

DeMaMech Exchange Program Report

Feb. 2005 – Jun. 2005

Delft University of Technology



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1. Personal data

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2. Executive Summary

I studied at TU Delft in the Netherlands for 5 months from February to June 2005. During that period, I have done 4 lectures and one small project.

The lectures are 3 technical courses, Fundamentals of material removal process, Measurement theory and praxis and Electromechanical systems, and one English course. Measurement theory and praxis and English course were held for 5 months, other two courses were held for 2 and half months. Every courses required us final exam at the end of the period of these courses.

As small project, I conducted research about development of micro-gripping with electrostatic force. This work was started from literature investigation, studying of electrostatics and studying how to use software package ANSYS. And after that, as analytical approach, simulations were done by using ANSYS. In parallel, experiments were implemented. And last an half month was spent for writing a report. As a conclusion of the results, it was confirmed feasibility of electrostatic micro-gripping. And it was proved that necessity of insulation layer wrapped conductive core, reliability in terms of temperature at range from 27.2 °C to 37.4°C. And differences between theoretical and experimental results were shown, and these reasons were given. Last conclusion was that experiments have shown that bi-pole gripper could pick up a part at lower applied voltage than mono-pole gripper.

About exchange life, regularly I went to school every weekdays for research work and lectures. But it was difficult to find good spaces to study at mechanical faculty due to some noise and many people. I was sorry that I could not get my space to concentrate on studying there. On Tuesdays and Thursdays, I went to practice soccer from 8:30 after studying. Other weekdays and even weekend, I had practices for the marathon. Every time, I ran about 8 km. And on Wednesday's night at around 11:30, international students started to gather one bar to meet their friends. So I went there often, otherwise we were not likely to have any communication with international students, because my accommodation was isolated each other with residents there. Equipments of accommodation was so fine, every thing was new and the room has own kitchen, toilet and shower room. On the other hands, this made me lonely.

Weekend I went traveling about the Netherlands, for example, Amsterdam, Rotterdam, Scheveningen and Den Haag. And I had a chance to see soccer matches at Kerkrade, and moto GP at Assen. We felt that it was easy to travel around the Netherlands because of good traffic system. But sometimes they had constructions and strikes that result in big inconvenience to transport.

3. Travel schedule

Period : February 2005 – June 2005

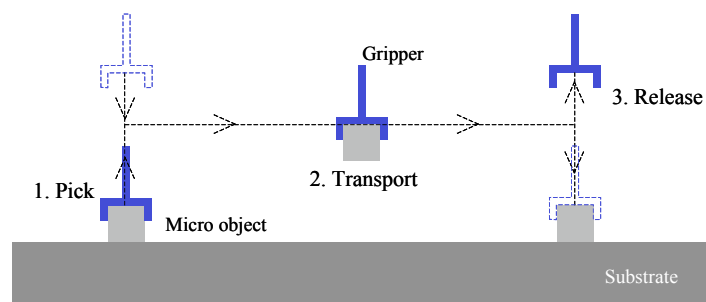
4. Research and Lectures

In TU Delft, I have done one small project and 4 lectures.

The small project was titled “Development of micro-gripping on basis of electrostatic force”. This is following project of previous one that is done by other students. Previous one showed a possibility of the electrostatic micro-gripping, and this time, development of the gripper was aimed.

Today two kinds of systems can be found in the micro domain, one of them is the system composed of only a few or one components such as MEMS, and another is the system composed of some parts as elements of functions, which is called micro-system. MEMS has been developed and has precision structures usually on nanometer order, but it is still hard to be built 3-dimensional structure by using current fabrication techniques. On micro-system, ways of building 3-dimension structure different. In order to establish more functional systems, the elemental parts or modules tend to be assembled, although micro-assembly that includes manipulation, gripping and placing is also not an easy task due to unpredictable phenomenon. So micro-assembly plays an important role in micro-system. In terms of micro parts, overall part and product dimensions are in the range of about 0.5 – 30.0 mm, parts in the range of 100 – 5000 mm, and high accuracy in the range of 0.1 – 10.0 mm is required.

In this project, only the gripper was focused on. Robotic systems such as robot arm or sequences to manipulate were not taken into consider. Main functions of a gripper are to pick up, transport and release



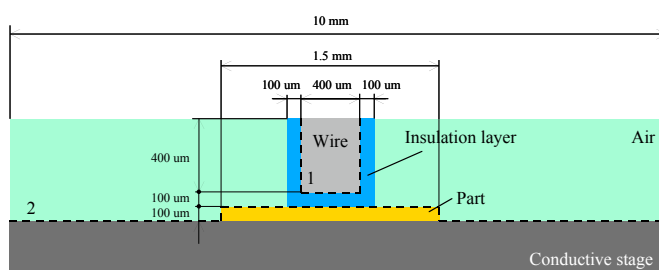
an objective part. In general, releasing is most difficult operation on micro-gripping due to unwanted forces like surface tension force or Van der Waals force.

Electrostatic force is useful for the micro-gripping. This force is attractive force and also repulsive force corresponding to properties of electrons. In case of positive against positive, generated force is repulsive: of positive against negative, generated force is attractive force. These forces help effectively to picking process and especially

releasing process. What's more, electrostatic force is controllable with changing specific parameters. Important parameters are applied voltage, material of insulation layer (relative permittivity of insulation material), thickness of insulation layer and so on.

On this research, investigation was approached from two ways, theoretical method and experimental method. As theoretical way, Finite Element Method (Fem) was implemented on commercial software package ANSYS. In this method, a continuous problem is first broken in to a discrete physical representation consisting a finite number of regions or finite elements. The governing equations for the discrete representation of the continuous problem are formed by combining the stiffness matrices and load vectors for the individual finite elements. These equations are then solved to produce an approximate solution for the continuous system. As a result, ANSYS evaluates how much the electrostatic force is generated. As experimental way, electrostatic gripping is done practically. At first, required setup was built including electrical circuit, and electrostatic grippers were made. For later comparisons, two kinds of insulated materials were used. Teflon (P.T.F.E.) (relative permittivity: $\epsilon_r = 2$) and trichloroethane ($\epsilon_r = 7.5$). And the grippers could be classified with the number of electrodes. One has one electrode and another had two electrodes. Each experiment was done at least 10 times, and percentages of possibilities represented evaluation of the parameters. Finally, theoretical and experimental results were compared. These comparisons typically showed difference between ideal and practical situation.

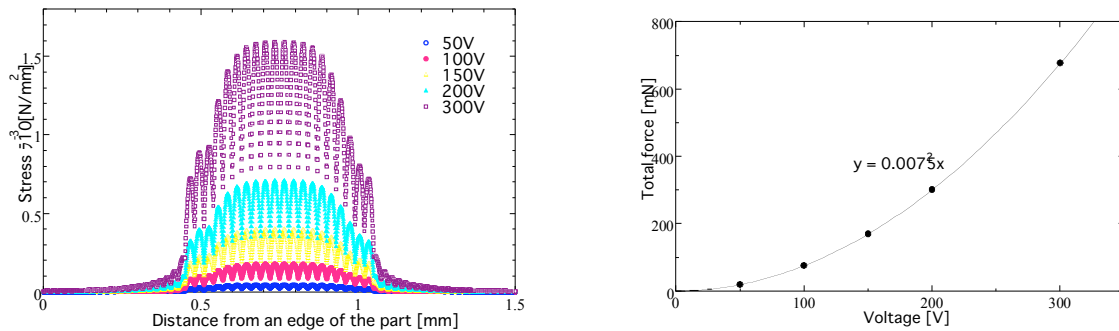
Here one analytical model and their result are shown. It is about applied voltage variance. The analysis model are depicted in the following figure. Considered area was $10\text{mm} \times 600\mu\text{m}$. Diameter of a wire was $400\mu\text{m}$ long and totally the gripper's diameter was set $600\mu\text{m}$. Thickness of insulation layer was $100\mu\text{m}$, which is from measured thickness of Teflon firms used in this research. The objective part has 1.5mm width and $100\mu\text{m}$ thick and is made from copper, which means that it is highly conductive. It was assumed that the end surface of the gripper and the top surface of the part had complete contact without any gap or contamination, and insulation layer was Teflon, that is, relative permittivity is 2. relative permittivity of air was set 1. Applied voltage was



Applied voltage [V]	Dot line 1	40, 90, 140, 190, 290
	Dot line 2	-10
Gripper		
Diameter of wire [μm]	400	
Thickness of insulation layer [μm]	100	
Material of insulation layer	Teflon (P.T.F.E.)	
Part		
Part size [mm]	Width	1.5
	Thickness	0.1
Material	Copper	
Relative permittivity [-]	Air	1
	Teflon (P.T.F.E.)	2

changed from 50V to 300V. That voltage were applied on the dot lines in the figure. One is on a surface of wire and another is on the stage and on the part.

The generated force on the top surface of the objective part was shown in the following figure. Horizontal axial is corresponded to the top surface of the part.



The resultant data is stress and data have waves. This may be due to FEM. This method deals with the analyzed area as divided small elements. The number of waves is equal to the number of elements. So they must have relation. Total generated forces are integral of the stress. From these results, 100 voltages should be enough to pick up the part.

Experiments were done and the following table shows the results.

	300V	200V	150V
Move	100	100	0
Possibility of Pick up	90	60	0
Release	67	50	-

unit : %

Move means that gripper could move the part but could not pick it up eventually, Pick up means that the gripper could pick it up successfully, and release means that gripper could release the part deliberately.

From this result, picking task need 300V, and 200V seems not enough. When we look at releasing task, the possibilities are higher than picking up task. But still 200V is not enough. This also shows that picking up is more difficult that releasing. This experiment showed that practical gripping needs about 3 times high voltage than theoretical model. These reasons are suspected that exist of influences from other forces and positioning error between the gripper and the part. It could be possible that imperfectness of gripper

due to mistake of making and damages during experiments.

The conclusions are briefly shown such as the following.

- Experiments proved that the electrostatic gripping to conductive parts is feasible with this setup. And a comparison between with an insulation layer and without an insulation layer has proven that the electrostatic gripper needs insulation layer in order to pick up a part in the air.
- The electrostatic gripper could not generate enough forces to pick up a part at such a voltage that is sufficient in simulating. This discrepancy in required voltages was suspected to come from other disturbing forces influence, influence of mutual position between a gripper and a part, and imperfectness of the electrostatic gripper.
- Experiment has proven that temperature changing at range from 27.2 °C to 37.4°C does not give any influence to the electrostatic gripping system.
- Experiments have shown that bi-pole gripper could pick up a part at higher possibility than mono-pole gripper, or bi-pole gripper could pick up a part at lower applied voltage than mono-pole gripper.

Here lectures are explained.

The course, Fundamentals of material removal processes was opened in English every Tuesday from 10:00 to 12:30. Students can be given 3 ECTS (European Credit Transfer System) credit points if they can pass an exam.

Detailed description of topics is about Classification of material removal processes, processes with geometrically well-defined cutting edges (turning, drilling, milling, etc.), processes with geometrically non-defined cutting edges (grinding, honing, lapping, etc.), other processes, tool characteristics, process parameters, recent developments, state-of-the-art machine tools. Learning goals are gaining knowledge about fundamentals of material removal processes, technological comparison of different manufacturing possibilities, limits of technology.

The course, Electromechanical systems was opened in English every Tuesday from 8:30 to 11:30. Students can be given 4 ECTS credit points if they can pass an exam.

As learning goals, students who followed this course, should be able to use the terminology used in electromechanics, describe the operating principles of motors (magnetic circuits, magnets, induced voltage), deal with the important limitations and

characteristics (losses, safe operating area, cogging, magnets, amplifiers), distinguish between the different construction forms of DC motors, choose a motor for a certain application (given a load profile, ambient conditions, heat), be a good partner of a specialist who designs electromechanical actuators, and describe the operating principles of magnetic levitation and propulsion of magnetic levitated objects.

The course, Measurement theory and praxis was opened in English every Thursday from 8:30 to 10:30. Students can be given 3 ECTS credit points if they can pass an exam.

In this course main attention is paid to measurement of mechanical magnitudes especially for servosystem application. Some topics are General performance characteristics of instruments. Input-output configuration of measuring instruments. Input impedance, correction methods. Static and dynamic behaviour, transfer functions. Amplitude modulation, Measuring devices for motion, standards and calibration. Displacement, velocity acceleration - measurement devices for both linear and angular motion, Force torque pressure sensors, Strain gauge principals, Temperature: thermoelectric sensors and radiation methods, Signal conditioning, manipulation and transmission, and Filtering, noise suppression.

The English course was opened every Wednesday from 5:30 to 7:30. Students can be given 3 ECTS credit points if they can pass the course. Students are evaluated though final exam, final report, small assignments, presentation and attendance. Though this course students could learn sense of English rather than grammar or writing English by using their own materials.

5. Exchange life

Here, the Netherlands is second place for me in this exchange program. I stayed here for 5 months and several days.

My accommodation was located near a campus of TU Delft and it is called normally "Roland Holstraan" from students. This room has own shower room, kitchen, toilet and internet connection. This internet connection is branch line from the university, so we could download papers from many journal sites. This was one of good respects of Roland Holstraan. On the other hand, this accommodation may complete too much for exchange students. In our diary life, we don't see neighbors usually. Many of exchange students including me want to communicate with as many people as possible, but people in Roland Holstraan is too isolated each other. I think that this problem is going to be improved by TU Delft. This idea is based on TU Delta, which is newspaper published by one organization in TU Delft. I read article in the Delta about this problem many times. This problem is one reason why I got fewer friends in the Netherlands than in Denmark

I wanted to achieve something in the Netherlands for unforgettable memory. Then I decided to try in a marathon because of one Japanese Ph-D there. He asked me to do it. I thought it was nice of me. But at that time, I had not been trained anything for 7 or 8 years. I started to prepare for the marathon since two days after I arrived at Delft. Concretely, I ran about 8 km distance around Delft city or the university 3 or 4 times a week as long as I didn't have muscle pain, often with Ph-D student. After 2 months training, I participated Rotterdam marathon with other 4 friends. This was first time for me to run in the marathon. As many people said so, after 30km it was so hard to keep running. Fortunately I could finish the marathon and the record was 3 hours and 45 minutes. Totally, I participated in the marathon twice, one was in Rotterdam and another in Copenhagen.

There is a sport center, where students and people related to TU Delft can use for training and playing many kinds of sports. I joined Dutch soccer team "Ariston" there. Every Tuesday and Thursday we enjoyed playing football for about 2 hours each time. And this team has games on Saturday for league matches. But I didn't join the game, just enjoy training with them.

In school, I was not given any space for small project studying. This is normal in TU

Delft, particularly at mechanical department. There, normally master students in mechanical are not given their own space for research work. This fact was totally difference from Japanese system. So it took time for me to make do it. And building of faculty is normally close at 10:00. At the beginning, I was suffering to find my space for studying. There are a lot of computers in the building and this space can be for studying to students. This means that there are many students using these spaces, even bachelor students. I felt that they made a noise a lot, so these were not good place for me to study. And everyday I had to look for the available space. As far as I see, many Dutch students need music while they are studying. Furthermore, when we are using such a public space, always we have to take care of our stuffs, because our stuffs may be stolen while go to lunch even a toilet. So that, when we go to somewhere, we have to carry all stuffs every times, otherwise, it might be disappeared after you back there.

In weekend, I went to many places in the Netherlands, for example, Amsterdam, Rotterdam, Scheveningen, and Den Haag. It was easy to travel around, because the Netherlands is not big country. So I could go to see football matches from Youth championship twice at Kerkrade, where is in southern Holland and motorbike race, moto GP at Assen where is in northeast Holland. And there is a big beach in Scheveningen. You could do bungee jump there and also trampolining, shopping etc.

Every wednesday, foreign international students gather at one bar at center of Delft. Here is place to see other international students. I went there sometime. But I think that it is not easy to build real friendship at a bar if you don't have common interest with them.

6. Suggestions to the project

Just let us make sure earlier when we can come back to Japan. We have to inform the date when we leave our room one month before the date to accommodation agent. As a matter of fact, I got the ticket of airplane 5 days before I was going to leave the Netherlands. As a common sense, it is too late. Furthermore, travel agency told me that my coming flight is on 10th of July by a email, nevertheless, the ticket is valid on 11th of July. I noticed it after I got the ticket.

7. Summary

I could enjoy my life at Delft, but also I got many compliment or difference from Japanese systems. I mostly suffered from a space for studying, because we could not be given space in their laboratory. This is not good to do research work, because I could not have sufficient meeting and discussion with my supervisor.

In TU Delft, there were many Japanese people and they were integrated well. This environment seems not good for practicing English. But it was wrong, I think. Maybe we tend to speak Japanese, but if you really want to speak English, you have a lot of opportunities to do that. For me, it was nice to see them there, simply because I am not likely to meet them in Japan, and I could learn lots of precious things for my future, study and so on from them. I really appreciate this exchange stay there.