Report

On the
DeMaMech EU-Japan Exchange Program
2005 – 2006

Marko Kieroth

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1. Personal Data and University Information

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2. Executive Summary (max 1 page)

I studied at the Keio University from October 2005 to July 2006 as a DeMaMech exchange student. During this time I joined to two laboratories, to work on two different projects.

In the “Laboratory of Manufacturing Science” of Prof. Tojiro Aoyama I did studies on a new kind of smart materials, called ERG (Electro Rheological Gel). Therefore I had to do a lot of experiments to classify the basic properties. It got some experience in working out, preparing and selecting experiments. Precisely, I determined the friction rate of the surface and the films alternation of thickness. The obtained data were used to find and research new applications using the advantages of ERG.

In the second half of my stay I belonged to the “Laboratory for Digital Design & Digital Manufacturing” of Prof. Hideki Aoyama. This laboratory develops tools for design studies. The tool developed in my project is addressed to make usability analyses in a very early stage of the design process.

In addition to project work I attended two technical lectures and a language class. The Japanese lessons gave me a good understanding of the traditional Japan. By contrast, to experience modern Japan, its students were the better source. Both are worth to absorb.

Within those ten months in Japan I got a good insight into the Japanese culture. So I learned that the own way is not every time the best, even if it seem to be the right one. This knowledge gave me also a new view to my own culture. I hope I could select the best of both for my own future way. The exchange student life included some challenges as well as a lot of benefits. One challenge was for example to live and study as an illiterate. Some benefits were the social network in the lab, or on the international dormitory. Within both networks I made a lot of international friends from Japan and other countries.

All things considered I would recommend everybody to apply for this program. It is a great possibility to go and see another world and evolve its own personality.

3. Travel Schedule

Germany to Japan

October 1st, 2005 — Berlin (Tegel) – London (Heathrow) –Tokyo (Narita) by British Airways

Japan to Germany

July 31st, 2006 — Tokyo (Narita) – London (Heathrow) – Berlin (Tegel) by British Airways

Between:

Trip to Kyoto, Osaka, Nara and Kobe
November 2005 (4 days during the golden week)

Trip to Seoul (Korea)
April 2006 (4 days)

IAA excursion to the Fuji Five Lakes
May 2006 (2 days)

Climbing Mount Fuji
June 2006 (1 day)

And some trips in and around Tokyo i.e. Kanagawa, Nagoya ….

4. Technical Report

4.1 Basic Properties and Possible Applications of Electro Rheological Gel

4.1.1 Introduction

Electro rheological gel (in the following called also ERG) is a new smart material based on silicon. This material changes its physical properties in the present of an electrical field. The effect of changing properties within an electrical field is known since 1950. In the past it was mainly used in electro rheological fluids (ERF). But these materials change their properties in the course of time, so the technical use is limited. Two time depending effects are for example sedimentation and erosion. ERG avoids these shortcomings by incorporating the ER-particle into a silicon gel matrix. This modification hinders principally the former significant effects like tunable viscosity. On the other side it causes interesting new effects like tunable friction.

The new manifestations of the ER-effect are due to the disappeared sedimentation almost time independent. Hence it results an increased predictability and repeat accuracy of the phenomenon. Because the material is largely unexplored, it has to be done a lot of pioneer work, to investigate congruencies between changes in behavior and changes in test setup. These congruencies allow identifying advantageous effects for special applications. Moreover it is possible to determine the causes to increase the benefit. According to this idea this assignment investigates the theoretically possible effects friction and displacement and considers the technical usability.

The friction analysis should clarify, which of the parameters are suitable for controlling the surface friction at best. Therefore it is necessary to determine the ideal shape of the electrodes and to optimize the composition of the materials.

To estimate the applicability of the appearing displacement attitude, it is necessary to measure the thickness variation of the ERG film. By doing this measurement with different weight-loading, it is possible to make conclusions about the load dependency of the effect.

The following experiments were carried out using a thin film of ERG on a so called “Single Sided Electrode”. Whereas single sided means that only one side of the ERG is connected to a voltage source. Thus the object that should be manipulated, have not necessarily to be energized. This handling benefit will later improve the usability and safety (electric shocks).

4.1.2 Basics

Electro rheology describes the possibility to change the rheological properties of a material, by exposing it to an electrical field. The first notice about the phenomenon of electro rheology (ER) was written in 1947 by W. M. Winslow. The Name Winslow-Effect is also in use to denominate this effect.

4.1.2.1 Electro Rheological Fluid

For a long time the scientific society studied the ER-Effect in so called electro rheological (ER) fluids. An electro rheological fluid (ERF) is a kind of suspension of ER particles. Assuming the ideal case, not stimulated, the solid particles distribute randomly in the fluid. The influence of an electrical field causes a directed attraction between the particles. In consequence of this attraction the particles arrange in chains parallel to the electrical field lines. As a result, the shear stress transfer vertical to the field lines increases reversible.

The interest in this fluids arise from the potential to establish simple, fast reacting and cost efficient connection elements between electronic and mechanical systems. Many researches saw the practical utilizations of such suspensions in active control devices such as dampers, shock absorbers, clutches, brakes. New projects deal with devices such as gripping devices, seismic controlling frame structures, human muscle stimulators, and spacecraft deployment dampers.

However, the realization remained unsuccessful due to such problems as particle sedimentation, aggregation or solidification, particle or electrode abrasion, and poor durability or temperature dependence. Positive ER materials have rheological properties that

dramatically increase with the applied electric field. Many efforts have been spent on developing high-performance positive ER materials, and many shortcomings are pertinent to these systems, for example, a narrow working temperature, solidification at low temperature, a high current density as a result of the high conductivity of water, and device erosion caused by water. Water-free ER fluids were developed under the assumption that they do not have the shortcomings of hydrous ER fluids. However, anhydrous ER fluids have another problem, the particle sedimentation, which could make ER fluids malfunction and limit practical applications. Also, anhydrous ER fluids show aggregations under a strong electric field.

4.1.2.2 Electro Rheological Gel

Instead of facing the disadvantages by optimizing the composition of the fluid, an innovative way was gone. The creation of a new material allows using the ER effect in a totally new way. Thereby the ER particles are not anymore dissolved in a fluid but are embedded in a silicon based gel.
As in the case of ERF, an electric field causes an attraction/rejection-effect between the ER particles. Parallel to the field lines the particles attract and orthogonal to the field lines reject each other. It is easy to imagine, that the attraction pulls the particles placed on the surface into the gel matrix. Whereas they move back to their initial position as the field disappears.

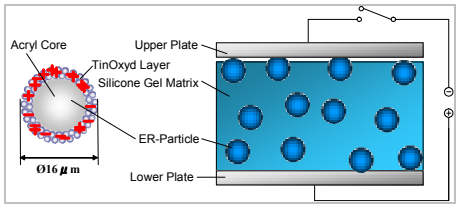

Figure 1

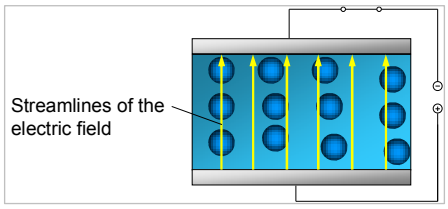

Figure 2

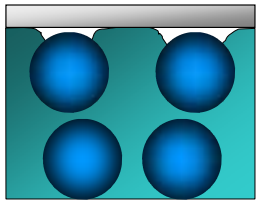

Figure 3

If the voltage is not applied, the upper plate slides on the ER particles (Figure 1). As soon as voltage is applied the upper plate sticks to the gel (Figure 2 and 3). Since the gel surface is not flat, the proportion of area where the upper plate touches the gel depends on how much the ER particles immerse.

4.1.2.3 Single Sided Electrode

Employing two opposite electrodes demands a slip ring or a brush in order to wire the moving part in some cases. That in turn causes extra effort and costs. To avoid this and to reduce the risk of an electric shock, this project deals with a one sided pattern electrode. A one sided pattern electrode is an isolator coated with a metal film. A comb like pattern is etched into this metal film. So the pattern includes the anode and the cathode. Principally there are no limitations for the shape as well as the material (isolator or conductor) of the above arranged construct. Nevertheless the strength of the effect is controlled by both parameters. In the following this above arranged construct is called upper plate.
The new setup causes new shapes of the field lines (Figure 4).

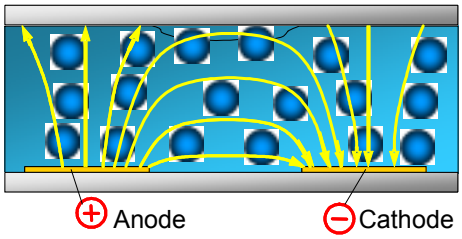

Figure 4

4.1.2.4 Friction

At the moment the adjustable friction rate is the property of the ERG with the highest application potential. The shear stress experiment (measuring the force that is necessary to

move the upper plate over the ERG surface) seems to be a proper way to benchmark this effect. It is a standard experiment that has to be done by every student who is involved in the ERG research. The ambition of this test is to develop a database, which includes the friction behavior of as much as possible kinds of ERG (different thickness, stiffness and particle concentration) combined with different electrodes and different upper plates. This data is supposed to establish a solid knowledge base for future research projects. Furthermore it should be checked, in how far it is possible to anticipate the other effects by observing the slide performance.

4.1.2.5 Displacement

Former measurements have shown that the thickness of the ERG layer changes by applying a voltage. At first view the ERG seems to change its density. But the responsible effect is another. It is the absorption of the ER particles at the surface to the gel-matrix.
The displacement measuring is done to evaluate this effect. Especially interesting is here, which gel, electrode, upper plate combination results in a fast movement with a wide range and a high stiffness.

4.1.2 Research of Friction

4.1.2.1 Material

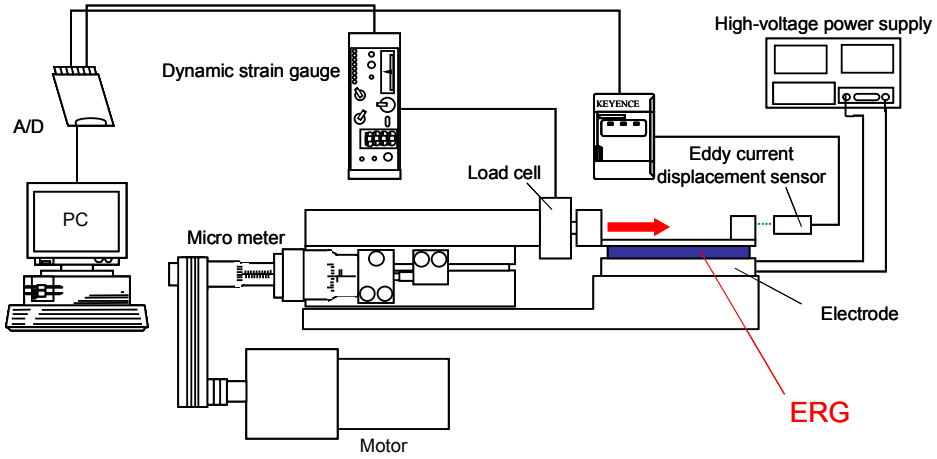

Figure 5

A film of ERG was placed between a single sided electrode and various kinds of upper plates. The electrode was fixed to the ground and connected to a power supply. To increase the voltage up to 1500V an ampler between power supply and electrode was used. The upper plate was connected to a sliding carriage which was moved by a micrometer screw. The screw was in turn driven by an engine via a belt. With the help of this experimental set up the upper plate could slide on the gel surface with a velocity of about 30µm/sec. The generated shear force was transformed into an electrical signal by a load cell which was placed between the sliding carriage and the upper plate. Using an A/D-converter card the signal was recorded by a PC. The position of the plate was detected by an eddy current sensor which was connected to a second channel of the A/D card.

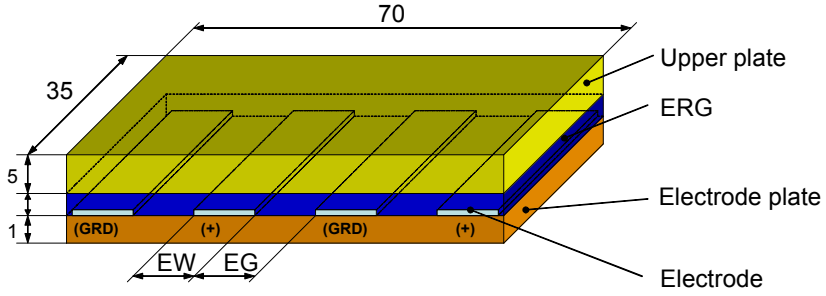

Figure 6

Size upper plates:	35x70mm	
Materials upper plates:	blue glass	(weight 48g)
	aluminum	(weight 27g)
Electrode shape:	electrode width	0,5mm – 2mm
	gap between	0,5mm – 2mm
ERG type:	elastic modules	0,021 – 0,043 N/mm²
	particle concentration	30 – 50 wt %

All those experiments were carried out in wet as well as in dry conditions. Wet means in this case, the measurement have to be done before the ER particle dispersing oil was extracted out of the matrix. So the ERG plates were used directly after cross linking of the gel. To get the dry conditions the surplus silicone oil will be removed in a 5 day drying process.

4.1.2.2 Procedure

After experimental parts were positioned according to the setup, the eddy current sensor had to be calibrated to zero. Recording of the electrical signals was done using the software called WAVESHOT version 2.01 with sampling rate of 10Hz. After having started the recording process, the engine had to be activated immediately. Data of the eddy current sensor as well as the load cell was collected while both plates were shifted against each other over a distance of 600µm with a velocity of 30µm/sec. Motion was stopped after 25 sec. The recording process itself stopped after 48 sec and the data was saved in a PRN-file. With a self written script it was possible to import the obtained data into an excel sheet that evaluated the data, compared it to other measurements and finally visualized it in diagrams. These steps were repeated for differed electrode/ERG combinations, for each upper plate material, and for dry and wet conditions. Voltages of 0V, 500V, 1000V and 1500V were applied.

4.1.2.3 Results

The recorded datasets can be shown in a diagram as follows. Four different curves plotted for four used voltages represent the friction behavior for one special ERG type/ electrode/upper plate combination.

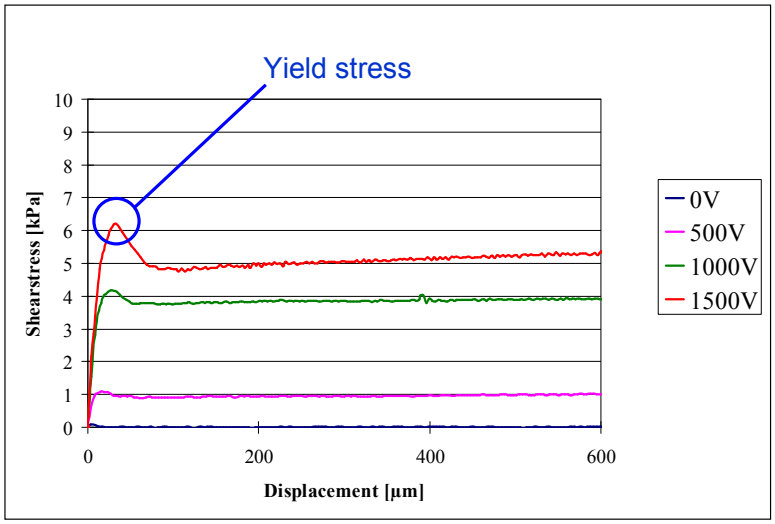

Figure 7

To make the data comparable the maximum of the first peak have been chosen as a characteristic point. It displays the yield stress, and is therefore an important number for many applications. The yield stress mark allows benchmarking the friction characteristics of the tested combinations in diagrams like the following.

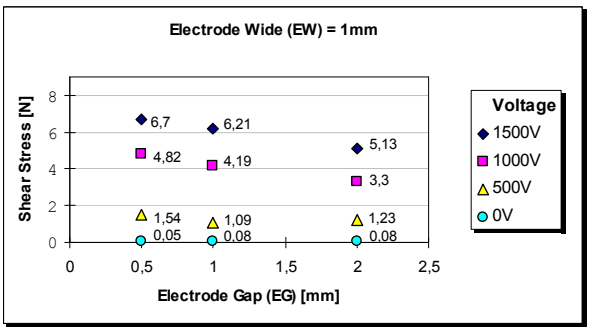

Figure 8

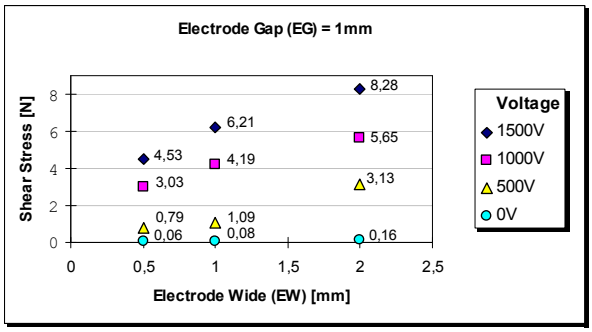

Figure 9

The diagrams exemplify the shear stress for the ERG type 03A05 by using an aluminum upper plate under dry conditions. The left diagram shows results for variation of the size of gaps between the electrodes at constant electrode width. The right diagram represents the observed influence of different electrode widths at constant size of the gaps between electrodes.

4.1.3 Research of Displacement

4.1.3.1 Material

To determine the best electrode ERG combination the experiment is build up in a frame depicted in Figure 9.

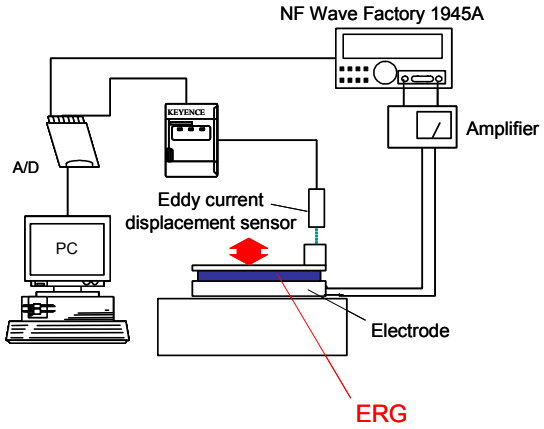

Figure 10

4.1.3.2 Procedure

A voltage between 500 and 2000 volt stimulate the erg in a frequency of 0.2 Hz. The eddy current sensor traces the change of position. The Notebook record this dater combined with a trace voltage from the wave generator 11 cycles in a row. After 5 times a weight about 50g is putt on the upper plate, for evaluating the load dependency of the effect. The won dater were also by a self written script imported to a excel script. The script superimposes the first five cycles and the last five and represents them graphically.

At first the measurement will be done with a number of five different electrodes. All of them are covert with an ERG type called 05A03. That is a well known Type of ERG. After finding the best electrode shape under assumption, that is the best shape for all ERG types, this electrode is taken to repeat the experiments with six different mixtures of erg.

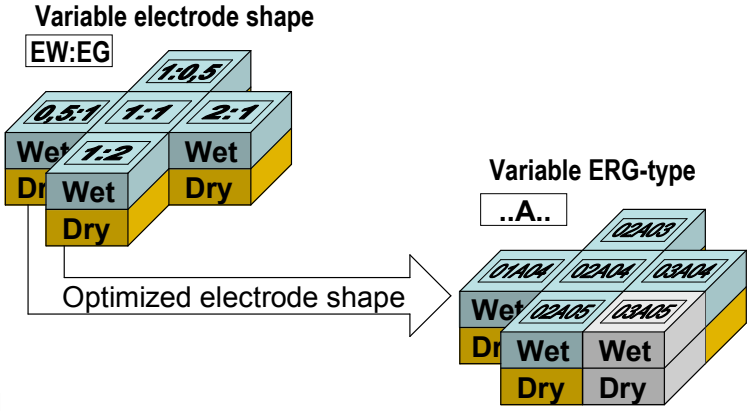

Figure 11

4.1.2 Results and Discussion

To publish the all results would go beyond the scope of this short report. The main cogitations are. A small gap wide and a big electrode wide combined with a conductive upper plate produced the best results for the shear stress experiment. Similar results were found for the displacement experiment. I conclude this setup produce the most vertical lines of electric flux, so it is close to the setup with two electrodes like in figure 2.
Furthermore it turned out, that the measured effects reach not their full strength until the, for producing necessary, silicone oil is extracted from the gel.

4.2 Evaluation System for Style Design Using Mixed Reality

The “Laboratory for Digital Design & Digital Manufacturing” of Prof. Hideki Aoyama develops tools for design studies. The tool developed in my project is addressed to make usability analyses in a very early stage of the design process. It allows us to evaluate design ability and operability of a product on the first concepts of shape design. To assess a design, a physical model made by a rapid prototyping machine will be overlaid with a virtual model in the mixed reality. To evaluate a design, a physical model made by a rapid prototyping machine will be overlaid with a virtual model in the mixed reality. Therefore the user wears a head mount display (HMD). The HMD feature two video cameras to digitize the real world in front of the viewer. Two small screens in front of the eyes display this view overlaid with a virtual model of the new product. It is possible to cause an interaction with the virtual model in the virtual space by touching the physical model with virtual hands. The position and shape of the virtual model and parts of it can be moved in the virtual space during an evaluation process. . In this way, the usability and design can already be maximized based upon first design ideas of a future.

Figure 12

Figure 13

When I joined the project, my lab members already had a working prototype. Like many times, it was a generation-spanning project. During my time we implemented new hardware and software functions to improve the usability of the system. I did this in cooperation with some other students of my lab. I had to execute the following tasks. :

- Generate CAD-models of candidates of a future product
- Make STL-files from the CAD-models
- Produce a physical model of the typical model(rapid prototyping)
- Mix a CAD model and physical model
- Check the operability of the function to be developed and the, by operating the virtual model in the virtual space.

Furthermore I studied Visual C++ to write a function that should simplify the modification of the model. Like the Professor prognosticate it was admittedly difficult. A big part of the older code was documented in Japanese. This language problem and the must to leave after my time was over bar me from finishing the code.
Also there I could learn two things for my future.
The first point is, that even if some German Professors use the words “It is difficult” to motivate you. A Japanese Professor say this to protect you from real problems.
And the second thing is Visual C++.

4.3 Lectures

During my studies at Keio University, I attended two technical lectures and one language class. The foreign students were expected to join the language class. So I did. And even if I am not talented for studying languages, the time was not wasted. The language course and therein discussed topics gave me an essential access to the Japanese culture.
To prepare myself for my second project, which was related to computer graphics, I joined the class “Advanced Course on Computer Graphics”. The second lecture I attended was about “Advanced Design and Production System” Both classes were hold in English.

5. Exchange Student Life

My arrival was well prepared. A member of my first laboratory picked me up at the Central Omnibus Station in Yokohama. It was Kazumasa Yokoo, a former DeMaMech-student. He gave me a short introduction for the metro payment system and guided me to my dormitory. On the next morning he showed me the way to the campus. There we arrived at 9:00 and the rooms where almost empty. That fact destroyed my picture of Japanese people working 18 hours a day. Later I realized that some of the students live more than two hours away from the campus.

During my lab time it turned out, that students in Japan don't care much about exact break times, as long as they work more as they are expected to do. So it is not unusual to see them preparing festivals or their holidays, sleeping or advancing their juggling skills. On the other side they stay as long as it takes to finish their work, sometimes even overnight. An appointment in the evening is not necessarily a reason to shift the work to the next day. They come back afterwards to finish their task. I had an associate who slept five nights running in the lab. We worked some nights together. This situation gave me the chance for some very interesting conversations. At daytime it was sometimes a little bit noisy in the lab. Some lab members talked about private things, others discussed their projects. Observing this, I recognized that it is very common and important in Japan to transfer knowledge directly from older students to younger. Therefore every student (except the oldest) has a senpai. That is another student who is in charge to explain him everything he needs to know. Usually he is one grade higher, and works on the same main project. The advantage of this approach is, that the younger student gets exact the knowledge he needs for the studies, and it is possible to realize projects about more than one student generation without handover problems.

Sometimes when I needed a break from the lab action, I went with some other exchange students for a coffee into the seventh floor of the Yagami campus main building and enjoyed the incredible view. On sunny days we could see the Tokyo tower and Japan's landmarks, the Mount Fuji and the Shinkansen (bullet train) at once.

But the student life in Japan does not only take place on the campus. Off campus I was introduced to the Japanese way of celebrating a party. Especially the people from my lab gave me the possibility to see behind the curtain of this Japanese ritual. They organized regularly parties. For this kind of event it is important to be on time, because they are official limited to two hours. Thanks again to Joachim, a German DeMaMech student, who gave me this information before my first party. To revel the people meet in a restaurant. There they usually order some food and often nomihodai (big drinking, also known as all you can drink). The food is partly very exotic. Once I got thin slices of raw frozen horse. After two hours, when this first party is official over the mood is usually so good, that the people decide to make a nijikai (second party). Therefore the group changes the place. In the next restaurant drinks are served without a food. It is needless to say, that this stay is also limited to two hours. Who is thereafter not in the unfortunate situation, to have an appointment next morning, probably ends up in a typical Japanese karaoke bar. Against my expectations Japanese and Foreigners had the same fun to interpret one of the 30000 offered songs on their very own way. However I realized that my Japanese fellow students came closer to the original version than the international students, who most likely were lacking many years of practice.

During my time in Japan I met a lot of students from all over the world. The Keio University is very international in its orientation. It has a lot of exchange programs and scholarship programs for excellent foreign students. And because most of us lived in a special dormitory I became very familiar with them and their cultures. Here also was food one of the ways to communicate culture.

Within the first weeks I sensed the life outside the campus and the dorm a little bit stressful, caused by the matter of fact, that there were so many people around me every time. Later I just felt stressed when it was raining and the people kept their umbrella on the level of my eyes. On sunny days an intriguing excited state dominated my mind.

In contrast to the experience of some DeMaMech fellows, I had no problems with the English level of the citizens. By and by I realized that especially people who don't trust their own English skills are often to shy to speak. I think they don't like to do things they are not perfect in. But after an opening phrase in my poor Japanese the spell was broken. Than they had to realize, that English is at the moment the only way to communicate. After finishing my diploma degree I will hopefully have more time learning Japanese. Then I can offer this alternative way to communicate on my surely occurring future trips to the insular state.
Sometimes I even felt, that people spoke to me just to practice their English skills, and sometimes just because I looked helpless. Once in Akihabara I studied a little bit insecurely my map to find a place where I wanted to buy some electronic parts for my experiments. When an employee of a car rental agency recognized this, he spent his whole lunch break to help me finding this shop. Later it turned out that this shop did not have what I was looking for. So he extended his break time about 20 minutes to find another store. I was very impressed by the helpfulness of this man, and it was not the only time that somebody spent much time for me as a stranger.
If there is not such a person or you don't want to ask. Japanese skills can be very helpful, especially for shopping food. With the comfortable concept of the convenience stores, which you can find every 500m, you can by food 24/7. But you never know what it is for sure. So I got some cartilage instead of chicken nuggets, ice with beans instead of nuts, vinegar-oil-mix instead of oil or fish sausage instead of liver sausage. Fish sausages are really not made for European taste. If a Japanese reader can not understand this sentence. Please imagine eating licorice.
Altogether the Japanese food is delicious, and I like it very much. In the last month of my stay I made peace with unisushi (sea urchins), when I tried it in a recommended sushi shop on the fish market (skiji). This market is a must for any Tokyo visitor. There you can find every kind of seafood in a good quality. Beside fish the Japanese cuisine includes also pork, beef and vegetables.
I could eat some of the delicacies in the respective regions which are famous for a particular specialty. For example the so called Japanese pizza (okonomiyaki) is originally from Osaka. It is a kind of omelet you prepare by yourself on the table. Some friends and I tried it on our city round trip which took us not only to Osaka but also to Kyoto, Nara and Kobe. We used the golden week, to visit these cities. Three of them were former capitals. Therefore there are a lot of historical landmarks like castles, temples and shrines. I would suggest every Japan tourist to go there. It is just 2h and 30min by Shinkansen from Tokyo. I can imagine going there again, because four days were just enough to call up enthusiasm but not enough at all to explore as much as I liked to.
Traveling to Seoul/Korea in March allowed me to see my girlfriend for four days. She took a language class at this time. In Korea I realized that Asia is not just Asia. The differences between these two countries seemed to be as big as the differences between Germany and Japan. I also got a heavy lecture about our damaged environment. Yellow dust (in Korean: hwangsa) is called the phenomenon when the air is filled with particular matter in a concentration that reduces the range of sight to two kilometers. The citizens protect themselves with masks and avoid leaving their houses. Over the last 20 years it reached a level that the government reckons with 160 victims a year. I read that North Korea and parts of Japan have the same problem, but none of these three can do anything, because the dust comes from china. It is a product of abrasion in the ever increasing deserts in the north of china. The permanent wish to shower and to brush my teeth reduced my enjoyment in Korea a lot.
Back in Japan and after some weeks of working, my lab members invited Lebout(a Belgian DeMaMech student), me and two German girls to a lab trip to the Fuji Five Lakes at the bottom of Mount Fuji. This trip was organized by students of three laboratories, the laboratory of Prof. Tojiro Aoyama (my first lab), the laboratory of Prof. Hideki Aoyama (my second lab) and the laboratory of Prof. Inasaki (the dean). The trip bore the meaning to integrate the new students into the group. Therefore most of us used the daytime to play games in a sports hall, and the hard guys played soccer in the cold rain (I went to the hall because I'm not so good in soccer). Afterwards we took a traditional Japanese bath in a hot spring, and in the evening

the students organized a program with self introduction rounds and games. We had fun and learned a lot. On the next day we went back home. In Japan holidays are very short.
View weeks later some friends and I went out to climb the Mount Fuji (3776 m). Friends told us that it's romantic to climb the hill in the night and see the sunrise on the top. So we did. The day was cold and rainy. Anyhow the question for waterproof or breathable clothes was philosophical. On the one hand the people with the light clothes became wet because of the rain. And on the other hand the waterproof fraction became wet because of sweat. So at the end everybody of us was freezing because of his wet closes in combination with the low temperature and strong wind on the top. The coldness, the darkness and the thin air made it a very strong trip, and we oftentimes thought about giving up. But nevertheless we managed the challenge. And we were rewarded with a great view. Defrosting in the first sunbeams with a can of hot coffee brought the happiness I was looking forward to. Even the ascent was hard I would recommend taking this chance whenever possible. And if you take a sleep in one of the stations it is much more comfortable.
If I think back to that time, I would say, it was a great time. I wish I had slept less in order to gain much more of those experiences.

6. Summary

All things considered, this exchange program broadened my horizon. I met a lot of inspiring people. Thanks to the financial support of the DeMaMech program and the help of the nice people from the international office I did not have to worry about organizational matters. So I could concentrate on project work. Whereby, the following matter of fact made me feel a little handicapped. Projects done in Japan can only be accepted for studies in Berlin in case that there is a professor in Berlin who is related to this topic and up to give me a mark on it. Nevertheless the ERG project gave me the possibility to get some practice in fundamental research. Furthermore I gained insight into programming virtual reality applications and gained understanding of the wide range of CAD. All those fields I never would get in touch with without my time in Japan.

The social and cultural experience I got within these ten month influenced my life strongly, and gave me new motivation for my study. Therefore, I would recommend everybody who has the chance, to join such an exchange program.
Thanks to everybody who made it possible.