1. Personal Data

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Host Institute 2

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2. Executive Summary

I stayed in Delft to make research in Technical University of Delft from September 2005 to December 2005. The research theme was ‘Introduction to the damping for micro-factory planer table suspension’.

The second university was Technical University of Denmark in January 2006. I took 3 weeks intensive course which name was ‘Laboratory Course in Process Simulation’.

Staying in Europe, I could travel many countries which can be experienced only in student age.

In this project I could learn European technology, English, European culture and many other things. Those experiences let me broaden my way of thinking.

3. Travel Schedule

August 22nd 2005 Departure from Japan to Berlin
September 5th 2005 Start of studying in TU Delft
December 22nd 2005 Completion studying in TU Delft
January 1st 2005 Transfer to Denmark
January 2nd 2006 Start of studying in DTU
January 20th 2006 Completion studying in DTU
February 1st 2006 Arrival in Japan

4. Technical report

4.1 Research in Technical University of Delft

Subject: Introduction to the damping for micro-factory planer table suspension

4.1.1 Introduction

These days, as the needs of small parts with high accuracy are getting higher, the needs of small machine is also getting higher. The advantage of this small machine is saving energy, saving space, and saving resource. Therefore, the project, μ-Factory has started in the TU Delft Advanced Mechatronics department. This project is aiming at producing small parts with high accuracy of 0.1μm with desktop size machine.

In previous research as a part of μ–Machining station, a high precision planer table for this station is presented. This table is designed to satisfy the static requirements, such as load carrying capacity and stiffness.

An air bearing with carbon porous carbon ring is selected as an air bearing for this suspension. This is why this type of bearing is less likely that the pneumatic hammer phenomenon happens for its moderate air flow in the air gap.

However, damping of the table does not referred to so far. Damping is an important factor which decides the quality of the product produced by this μ–Machining station as load carrying capacity and stiffness. When the bearing itself is oscillated in a frequency which is same as the eigen frequency of the bearing, the vibration would be amplifiered. If the damping of the table is bad and there is a disturbance that resonates with the stability of the table, that will lead to an error between the tool and work material directly. Even if a table with high stiffness is designed, the table with bad damping is meaningless for this μ–Machining station, because this project has been aiming at the accuracy of 0.1μm.

Therefore, the main goal of this research is to know how the damping of the air bearing with porous carbon ring is.

4.1.2 Experimental approach

4.1.2.1 Experimental setup

The experiment was conducted as the following way to measure the damping of the air bearing with porous carbon ring. The experimental setup is shown in figure1.

In this setup, air bearing with porous carbon ring is put on the granite table, and air is supplied to the bearing from external pump. Air gap is measured by subtracting the displacement with no supplying air from that with supplying air. With mounting additional weights between the air bearing and aluminium plate, air gap can be changed. This is the way to measure the static characteristic of the bearing.

Then, impulse hammer is applied as an input. Output is given by the displacement between the aluminum plate and eddy current sensor. Hitting the top of the aluminum plate 20 times by the hammer, Siglab which is a kind of FFT analyzer averages the bode plot of the transfer function between the input and the output 20times. The data from Siglab is sent directly to the PC. This is the way to measure the dynamic response of the bearing. Supply pressure is fixed to 0.5[MPa].

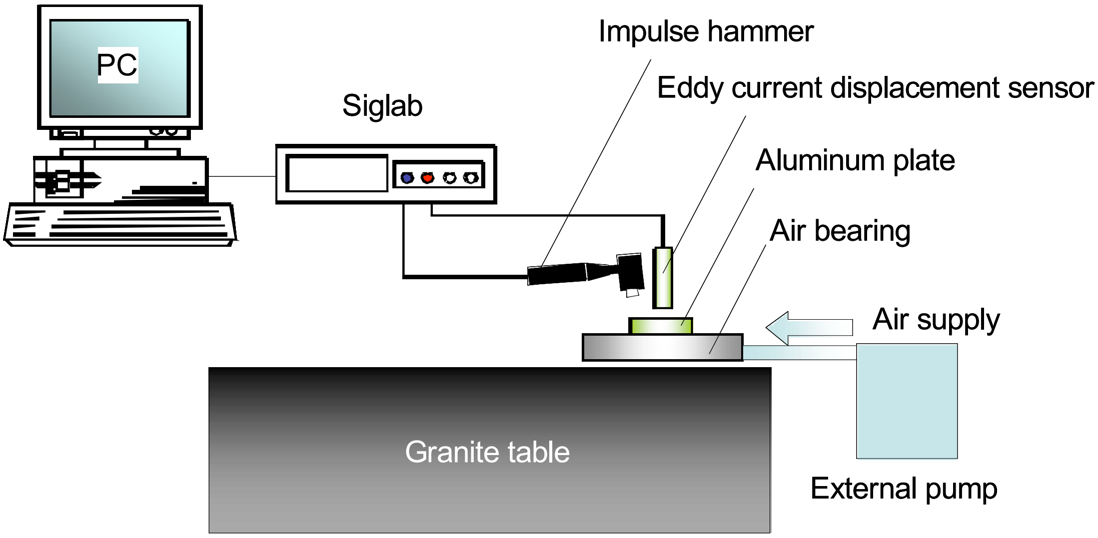


Figure1. Experimental setup

4.1.2.2 The results of the static measurement

Table1 shows the results of the static measurement. Load carrying capacity is summation of the mass and stiffness is calculated by differentiating the load carrying capacity in respect to the air gap. The undamped natural frequency of the bearing, ω_n is calculated by equation (1)

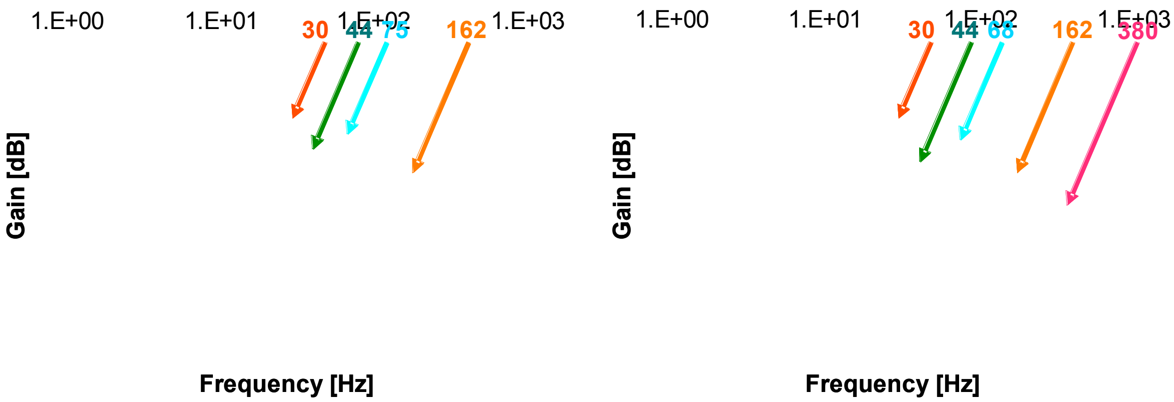
$$\omega_n = \sqrt{\frac{k}{m}} \qquad (1)$$

Table1. Results of the static measurement

Air gap[μm]	Load carrying capacity[N]	Stiffness[N/m]	ω_n[Hz]
58.5	3.84	1.81E+05	108
50.2	5.80	3.22E+05	117
44.9	7.76	4.93E+05	126
42.1	9.72	6.26E+05	126

4.1.2.3 The results of the dynamic measurement

Figure2 shows the results of the dynamic measurement when the air gap is 58.5[μm] and 44.9[μm].



Air gap: 58.5[μm]   Air gap: 44.9[μm]

Figure2. Results of the dynamic measurement

Only from figure2, it is hard to know which peak is the accurate damped natural frequency, ωd.

The peak at 30[Hz] are estimated to be the resonance of the granite table and that at 44[Hz] is because of the table which the eddy current sensor is attached to. Those could be known by hitting the each table and measuring the dynamic response without supplying air.

There is a following equation, (2) between damping ratio, ζ and the eigen frequency.

$$\zeta = \sqrt{1-\left(\frac{\omega_d}{\omega_n}\right)^2} \qquad (2)$$

Considering the equation (2), ω_d must be lower than the undamped natural frequency ω_n. Except 30[Hz] from granite table and 44[Hz] from the table which the eddy current sensor is attached to those peaks are the only one that is lower than ω_n (108[Hz] when the air gap is 58.5[μm] and 126[Hz] when the air gap is 44.9[μm]). Therefore, those peaks must be the ω_d of the air bearing.

The peak around 380[Hz] when the air gap is 44.9[μm] cannot be seen when the air gap is 58.5[μm]. This is because an additional mass is mounted above the air bearing with double sided tape in the former case. There is nothing except the additional mass that is different in those two experimental setups.

The fifth peak at 162[Hz] is estimated to be the resonance of the aluminium plate and its double sided tape. This peak can be seen in both experiment (figure 3-1 and figure3-2), and there is nothing else except the aluminium plate that brings a big resonance to both of the experiment.

Finally, the damping ratio, ζ can be calculated from equation (2). ζ of this air bearing are 0.68 when the air gap is 58.5[μm] and 0.65 when the air gap is 44.9[μm].

Although this measurement, especially the dynamic measurement is conducted under many disturbances and the air gap in this measurement around 50[μm] is not the practical air gap which is 5-10[μm], this damping ratio is rather a good result and good damped.

4.1.3 Analytical approach

The static analysis is done by Femlab which is a kind of FEM (Finite Element Method) software to see how accurate the static measurement was conducted. Figure3 is the analytical result of the pressure distribution in the air gap of the bearing. Figure4 shows the good fitting in load carrying capacity from experiment and that calculated from FEMLAB. Therefore, it can be said that the static measurement itself is quite a good result.

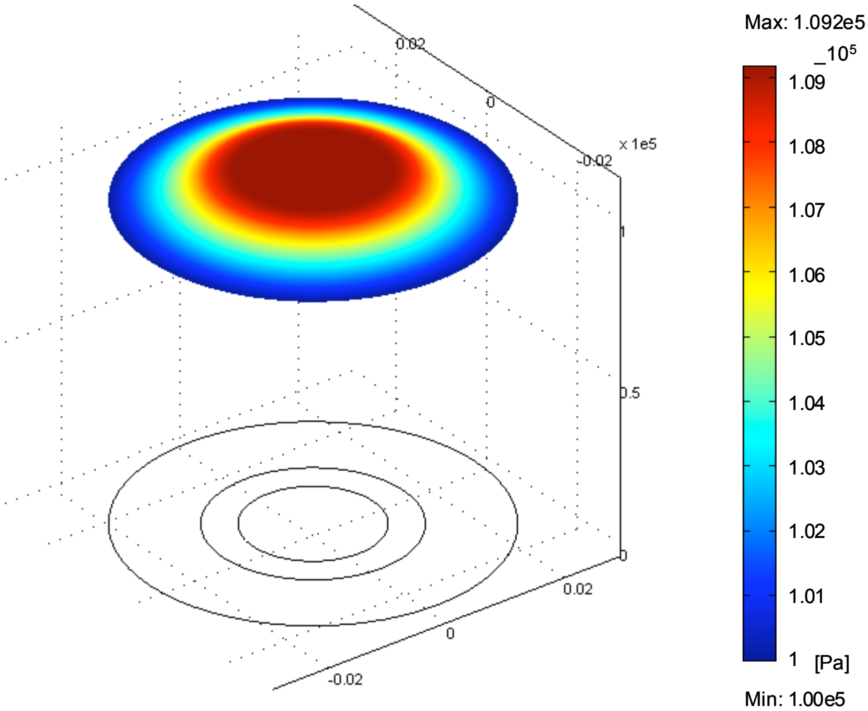


Figure3. Pressure distribution when the air gap is 40[μm]

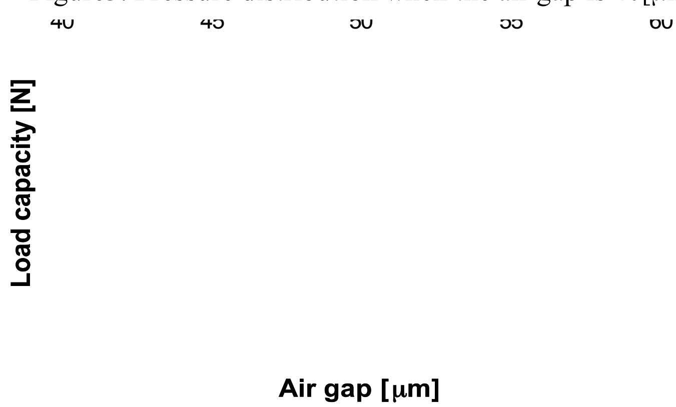


Figure4. Good fitting in load carrying capacity

4.1.4 Conclusion

The damping ratio, ζ of this air bearing are 0.68 when the air gap is 58.5[μm] and 0.65 when the air gap is 44.9[μm]. Although this measurement, especially the dynamic measurement is conducted under many disturbances and the air gap in this measurement around 50[μm] is not the practical air gap which is 5-10[μm], this damping ratio is rather a good result and good damped.

4.2 Lecture in Technical University of Denmark

4.2.1 Course information

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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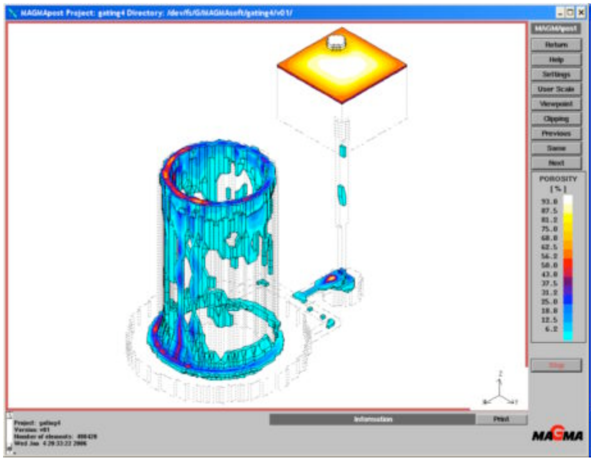
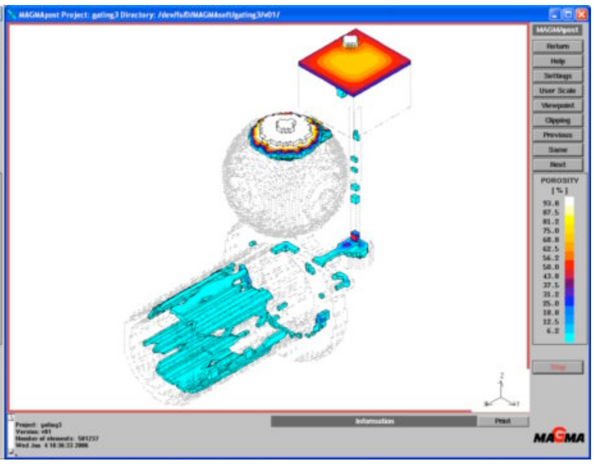
Department: 42 Department of Manufacturing Engineering and Management
Home Page: http://www.ipl.dtu.dk
Key words: Numerical modelling, Process analysis, Plastics processes, Control volume method, Finite element method

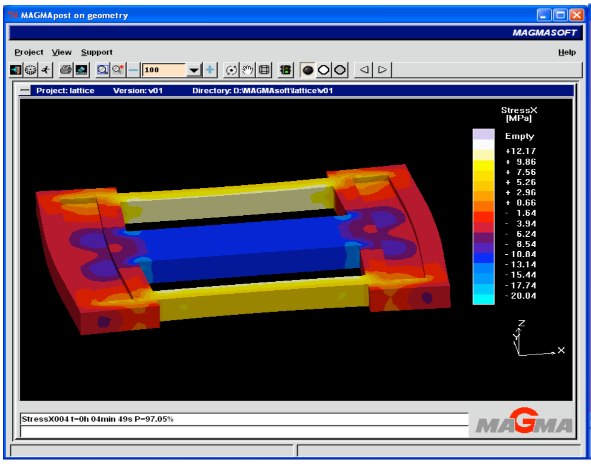
4.2.2 1st week

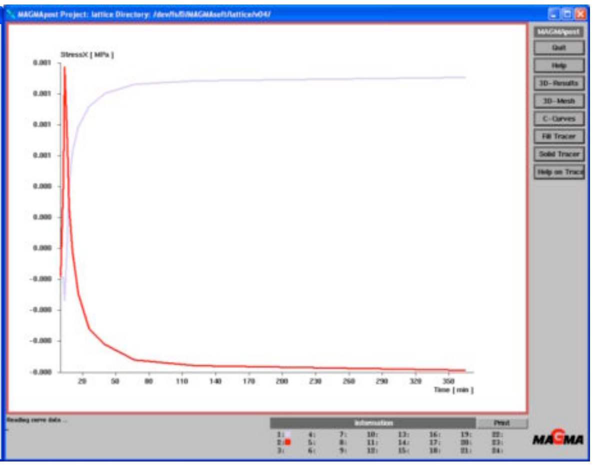
The aim in here is to use MAGMA Soft to help design a useful gating system for a simple pipe casting. The simulation was conducted to analyze the casting in relation to how solidification proceeds and to get an idea of whether feeders are needed and how a gating system should be designed.





The next exercise deals with the casting of a stress lattice. The purpose of the exercise is to analyse the transient and residual stresses.

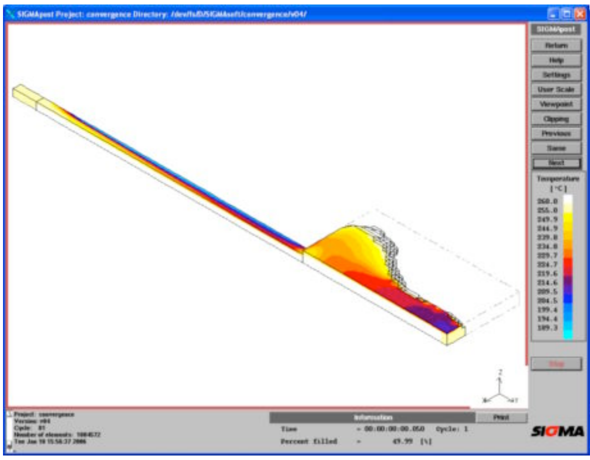
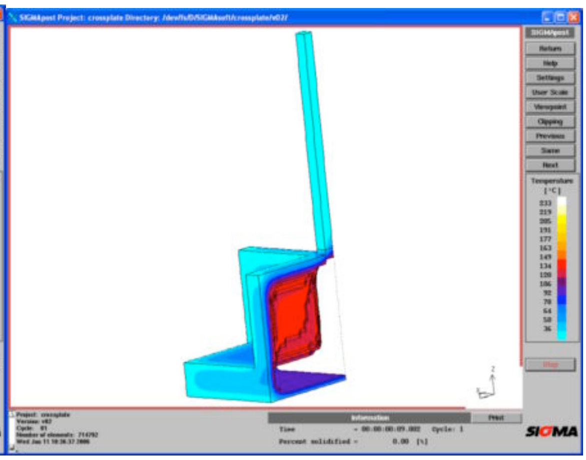
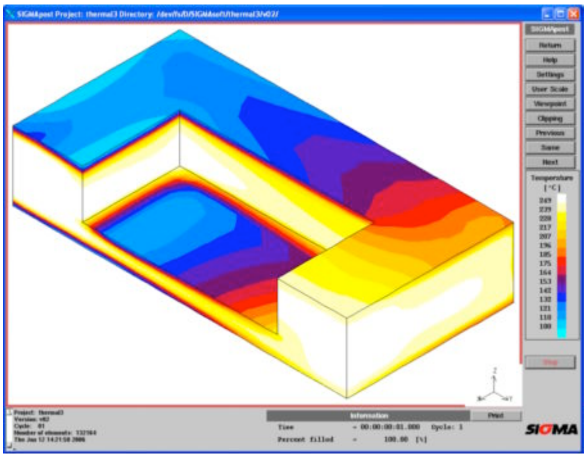
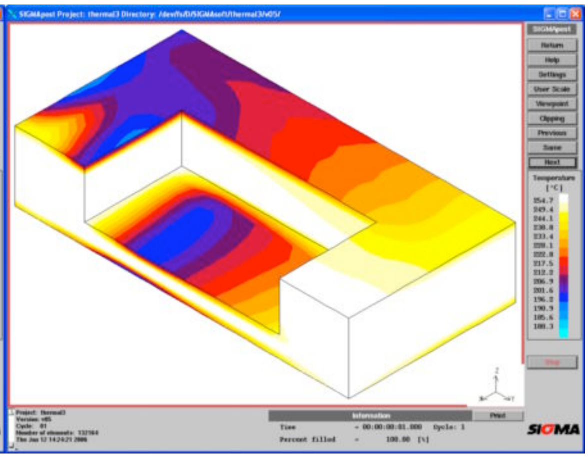
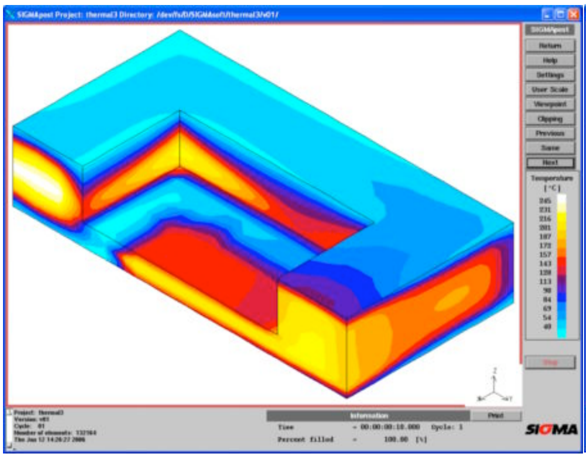
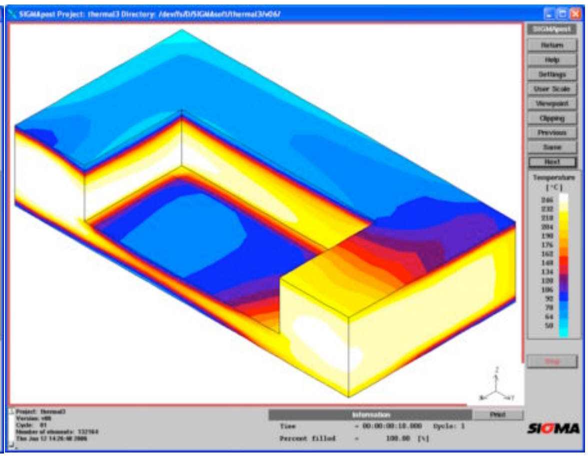




Besides, the linear contraction of a steel and aluminium plate is analyzed in MAGMA Soft.

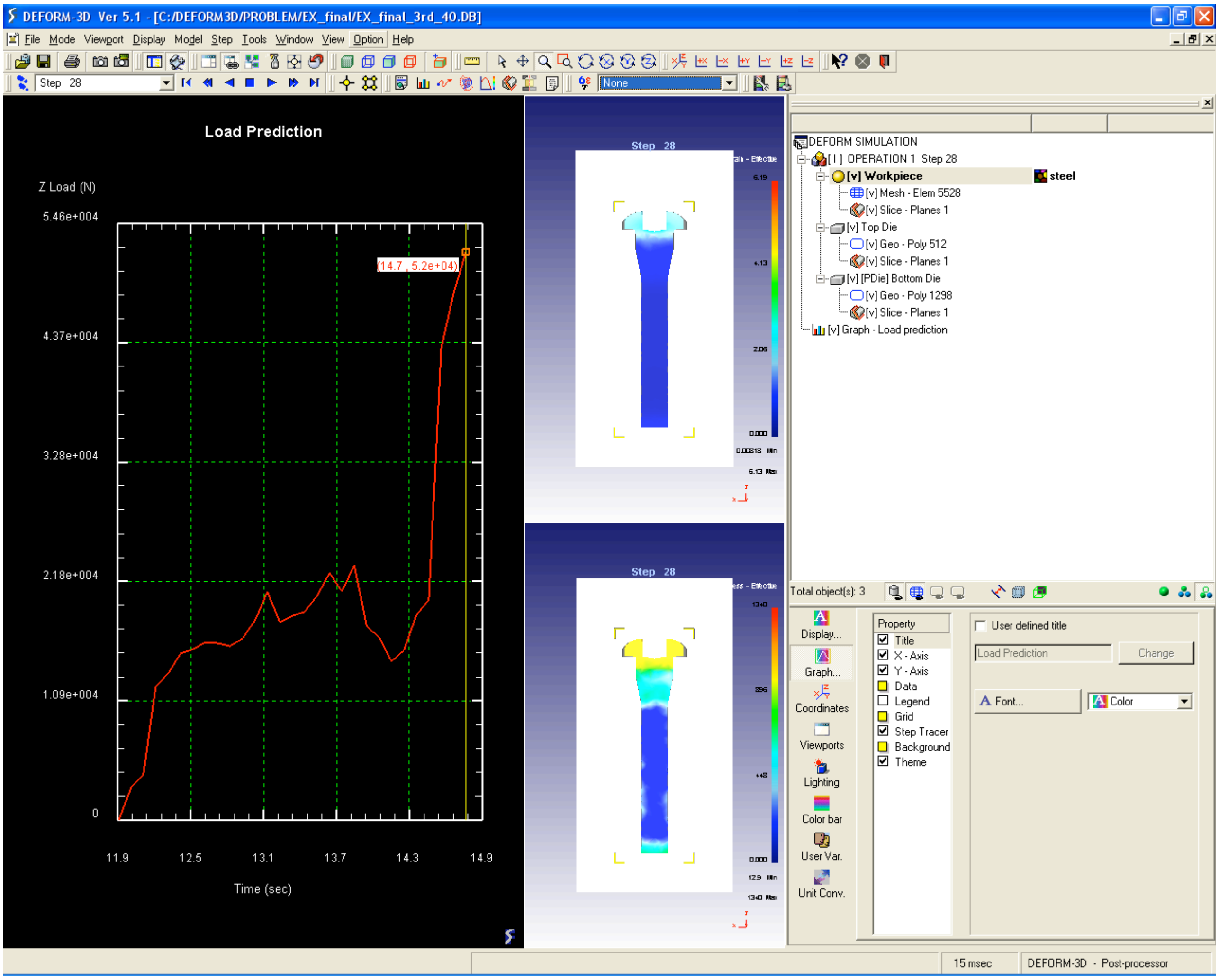
4.2.3 2nd week

Some numerical simulations of die casting of metals and plastics are conducted using SIGAMA Soft to discuss welding line, filling time, position of runner and so on.

4.2.4 3rd week

The aim for this exercise is to find an acceptable way to form the screw which is manufactured by cold forging processes. After that optimal forming steps and material parameters are suggested. All the simulation here is made by DEFORM.



5. Exchange student life

I stayed in Delft to make research in Technical University of Delft from September 2005 to December 2005.

I shared kitchen, shower, toilet, and living room with 15 Dutch students in Delft. Monthly payment for the accommodation was about 230 euro per a month. I cooked my meal myself because the restaurant in the Netherlands is expensive and the foodstuff in the supermarket was quite cheap.

There had many parties in our building every Friday and I could dance and drink cheaply, less than 1 euro per a bottle of beer. In this way, I could feel many Dutch styles. Almost every Dutch can speak English very well. Therefore, it was a good chance to improve my command of English.

The research style was quite different from Japanese style. It was the biggest culture shock for me in this project. I had known that I had to think myself and move myself and I tried to do so in practice. However, that was not enough for them. I made a research with one PhD student and we had a weekly meeting. There, we discussed what I did last week and what I will do in this week in detail. However I tried to make research, the university itself closes at 10 p.m., then, it was required to concentrate in a day time and make some results within a few days. Although almost all the exchange student could not get their own desk or space, I luckily had my own space in my case. However, I could not get sufficient instruments for experiment to make accurate results. Therefore, it was quite difficult to get good results only in 4 months.

After staying in Delft, I stayed in Lyngby which is nearby Copenhagen in January. I shared kitchen, shower, toilet, and living room with 6 international students. Accommodation offices in both countries help us find our room and the procedure was not so much difficult. Here, I could feel many international cultures and foods. I also cooked my meal myself because the restaurant in Denmark was extremely expensive. The intensive course itself was good prepared to finish just in 3 weeks. The teachers kindly talk to us Japanese and had no time to feel any stress.

Staying in Europe, I could visit 20 countries as a travel in weekends, before the project, after the project, and during the Christmas vacation. In my opinion, you should not have any stereotype, and should have open mind. You should do everything what you want to do. Then, you can broaden your way of thinking.

6. Summary

I went to the Netherlands and Denmark as a part of DeMaMech project. In each of the university, I could feel different culture from Japanese one.

It was quite difficult to make some results in research because of the bad quality of the experimental instruments and the lack of time. However, it was a great experience to make some research with foreign researcher.

Goodness in this project is not only the research in foreign countries, but also an experience to live together with the native students. This lets us know the real native way of life and bring many international friends. Everything was new to me; those were really an exciting experience.

To conclude this, this project was good experience for me and I hope this project will be continued.