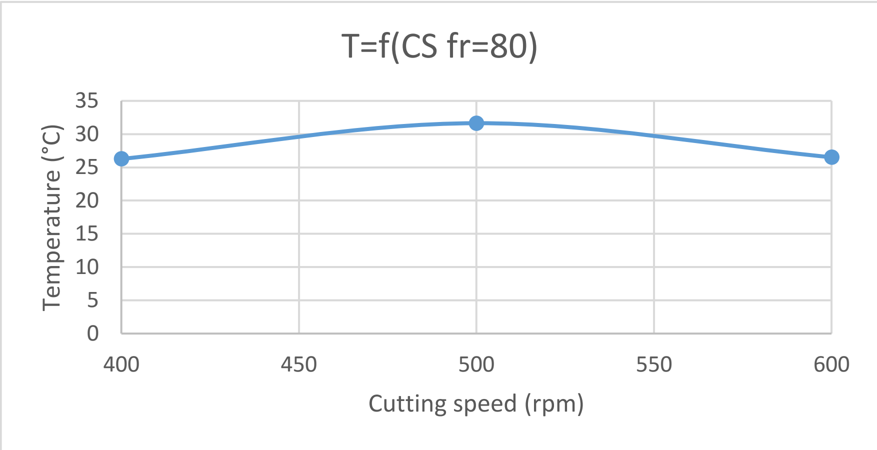


Figure 4.1: Temperature as a function of the cutting speed for a feed rate at 80 mm/min

With the graphs of the temperature as a function of the cutting speed we can analyze that the temperature is higher and increase when the cutting speed is at 500 rpm.

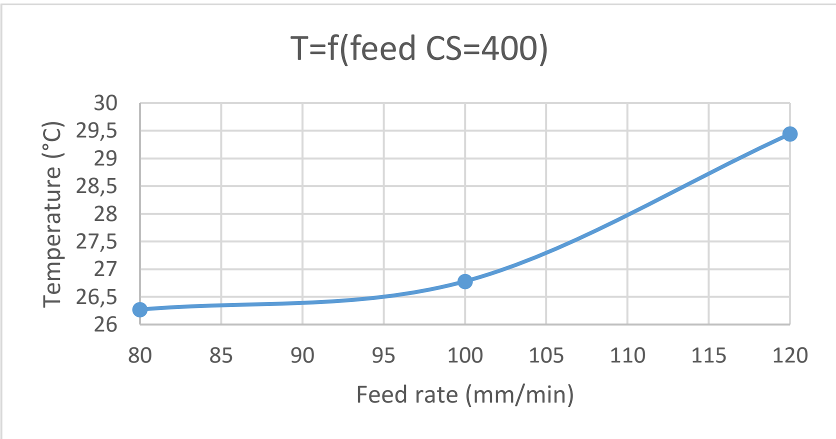


Figure 4.2: Temperature as a function of the feed rate for a cutting speed at 400 rpm

The temperature as a function of the feed rate, when the cutting speed is at 500 rpm and 600 rpm the temperature decrease when the feed rate increase.
For a cutting speed at 500 rpm the temperature is the most important, decrease when the feed rate increase but stay higher than for the other parameters.
But for a cutting speed at 400 rpm the temperature increase when the feed rate increase, as you can see on the Figure 4.2, so we can conclude for this parameters that the temperature is proportional to the feed rate.

The temperature increasing when the feed rate increase but for a low cutting speed only.
For a cutting speed at 500 rpm the temperature is higher but decrease as a function of the increasing of the feed rate.
At a low cutting speed= 400 rpm the temperature increase when the feed rate increase.
For a higher cutting speed the temperature is very low.
To conclude the best parameters for a low temperature is a high cutting speed and a small feed rate.
The feed rate have an important effect on the temperature.

4.2 Surface roughness

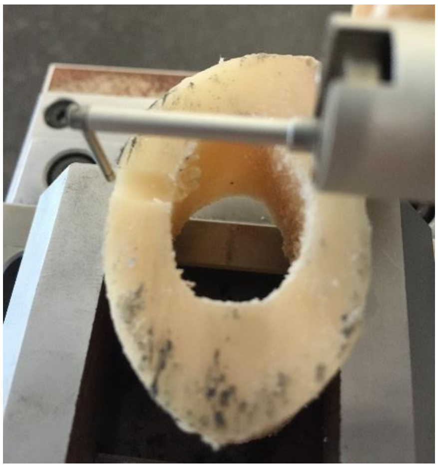


Figure 4.5: Roughness test on the bone hole

For a cutting speed at 600 rpm the surface roughness increase when the feed rate increase same for a cutting speed at 400 rpm. But for a cutting speed at 500 rpm the surface roughness decrease when the feed rate increase.

The best parameters is a cutting speed at 600 rpm and a feed rate at 120 mm/min.
When the cutting speed is high the feed rate will increase when the feed rate increase. The best parameters for a good surface roughness is feed rate at 120 mm/min and a cutting speed at 600 rpm it's also a good parameters for a low temperature.
So for a low temperature we have a good result for the surface roughness and for a high temperature the result for the surface roughness is bad.

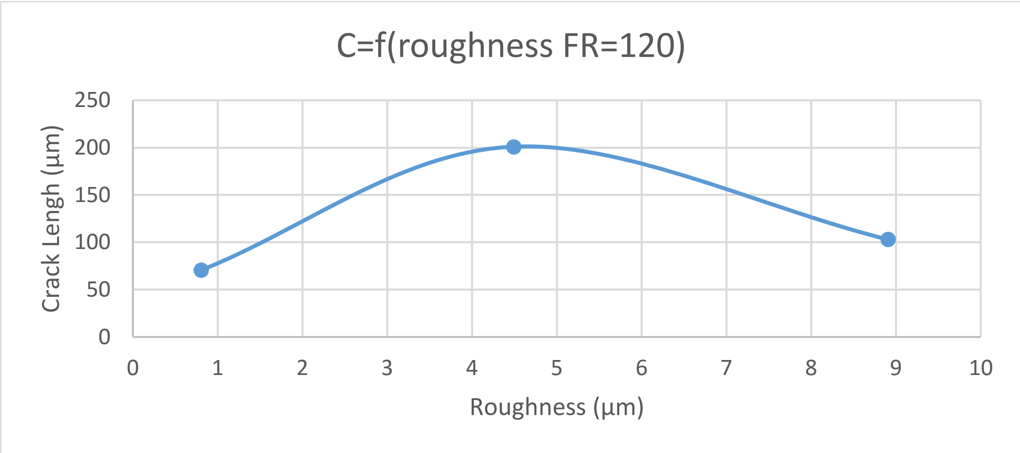


Figure 4.6: Crack size as a function of the roughness for a feed rate at 120 mm/min

The best parameters is for a feed rate at 120 mm/min and a cutting speed at 600 rpm, the temperature is low, there is a good surface roughness and the size of the crack is acceptable. The analysis of the surface roughness compare to the cracks size show that each time there is a bad result for the roughness, more important is the size of the crack.

And previously (4.1) the temperature analysis show that for a bad surface roughness the temperature is higher.

So the important size of the crack can explain the increased of the temperature.

4.3 Surface integrity

4.3.1 Scanning Electron Microscope

Figure 4.7: Result of SEM analysis

For a high cutting speed at 600 rpm and a low feed rate 80 mm/min the crack is very small, so this parameters cause less damage in the surface integrity of the bone. The result of the crack size is on the Figure 4.4.

When the feed rate increase there is more important crack. So the increasing of the feed rate have a bad effect on the surface integrity of the bone.

For a low temperature and a good surface roughness, the surface integrity is good with a crack size of 103µm this is acceptable.

For high temperature and bad surface roughness, the crack size is more important 204µm.

4.3.2 Energy Dispersive Spectroscopy

Namely, the human body is composed of Oxygen, Carbon, Hydrogen, Nitrogen, Calcium, Phosphorus, Potassium, Sulfur Sodium, Chlorine, Magnesium there is a few percentage of Silicon and other elements (Figure 4.4).

In this experiment, the EDS revealed the presence of Calcium, Nitrogen, Phosphorus, Oxygen, Silicon, Magnesium and Oxygen. All this elements are acceptable because they are part of the human body composition.

The EDS analyze reveal that element present is only due to the bone that mean there is no transfer of element from the tools to the bone.

Cutting Speed (rpm)	Feed rate (mm/min)		
Ø 4mm	80	100	120
400	Ca:16.5% O:46.4% P:6.6% N:30.4%	Ca:21% O:39.4% P:7.3% N:32.3%	Ca:6.6% O:55% P:3.2% N:35.2%
500	Ca:22.3% O:42.6% P:7.4% N:29.1%	Ca:21.8% O:41.6% P:8% N:28.5%	
600	Ca:21.7% O:20.6% P:6.6% N:51.1%	Ca:7.9% O:25.3% P:2.9% C:64%	Ca:3.4% O:50% P:2.1% N:44.5%

Figure 4.8: EDS from the bone sample

Cutting Speed (rpm)	Feed rate (mm/min)		
Ø 4mm	**80**	**100**	**120**
400	**Ca:26.3% O:42% P:9.3% N:22.4%**	**Ca:31.6% O:37.9% P:10.2% N:20.3%**	**Ca:27.3% O:40.6% P:7.6% N:29.6%**
500	**Ca:22.3% O:40.6% P:7.6% N:29.6%**	**Ca:36.5% O:34.8% P:10.4% N:18.3%**	**Ca:18.1% O:26.5% P:2.7% N:47.1%**
600	**Ca:29.6% O:40.7% P:9.5% N:20.5%**	**Ca:25.2% O:44.8% P:8.4% N:21.6%**	**Ca:41.4% O:29.4% P:10.5% N:18.7%**

Figure 4.9: EDS from the bone chips

CHAPTER 5

CONCLUSION

The surface integrity and the surface roughness of the holes drilled in the cow tibia bones were measured. Drill bit of 4mm diameter had been used for drilling the cow tibia bones. The experiments was carried with different parameters of the feed rate at 80mm/min, 100mm/min and 120 mm/min and different parameters of the cutting speed at 400 rpm, 500 rpm and 600 rpm.

The analyze show that for a good result of the surface roughness with a law temperature about 26 °C and the crack size is small also the best parameters is feed rate at 120 mm/min and a cutting speed at 600 rpm.

During my internship, I learned to work independently and I have developed my English very fast. I have participate at each step of this project, every experiments and every tests. I have done my own analysis of the result with the help of professional.

I think is a good experience for student like me to do an internship in a foreign country to do some progress in English, see how the other people work and discover a new culture, a new country. This internship help me a lot for my following studies and will stay a great experience on a personal level.

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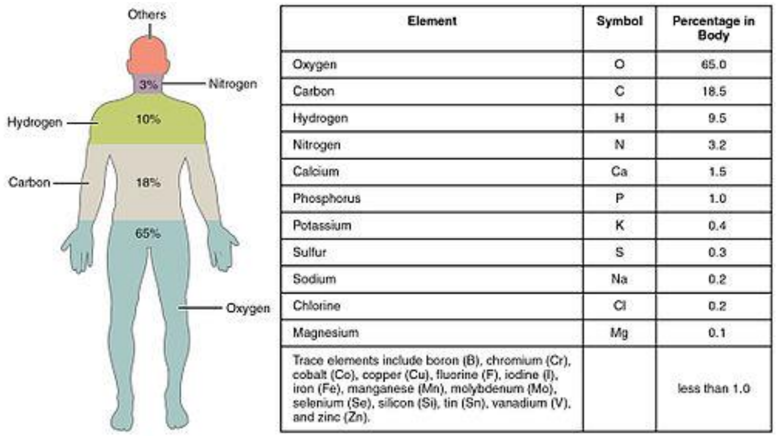
Appendices



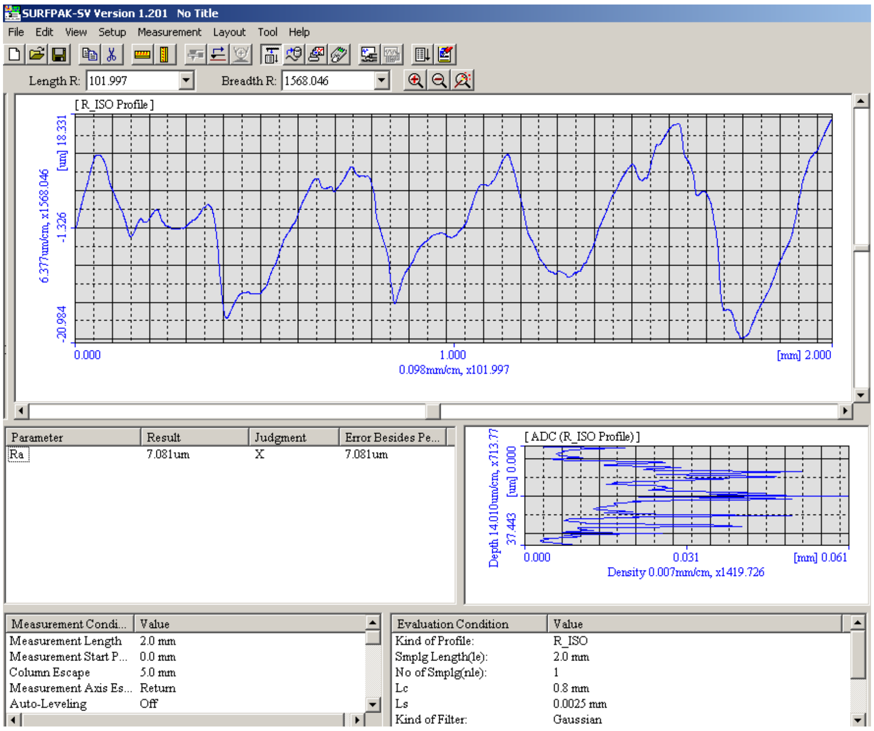
Element	Symbol	Percentage in Body
Oxygen	O	65.0
Carbon	C	18.5
Hydrogen	H	9.5
Nitrogen	N	3.2
Calcium	Ca	1.5
Phosphorus	P	1.0
Potassium	K	0.4
Sulfur	S	0.3
Sodium	Na	0.2
Chlorine	Cl	0.2
Magnesium	Mg	0.1
Trace elements include boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).		less than 1.0

Figure 4.3: Element compostion human body

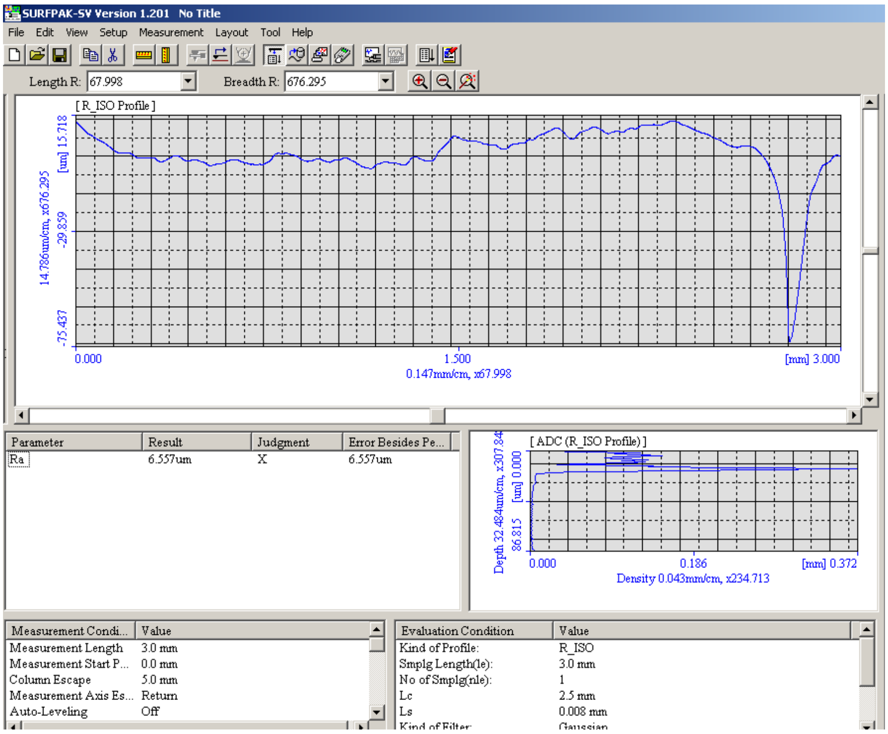
Cutting speed (rpm)	**Feed rate (mm/min)**		
	80	**100**	**120**
400	**L= 98.1µm** **W=5.77µm**	**L=63.9µm** **W=3.98µm**	**L=201µm** **W=4.04µm**
500	**L=70.6 µm** **W=3.67µm**	**L=204µm** **W=4.76µm**	**L=134µm** **W=6.24µm**
600	**L=31.9µm** **W=2.82µm**	**ERROR**	**L=103** **W=3.03µm**

Figure 4.4: Crack size use for the comparison to the surface roughness

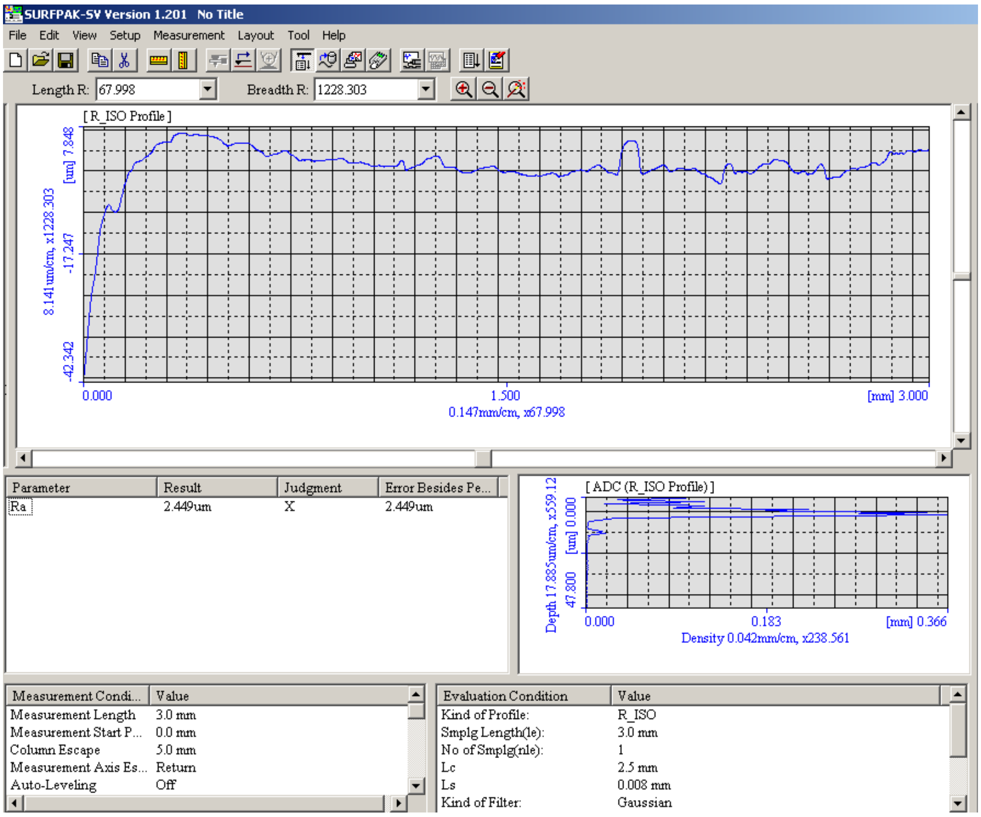
APPENDIX I



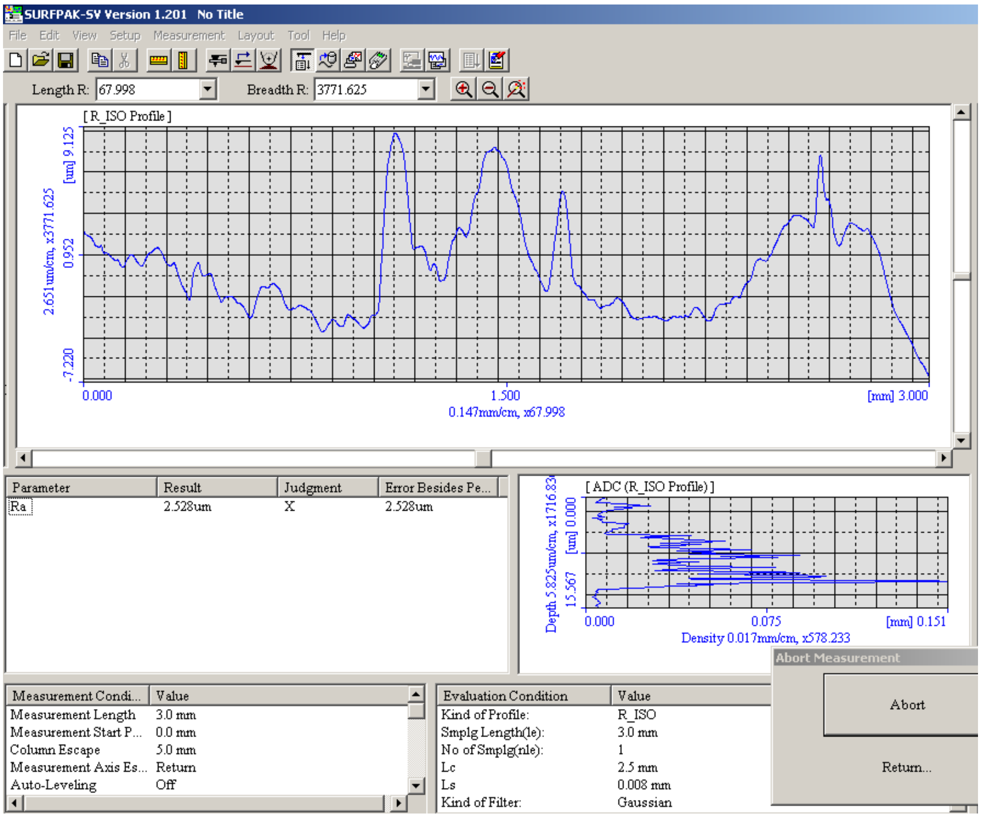
APPENDIX I-a: Result of surface roughness for experiment n°1



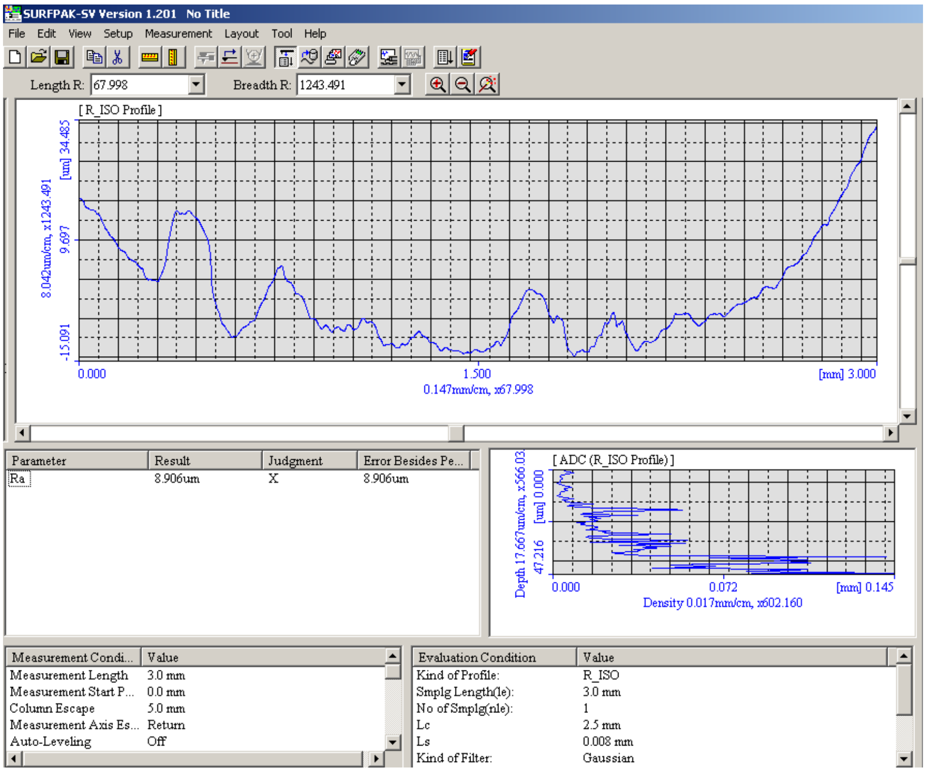
APPENDIX I-b: Result of surface roughness for experiment n°2



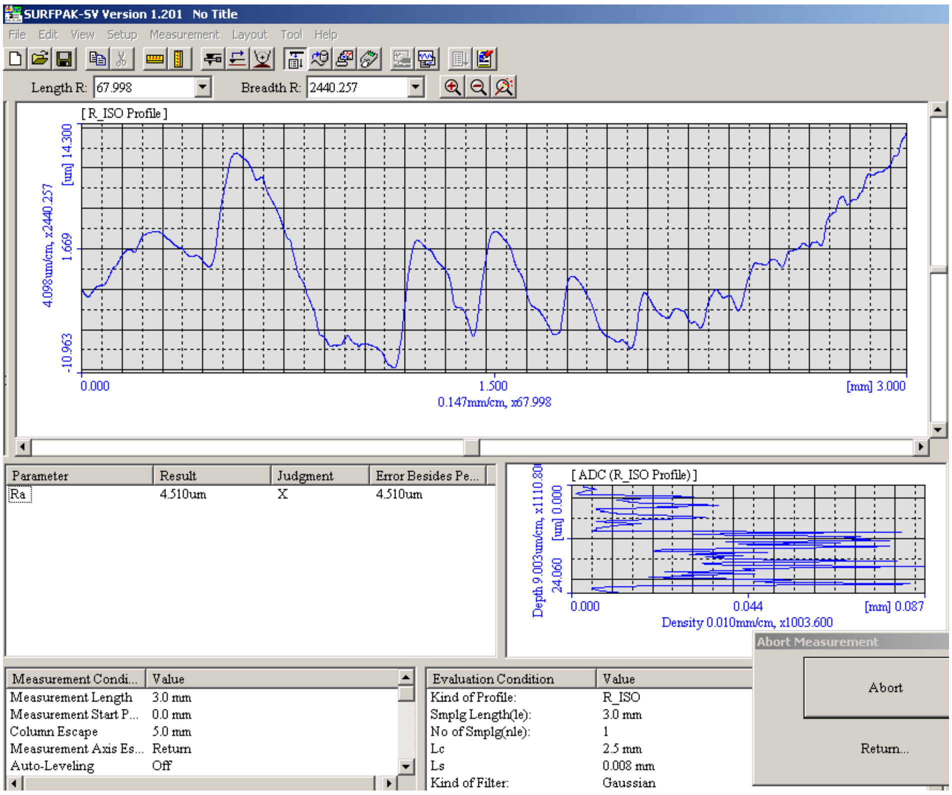
APPENDIX I-c: Result of surface roughness for experiment n°3



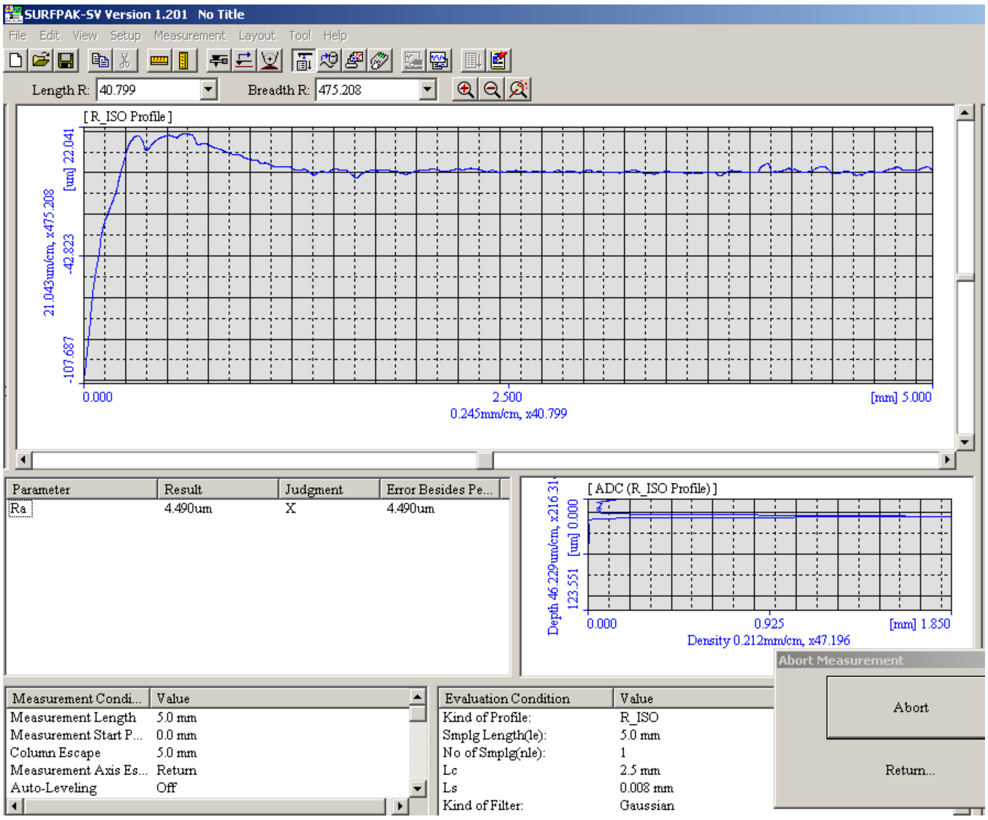
APPENDIX I-d: Result of surface roughness for experiment n°4



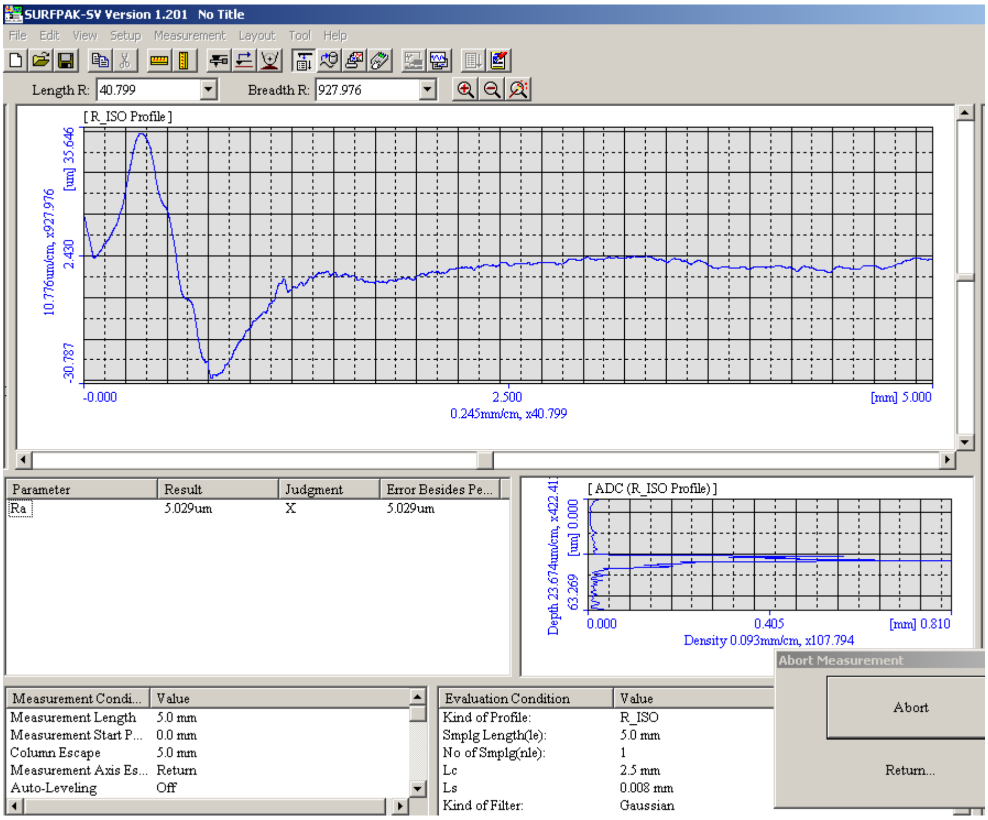
APPENDIX I-e: Result of surface roughness for experiment n°5



APPENDIX I-f: Result of surface roughness for experiment n°6



APPENDIX I-e: Result of surface roughness for experiment n°7



APPENDIX I-g: Result of surface roughness for experiment n°8