Exchange student report

(exchange program between Europe and Japan)

In the technological field of

Design Manufacturing and Mechatronics

(DeMaMech)

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Home University: Delft University of Technology

Hosting University: Keio University

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1. Personal Data

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2. Executive summary

In the year 2004 an exchange program between Europe and Japan is started. By this program I was exchanged from Delft University of Technology (The Netherlands) to Keio University in Japan. During 5 months I worked on a research project in Mitsui Laboratory.

The goal of this research was creating static models of flexure hinge based positioning stages. A measurement device is created to measure hinge stiffness, secondly different analytical and finite element models are compared to each other to model mechanism stiffness and piezo electric actuation.

The exchange program started with an introduction course, this introduction course is very useful to adapt to Japanese life. This year the course was a 2 weeks program, in my vision 1 week can be sufficient.

During the research work I had opportunities to travel through Japan. Keio University is located in Yokohama, from here Tokyo was easily explored. Also trips to Kyoto, Hakone, Kosetsu and Nikko were made.

Life in Japan for a European student has many challenges.

- The level of English knowledge of many Japanese people is low. To communicate patience and creativity is often necessary.
- To realize social contacts a independent and active behavior is necessary.
- Life in Japan, especially Tokyo, is expensive.

Life at the University in Japan is in many situations different from student life in Europe.

- The requirements for graduation (after the entrance exam) are a little lower than in Europe.
- The university is always open, normally Japanese students arrive during the morning and go home during the evening.
- European students build more a personal life during study life, most of the Japanese students still live with their parents.

Japanese people are used to live in a group. European people are much more individual. Japanese people developed excellent group mentality and behave quiet in over-crowded places and situations. This is a nice and special experience.

3. Travel Schedule

Japan (15 September 2004 - 20 Febuary 2005)

KLM has direct flights from Schiphol to Tokyo with interesting student specifications and a reasonable price.

Kyoto (20 November 2004 - 26 November 2004)

Kyoto is the old capital of Japan. The city is full of beautiful temples and shrines and there is an old district for going out. This area is Gion, today Geisha's can be spotted in this area.
Specially during autumn and spring Kyoto is crowded by tourists because of the nice views with blossom and colored leaves.

Hakone (30 December 2004 - 2 December 2004)

Hakone is a beautiful mountain area near Mount Fuji. Many tourist visit Hakone and it is easy to take a look around by bus, boat and rope way. A lot of Hotels have a onsen, an onsen is a Japanese hot bath. The water is volcanic water from natural springs.

Kosetsu (29 January 2004 - 30 January 2004)

Kosetsu is a place near Tokyo where you can go skiing or taking an onsen. There is even an onsen in nature where you can enter for free.

Nikko (13 February 2004 - 14 February 2004)

Nikko is an old training area for ascetics. The architecture is amazing.

Remarks:

- Traveling through Japan is not difficult, in bigger cities all information is also presented in our alphabet. So signs can be read. Asking local people is easy, if they speak (a little) English they help very well.

- Some stations in Tokyo are very big, one station can have about 50 exits. To find your way don't try to remember, every location can be found very well by following the signs.

- Japan is really worth to discover!

4. Research

Mitsui Laboratory is a laboratory for precision measurement and micro processing, research is done in the following fields;

- Optical measurement of rotation of a micro spindle
- Scanning Tunneling Microscope (STM) to measure the geometry of micro parts
- Monitoring of the position of NC machines
- Determination of the optimum clearance for sheet metal punching
- Effect of vibrating electrodes in Electro Discharge Machining (EDM)

4.1 Introduction

For sheet metal punching Mitsui Laboratory installed a flexure hinge based positioning stage (see Figure 1). A flexure hinge based positioning stage consists of a platform connected to the outside world by levers with certain notched areas. The notched areas function like hinges and the levers have the function to realize a transmission ratio between actuator and platform. To manufacture a flexure hinge based stage mostly Wire Electro Discharge Machining (WEDM) is used.

This positioning stage can actuate the platform in 2 degrees of freedom respectively the lateral X and Y direction. The arrows in the figure represent the force directions of piezo electric actuators. Piezo electric actuators are actuators that generate a force and/or a displacement when they are loaded by a potential difference.

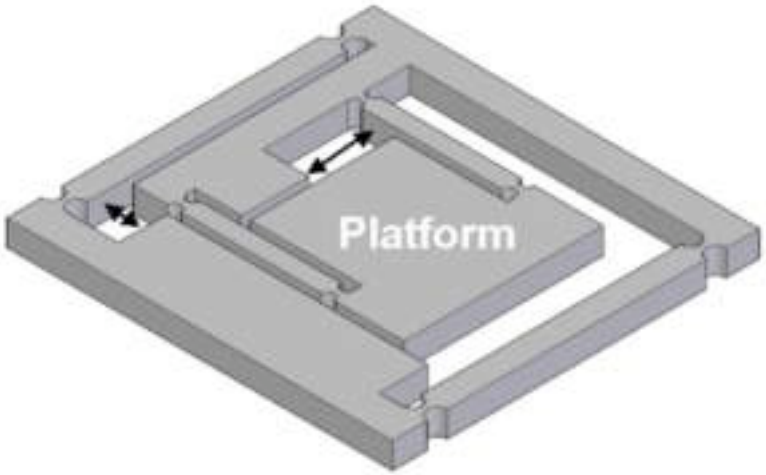

Figure 1: Flexure hinge based positioning stage

The deflection of this stage was about half of the expected deflection from the theoretical model. This is not unique, also in literature is written about differences between modeling and measurements of positioning stages of about 50%.

In this project the influence of the following effects is investigated to determine more accurate models:

- Single flexure hinge stiffness
- Lever stiffness
- Preload on the piezo electric actuator

4.2 Single hinge stiffness

To determine the stiffness of single hinges an experimental device is created and the measurement results from this device are compared to the results from 2 theoretical models, an analytical calculation and results from finite element software.

The measurement device is presented by **Figure 1**. When a mass is added to the upper beam, a moment on the hinge is introduced which will rotate the hinge. The right sight of the upper beam will deform a little bit by the added mass. The left side of the upper beam is used as reference for the resulting angle. This angle is measured by two capacitive sensors.

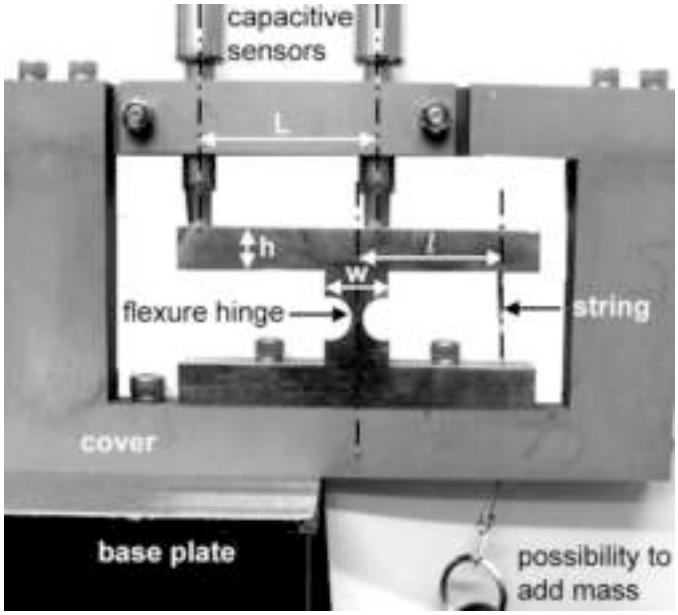

Figure 2: Measurement flexure hinge stiffness

The stiffness of the hinge is calculated by:

$$K = \frac{M}{\theta}\left[\frac{Nm}{rad}\right]$$

Where M represents the moment on the hinge and θ represents the measured angle. An error analysis is done to evaluate the measurement accuracy. The measured stiffness is dependent from the geometry of the hinge, the distance between the capacitive sensors, the applied moment and the young modulus of the hinge material. Uncertainty in these properties results in an uncertainty of the measurement By some mathematical laws the uncertainty of the measurement device can be calculated by the single uncertainties, this results in the following expression:

$$\frac{\delta d}{d} = \frac{\delta m}{m} + \frac{\delta l}{l} + \frac{\delta L}{L} + 0.5\frac{\delta R}{R} + \frac{\delta E}{E} + \frac{\delta b}{b} + 2.5\frac{\delta t}{t}$$

The symbols represent the following properties:

d	Measured distances by capacitive sensors	[m]
m	Added mass to the upper beam	[kg]
l	Distance between mass and center of hinge	[m]
L	Distance between capacitive sensors	[m]
R	Radius of the hinge	[m]
E	Youngsmodulus of hinge material	[N/m^2]
b	Width of the hinge	[m]
t	Thickness of the hinge	[m]

The uncertainties of the single properties are measured and determined by a 95% confidence level (2σ). The uncertainty of the measured distance results in the same uncertainty for the measured stiffness (for small measurement angles).
This results in a measurement uncertainty of ±2.5%. Statistical is proved that if the uncertainties are independent and random then the sum can be calculated by the quadratic sum. This results in a uncertainty of ±1.4 %: Since the measured deflection and calculated deflection differs 50% this measurement accuracy is acceptable.

From the measurement results can be concluded that the theoretical models will provide the calculation with an uncertainty of the flexure hinge stiffness of about 10%.

4.3 Total mechanisms

Different models are made to calculate the stiffness and deflection of the mechanism when a certain potential difference is placed over the piezo actuator. Stiffness of the flexure hinge mechanism is calculated by an energy model and finite element calculations by software and by hand.

The energy model is based on the principle of potential energy and work. For a certain deflection of the mechanism the potential energy of the mechanism and the used work to realize the deflection are equal. By this fact the stiffness of a mechanism can be calculated. To realize the finite element calculation by hand a stiffness matrix for a flexure hinge element is calculated by stiffness factors found in literature. The matrix calculations are done in algebra software Mathcad. Secondly finite element calculations are done by software, Ansys is used to generate the mesh and calculate the mechanism stiffness.

To model the piezo electric actuator the specifications from the manufacturer are used. Piezo actuator specifications specify a maximum voltage and the concerning elongation and blocking force for a static situation. These specifications can be used to make a model from the piezo. This is done by an analytical method and by Ansys software.
In the graph presented by Figure 3 the analytical piezo model is plotted next to the stiffness calculated by finite element software and the energy method. The crossing point of the piezo model with the Y-axis represents the blocking force, the elongation for this situation is zero. The crossing point with the X-axis represents the maximum elongation, at the point of maximum elongation the piezo cannot deliver force anymore.

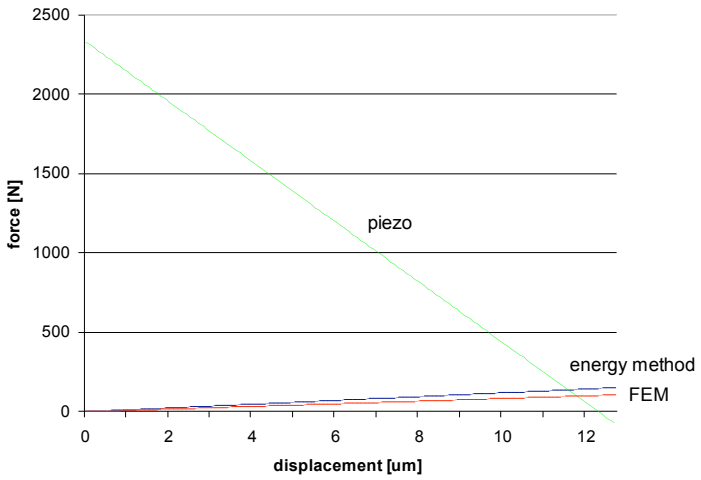

Figure 3: Piezo working point

The crossing points between piezo and the stiffness models of finite element calculation and energy method represent the elongation of the piezo for the maximum voltage. This elongation can be multiplied by the transmission ratio of the mechanism to calculate the mechanism deflection.

From all these models can be concluded that the finite element calculation by Ansys software is provided with the highest accuracy because:

- Shear force in the hinge is taken into account
- Beams are modeled with a certain stiffness
- Bending of the piezo actuator is taken into account

Still there is a difference (minimum 20%) between the models and the measured deflection. This difference can be explained by the applied preload given to the piezo during installation. This preload is about 40% of the blocking force of the piezo.
Normally a preload is added to a piezo to overcome tensile forces in dynamic situations, preload to the piezo in Mitsui Laboratory is not necessary since the positioning stage is only used in static situations. From literature is concluded that this preload will significantly reduce the stroke of the piezo actuator. The value of reduction is not proved, it would be interesting to measure stroke reduction of piezo actuators under a certain preload.
Secondly can be concluded that to realize the biggest stroke of a piezo actuator, the actuator should be installed in such a way that only elongation of the piezo will occur and no bending, because bending will make the actuator less efficient.

5. Exchange student life

Student life in Japan is different from student life in Europe; in this chapter the most important experiences and differences are mentioned. Some differences can be an advantage, some are disadvantages but advantage or disadvantage will depend on your own point of view, I tried to experience them just as interesting.

5.1 Social life

In the first days you directly recognize that students make a lot of time for helping and supporting to start the life in Japan. People are very kind, helpful but also shy. Japanese people will only help if they are sure that they will be successful in helping, a failure is not possible. In the first days a welcome party was organized, during most parties students drink together and have a dinner. It is useful to have a good time together and have a good conversation because during the work at the lab starting a nice conversation will be much more difficult. In my experience the exchange student should "break the ice". Only by showing how you are you can get more information about Japanese students.

To have a nice time after the time at the university you should be independent and search for some nice activities. Japanese students don't do many activities beside their Master study. European students build much more a personal life during study life. Most of the students live with their parents. The students accept the choice of an exchange student to experience also the life outside the university but they won't participate.

To realize social contacts it is useful (in my experience) to find a place or a club where you can practice a hobby. I have a good experience with salsa-dancing, I checked 5 salsa-bars and then I found nice people, I met them every week to dance and talk. This was very pleasantly for me since people in the salsa bar developed a personal life very well and like international contacts. Secondly they were less formal Japanese, so communications were more direct.

Most people in Japan live in the cities, the mountain side is less crowded. Houses in the cities are small and public transport is used intensively. Japanese people are used to live together, they behave very social and quiet in over-crowded places. They developed group mentality very well, this is a nice experience. Sometimes this group mentality and a good group atmosphere seems to be more important than to make "the best decision". During communication mostly "the nail which sticks out most" will be hit. So decisions can really be influenced by the way of presenting and formulating.
Japanese people gave me the explanation that they communicate using hints, for European people this seems to be a indirect way of communication.

5.2 Working in a laboratory

Working at a Japanese laboratory has easy parts and difficult parts. The easy part is that there is a lot of money to realize a device, there is a good availability of manufacturing machines and students help each other.
The difficult part is that every student should realize a complete device, at European universities the result from a research is mostly only a design. It is very useful to experience the total trajectory in stead of only designing.

Secondly it is difficult to get the total history about a research. Questions are answered only specific to the question. Students don't tell more about the subject than just the answer on the question. It is not clear for me if this has a cultural reason or it is because they have difficulties with the English language. But even in the last month of my research I discovered activities they had done in relation to my subject. Answering the right questions and criticize the answers (for yourself) seems to be very important.

Students in Japan act like they are very busy but most students work less efficient than European students. The most difficult part of an university study is the entrance exam. Most students finish the study in 5 years, every year they have to graduate. The level at Euopean Universities seems to be a little higher. My impression is that the most important thing for Master students in Japan is to report good measurement data. They do less research on modeling and developing analytical skills.

Graduations, welcome and goodbye are celebrated by nice parties. Most professors invite the students also once a year at their home. Most laboratories make also every year a trip to a tourist place or go skiing together. Japanese students really like these activities, these activities are planned very well in advance.

5.3 Short facts

- Normally students arrive at the university just before lunch and leave in the evening.
- The university is always open. Some students stay during the night. One of the members of my lab went only 6 times home for taking a shower and changing clothes during one month, this is very exceptional and nobody expects behavior like this from an exchange student.
- Students almost continuously talk with each other during researching. They laugh a lot, but mostly they speak only in Japanese.
- To create a device in the laboratory you have to make almost everything by yourself.
- Professors have more time for students since there are more professors per student.
- During the research the most important activity seems to be the generation of interesting measurement data.
- At the laboratory everybody has his own desk.
- European students are more developed in personal life.
- Japanese students like to have a party but parties should be planned well in advance.

6. Suggestions

The level of English is in some laboratories a problem during communication. Students and professors will not always speak very well English. Checking the communication is very important to realize something. Patience is obligatory.

Realizing social contacts can be difficult at the laboratory since (Master)students have another social life than we are used to in Europe. To realize social contacts it can be useful to join a hobby club (for example sports).

Life in Japan is relatively expensive. The scholarship was spend totally in the first 3 months. The amount of 700 euro per month is enough for primary living costs (housing rent and food). Going out and traveling cannot be paid from this scholarship.

Keio University has a special health insurance for students, this health insurance is more useful than a health insurance from a European company. When you have a health problem you will be helped much faster with a Japanese insurance because a Japanese insurance really proves that you can pay the bill (since health costs are about 2-3 times the costs in Europe). Next exchange students should be informed about this insurance.

The exchange program started with an introduction course of 2 weeks. This introduction course was useful, sufficient and a lot of fun. When I arrived in Japan I had no (big) problems to adapt to the life in Japan. In my vision a introduction course of 1 week could be sufficient.

7. Conclusion

For the DeMaMech (Design Manufacturing and Mechatronics) exchange program research is done at Keio University in Japan.

The goal of this research was creating static models of flexure hinge based positioning stages. A measurement device is created to measure hinge stiffness, secondly different analytical and finite element models are compared to each other to model mechanism stiffness and piezo electric actuation.

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