DeMaMech Exchange Student Report

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2 Executive Summary

I stayed in Leuven, Belgium and went to Katholieke Universiteit Leuven from September to December. Then I did a research and took lectures (but did not take exam). My research was a part of MEMS project in Belgium. It was about a micro turbine and my part was fabrication technique for a rotor of a micro turbine. Before I left Leuven, I succeeded making in making one blade. Students (PhD) are independent and professors do not usually instruct students each time. So they need to think about their research way by themselves.
Leuven is a town for the university. Buildings of the university spread out in whole town. The town is full of students. So it is good atmosphere for students there. Buses are free for students.

I stayed in Lyngby, Denmark ant went to Technical University of Denmark for 3 weeks in January. Then I took a 3 weeks intensive course. The course I took consisted of lectures and exercises. Each week we took a lecture on Monday and did exercises after the lecture to Friday. Teacher made some groups and did exercises in group and wrote one papers in group at the end of each week. Course title is Laboratory Course in Process Simulation. I studied about computer programs for simulation of metal casting, die casting of plastics as well as mechanical forming of metals.
In Denmark things are so expensive because tax is so high. So many students cook their meal by themselves at home. Some of buildings are locked so early. I think the reason is sunrise is late and sunset is early in winter there.

Both countries English is spoken well. Even if we can speak only English, it is fine for us to live there.

I had some suggestions which I want to be solved in the same project next year.

3 Travel Schedule

06.09.2004 – 02.01.2005 Katholieke Universiteit Leuven (Leuven, Belgium)
02.01.2005 – 21.01.2005 Technical University of Denmark (Lyngby, Denmark)

4 Technical Report

4.1 Research in Katholieke Universiteit Leuven

Subject

Electro-Discharge Machining for a Method of Fabrication for a Rotor of a Micro Gas Turbine Unit

4.1.1 Introduction

4.1.1.1 Situation

Miniaturization portability is nowadays trend. Many portable devices, systems and etc have been developed these days. It could be wireless and be desired to work in difficult places to get power. Therefore several groups are working on the development of micro power generator based on fuel cells, thermo-electronic device, Stirling engines and etc. A miniature gas turbine also is required in those situations. Therefore Micro turbine is under development that generates electrical energy from fuel. The main parts are compressor, turbine, combustion chamber and generator. How to make parts of a miniature gas turbine is one of the most difficult aspects of this study. There are several ways to make micro 3-dimension structure such as etching, LIGA, laser micromachining, focused ion beam machining, powder blasting, microstereolithography, moulding etching and micro EDM. From Jan Peris's study Kersit 601 (Si_3N_4 + TiN) is chosen as a material of a rotor because of its high thermal shock residence. Therefore we use EDM to machine a rotor because Kersit 601 is too hard to be machined by conventional fabrication technique and EDM has some advantages to machine this material.

However, there is a big problem in EDM process, which is electrode wear. Overcoming this problem can make it possible.

4.1.1.2 Aim

Machining a very small rotor (approximately diameter is 10-30 mm) is not easy. Some fabrication techniques for making a micro structure are available all over the world. However, only few fabrication techniques can be used in K.U. Leuven at this moment. For long time research we can think about all fabrication technique. On the other hand, for short time research we should think only fabrication techniques which are available in K.U.Leuven now. In previous research 2-dimension turbine rotor is machined by die-sinking EDM [8]. The aim of this study is to make strategy to machined 3-dimension complex shaped micro turbine rotor with available methods of fabrication techniques in K.U.Leuven.

4.1.2 Method of fabrication

4.1.2.1 EDM

Electro-Discharge Machining (EDM), or spark erosion, is a mature machining process in the tool making industry, and is especially applied for the machining of hard materials which are

difficult to machine with conventional manufacturing process. In EDM process requirement is just that both workpiece and tool electrode are electrical conductive. EDM has developed itself and made variety EDM process such as die-sinking EDM and wire EDM. EDM has become economical machining process to make complex components of any electrically conductive engineering materials.

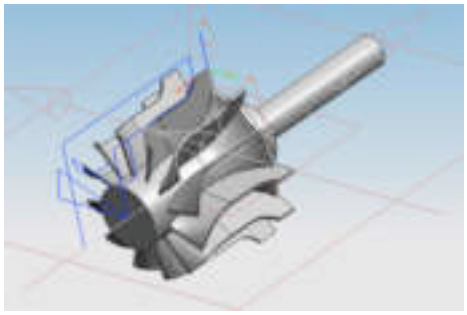
2.1.2.2 EDM process

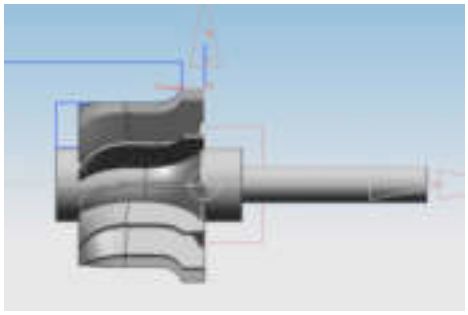
Electro-Discharge machining is an electro-thermal machining process which removes workpiece material by the erosion action of electric discharges. The discharges are created between a tool electrode and a workpeice electrode. Both electrodes are immersed in a dielectric fluid and separated by a small working gap. When a voltage is applied between the electrode and the corresponding electric field in the working gap exceeds the dielectric breakdown level, a discharge is created. The applied voltage is generally pulsed at a predefined frequency, creating successive discharge. Each discharge melts and evaporates a small amount of material on both tool and workpiece electrode. The evaporated material and a portion of the melted material are removed by the electric fluid. The remaining material resolidified and creates a crater-like surface on both electrodes. By applying a large number of sparks, large material volumes can be removed. The material removal on the tool electrode can be kept an order of magnitude lower than the material removal on the workpiece by an appropriate selection of electrode materials and by appropriate machining setting.

The first phrase is the preparation phrase of the discharge channel which is initiated at the moment the generator applied the necessary voltage between the electrodes. When a critical electric field is exceeded between a spot on the workpiece, conduction paths grow at microsecond speeds through the dielectric fluid, in the form of branched trees, called streamers. These streamers are precursors of the effective dielectric breakdown. In a second phrase the electrodes are locally melted by the discharging spark. The discharge consists of a plasma channel surrounded by a gaseous mantle. The plasma channel, consisting of free electrons and positively charged ions, is characterized by high pressure and high temperature. The free electrons accelerate towards the anode and heat up the anode during impact, while the ions strike and heat up the cathode. On both electrodes, material is melted and evaporated by the high power concentration of the plasma channel. It is found the diameter of the plasma channel at the cathode side remains constant, while the plasma channel enlarges at the anode side. This means that the current density at the anode side decreases. When the generator cuts the electric current at the end of the discharge pulse, the plasma channel disappears and the corresponding pressure drop cause the melted electrode material is ejected into the surrounding dielectric fluid. With this action the cycle of a single discharge is finished. When the dielectric is sufficiently deionized, another pulse can be applied in order to produce the next discharge.

4.1.3 Rotor

In this research I used NX3 Unigraphics (UGS Corp.) to design a rotor. I designed it using examples of photos of rotor of Smart□. This time I did not design with hydrodynamics and thermodynamics. Size of a rotor (only a rotor part not included a pole part) is diameter 26.2mm and height 20mm, which is smaller than examples.





4.1.4 CAM

According to the design I also made CAM data with NX3 Unigraphics. Figure 6 illustrates its simulation. It shows that I mill only one groove between blades beside Z-axis because only 3-axis milling machine is available. The groove of this part can be perfectly cut by even 3-axis machine. I made simulation many times and I changed design each time case by case. In those figures I put 2 cylinders in front and back of the rotor to reduce movement of an electrode.
One program is to make only one groove just beside Z-axis. Therefore I need to rotate the workpiece and repeat the program 12 times to make all blades.

4.1.5 Experiment

4.1.5.1 Programs

Unigraphics can make PTP program. However, I had to consider wear compensation. So I needed to change program with consideration of tool electrode wear. A postprocessor program was made to change PTP program to the program that can calculate tool electrode wear. This post processor we can choose wear ratio. Wear ratio is given with how long electrode moves to cut workpiece, not with volume of removed material from the workpiece.

4.1.5.2 NC programs

In the program the most important elements is NC programs. I used three kinds of NC programs. They are main NC program, technological NC program and geometrical NC program.
The mail program only contains the NC command successively load the technological NC program for the machining cycle. The technological NC program contains all technological machining parameters and successive calls for the geometrical NC programs for the different layers. The geometrical NC programs basically contain the tool path vectors together with wear compensation and feed limitations.

4.1.5.3 Setting

I used ROBOMILL200 (CHAMILLES) for milling EDM. NC program was sent to EDM machine through the computer because EDM can not load whole program due to its data capacity. Figure 11 illustrates milling EDM machine.

Copper was used as electrodes. The outside diameter of the electrode is 2.0mm and the inside diameter of the electrode is 1.2mm.

Stainless steel is used as workpiece because Kersit 601 is expensive to use test. The workpiece had been machined to the starting shape by conventional cutting operation. To hold workpiece I used the clamp, which can rotate workpiece each 15 degree accurately.

4.1.6 Result

After machining two grooves I got one blade (Figure 14). Table 3 shows machining time and tool electrode wear. However, some parts of the bottom of the groove were not machined well.

I measured roughness of the surface with Form Talysurf Series 120L (Taylor-Hobson). I did not do finish machining because of lack of time. Therefore roughness is not good enough for rotor. The smoothest part is outside of the blade. The reason why this part gets the smoothest surface is this side was machiened pertically. The roughest side is machined not pertically. But even the smoothest surface is not good enough for a micro turbine rotor.

4.1.7 Conclusion and direction for future works

With milling EDM I made one blade, which means that I can make a rotor although material is not Kersit 601 (desired material for a micro turbine rotor at this moment), but stainless steel. Kersit 601 is possibly supposed to be machined by milling EDM.

Roughness of the machined rotor is too rough to use as a real micro turbine rotor. We need many machining steps to obtain desired shape and roughness. Only one process can not make it.

To conclude Milling EDM is one possibility to make a micro turbine rotor.

4.2. Lecture in Technical University of Denmark

4.2.1 Course guidance

42250 Laboratory Course in Process Simulation

Danish title: Øvelseskursus i processimulering

Language of instruction: English Credit Points (ECTS): 5

Type: B.Eng. Mechanical Engineering

M.Sc

Taught under open university

Recommended semester: B.Eng. 5th semester

M.Sc. Intermediate part of M. Sc. Programme

Scope and form: Exercises

Duration of Course: 3 weeks

Date of examination: No exam

Evaluation: Evaluation of experiments and reports

Evaluation: pass / not pass, internal examiner

Qualified Prerequisites: 42301 / 80001, Production Technology I

Optional prerequisites: Computer user knowledge

Participants restrictions: Maximum: 16

Aim/objectives:

To make the students familiar with some of the most important computer programs for simulation of metal casting, die casting of plastics as well as mechanical forming of metals.

To enable the students to make simple computer simulations with these programs.

Content:

The course is divided into three parts covering simulation of metal casting, plastics casting and metal forming. Each part starts with an introduction to the process followed by an exercise where the process is simulated. A small report must be delivered in the end of the course.

Remarks:

First og middle part of study.

Responsible:

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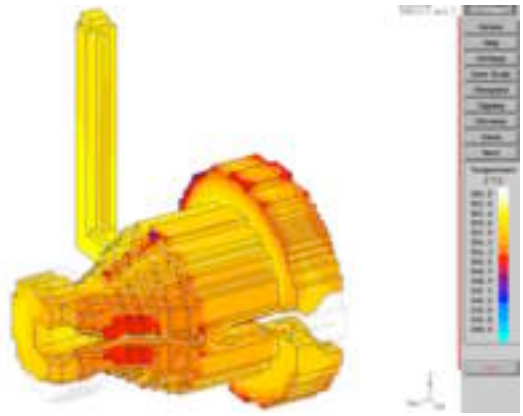
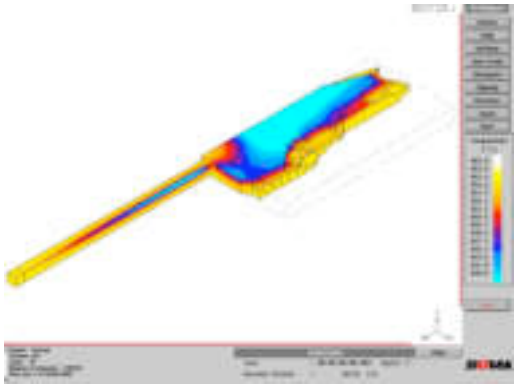
Key words: Numerical modelling, Process analysis, Plastics processes, Control volume method, Finite element method

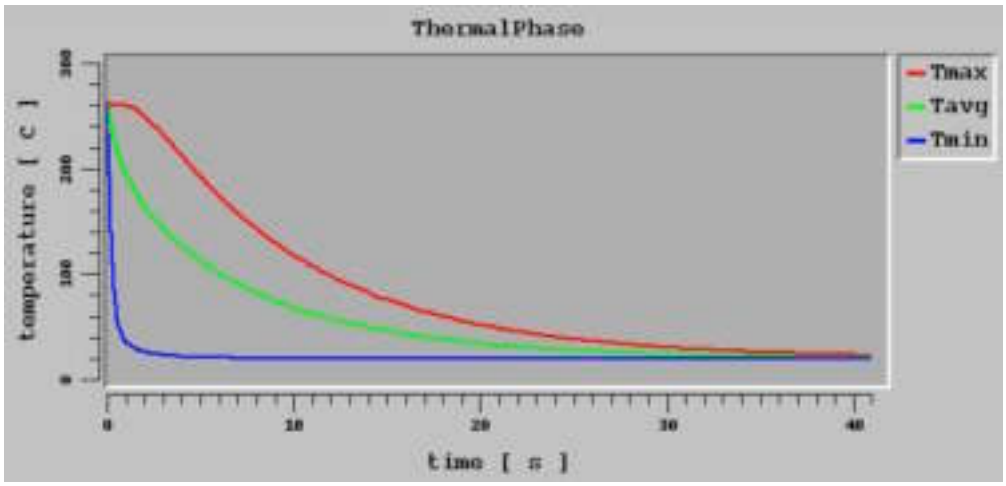
4.2.2 Course description

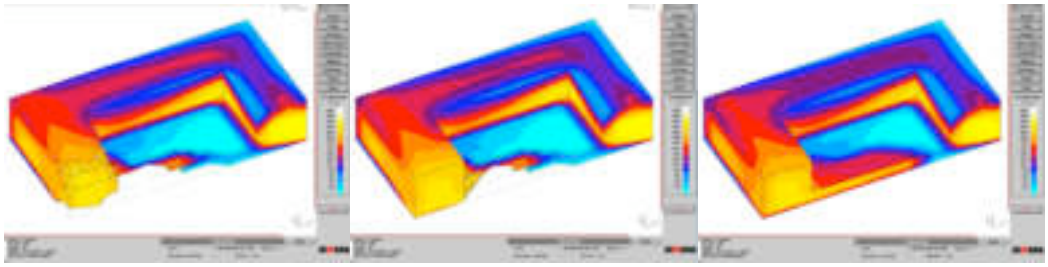
4.2.2.1 1st week

We made some computer simulations of die casting of metals and plastics with SIGMA soft. We talked about some problems in simulation such as welding line, filling time, position of runner and so on.



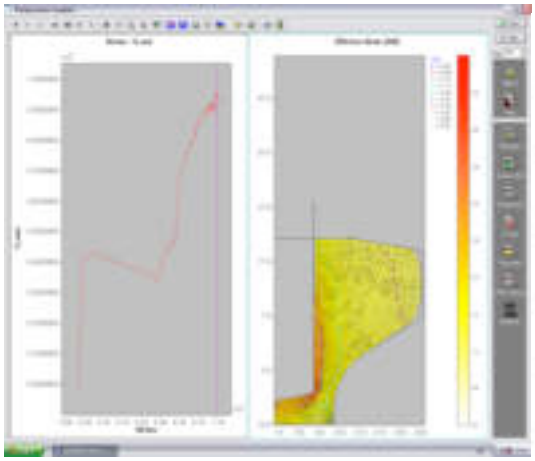


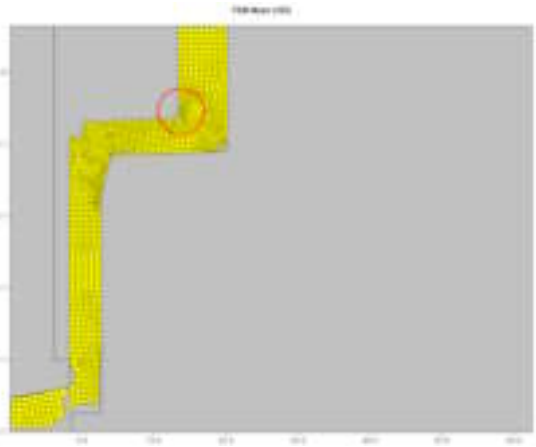


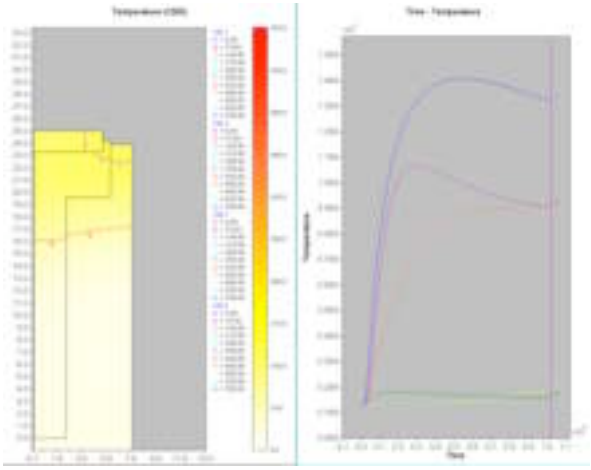


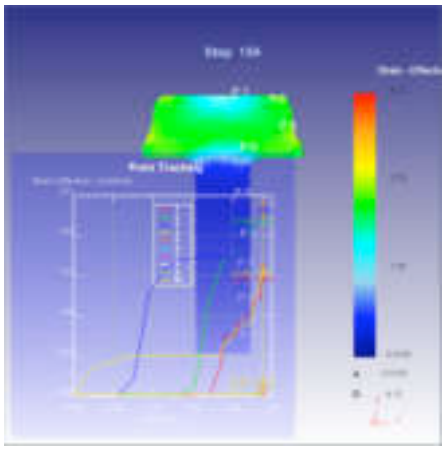
4.2.2.2 2nd week

We made some computer simulations of mechanical forming of metals. We observed stress curve, strain curve and temperature curve. Then we discussed problems in simulations such as forging cross, die deflection and so on through simulations.



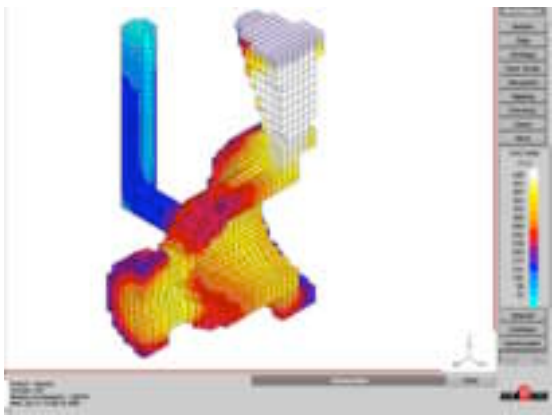


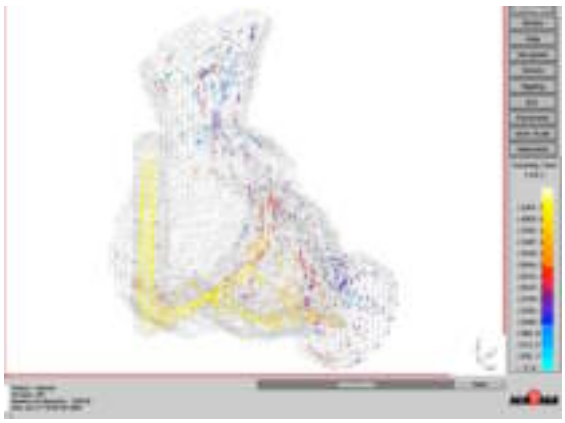


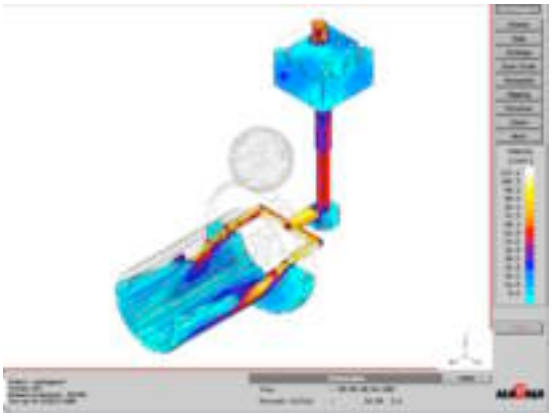


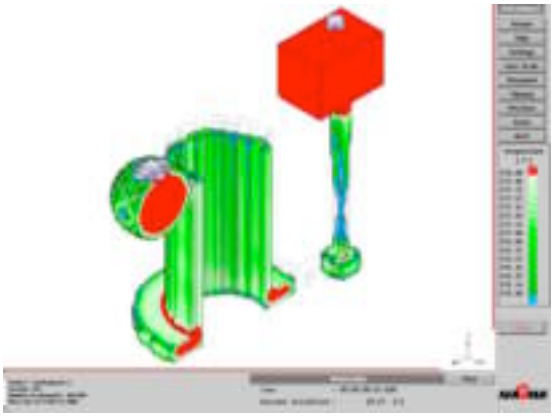
4.2.2.3 3rd week-1

We made computer simulations of die casting of plastics with MAGMA soft. MAGMA soft is similar with SIGMA soft. This time we discussed feeder, cooling process and so on.



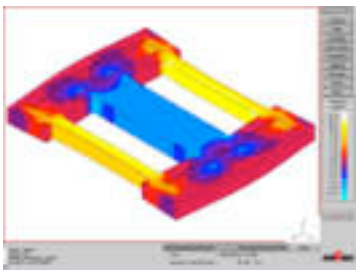


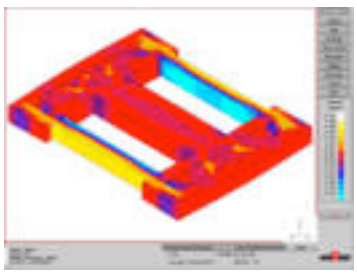


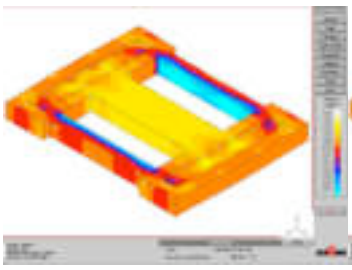


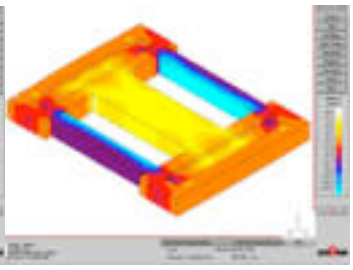
4.2.2.4 3rd week-2

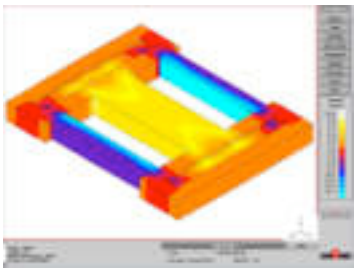
We made some computer simulations of cooling process, especially about shrink problems. We discussed about that and analyzed some data and compared analytical data and simulation data.











5 Exchange student life

5.1 Life in Katholieke Universiteit Leuven

Katholieke Universiteit Leuven has many foreign students. Most of them are exchange. So most of them stay in Leuven for about 1 year. They come from all over the world. For example they come from Europe, Asia, North and South America, Africa and so on. Normally they can not stay in student residence. It is only for full year academic students. Exchange student usually rent a room in Leuven city. Accommodation office can help them to find a room. There are 2 type of rooms. One is just a room and the other is studio. The former is a room with own basin and shared kitchen and bathroom. It costs about 200 to 300 euro. The latter is a room with own basin, kitchen and bathroom. It costs about 250-400 euro. Most of them has internet points. Some of students live with Belgium family.

At the beginning of semester there is guidance for exchange students. It consists of welcome speech for exchange students, instructions about life in Leuven, which are about supermarkets, sport centres, traffic systems, traffic rules and so on. It is not obligation. It does not matter if students go or not.

The university also has exchange student centre, which is called “Pangaea”. It is for exchange student. It has language class, not only English also other languages. Students have to pay fee, but it is very cheap. The centre also has a coffee room. If students pay 5 euro, they can use this room. Students can drink coffee for free there. A lot of students gather in this room. If students use this room, it is easy to find international friends. The centre also helps students who have problems, for example they have homesick, they can not make friends and so on. The cantre have events as well, for example tours to some cities. I took the tour to Brugge. The tour price is included a bus and a guide.

There are some parties for international students. Normally canteens are used for parties. Students can meet many other international students there. Usually it starts from 9pm and finish until when they want finish!

Students can rent a bicycle for cheap price. The university has this non-profit facility. Computer rooms are available for 24 hours and students can eat good and cheap food in a canteen. 2nd bite French flies are free! So Students never get starve.

There also many parties in bars. Parties usually take place on Thursdays because students whose hometown is near Leuven go back to their hometown on Fridays.

Students can have free bas card from the university. They can use bus in Leuven city and around Leuven for free.

5.2 Life in Denmark Technical University

There are residences only for foreign students. They are in university. It is a room with shared kitchen and bathroom. It also has laundry facility. Students can wash and dry their clothes. Accommodation office can introduce host family or other building to international students. Some of students live there. In Denmark eating out is very expensive. So many students cook their food at home. There are canteens and small supermarket in the university. This market is not so big, but it is convenient because even closest supermarket is a bit far from the university. International student office can help students who have problems. Computer rooms are available for 24 hours with their student card and account. They can also connect their own lap top computer with internet there. There is also bar in the university. Tuesday is only for international students.

I have heard that there is a system, which is that Danish students help international students. Before students arrive in the university, they can send form to international student office.

Not so many bars are near the university. So students go to Copenhagen for parties, disco. There are night bas systems in Denmark. So students can go back home late even though it is twice as expensive as day bus.

This country English is spoken very well. So it is fine if we can not understand Danish.

6 Suggestions to the Project

All universities should keep places where students live during their stay. In our case some of us could not get a room because accommodation office said that we stayed in Leuven for only 4 months (Usually students stay for more than 1 year. Most of landlords want to rent out a room for more than 1 year.), but we sent a accommodation form about more than 3 months before our arrival.

If students want to do some research there, they should apply for long time course and students should go to only 1 university instead of 2 universities. To do good research students had better be used to living and studying there. If students go to 2 universities, it takes some time for them to get used to living and studying there. In addition, if students get accommodation problem (as I wrote above), it is more difficult. Besides, students focus on only one subject instead of doing 2 researches in 2 different universities.

For short term students if they are wanted to do research, they should go to only 1 university instead of 2 universities as well. In my opinion 4 months are too short to do some research. If they are wanted to get good experience, it is ok for them to have to go to 2 different universities. Students can get different lectures, culture, friends from 2 different countries.

When we asked coordinators some questions of this project, some case they answered so late or did not know about the project well. If even coordinators do not know the project well, students get confused easily.

Students should not only study but also travel or make friends to get good experience. Because students are in different country which has different culture, people and etc, they should try many things which is difficult to do in Japan.

7 Summary

I went to Katholieke Universiteit Leuven to do a research for 4 months and went to Denmark Technical University to take course for 3 weeks. The subject I did was slightly different from my research in Japan. So it was difficult to do it. Besides, I had only 4 months to do it. I made some outputs at least, but I do not recommend applying for this project for short term if students really want to focus on research and to make a very good output such as thesis, academic paper. If student want to do it, they should apply for long term one. However, I do not deny the short term one. From the short term one students can get good experience for short time. They can feel different atmosphere and meet many people and make many friends. I am sure that it can widen their world.

To conclude, this project is good for students. I would like to recommend it to my junior, but in my opinion it has some problem which should be solved to make the project better.