# EU/Japan Pilot Project Report

Keio University Science and Technology
School of Integrated Design Engineering
Tojiro Aoyama Laboratory
Kazumasa YOKOO

## 1, Personal date

Name　: Kazumasa YOKOO
Email　: yokoo@ina.sd.keio.ac.jp

Home institute　: Keio University Science and Technology
School of Integrated Design Engineering
Tojiro Aoyama Laboratory
Supervisor　: Prof. Dr. Tojiro Aoyama
Address　: 3-14-1, Hiyoshi, Kouhoku-ku
Yokohama-shi, 223-8522, Japan
Building 34 room 202/203

Host institute 1 : Technical University of Berlin
Department of Mechanical Engineering and Transport Systems
Engineering Design and Methodology
Supervisor　: Prof. Dr. –Ing Lucienne Blessing
Address　: Strasse des 17. Juni 135
D-10623 Berlin, Germany
Main building room 4128

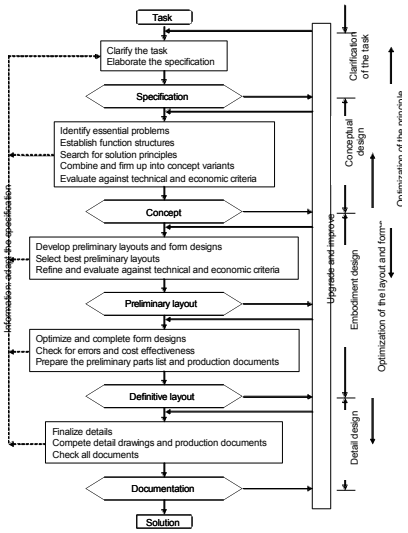
Host institute 2 : Technical University of Denmark
Department of Manufacturing Engineering and Management
Supervisor　: Assistant Prof. David Dam Olsson
Address　: Anker Engelundsvej 1
Building 425
2800 Lyngby

## 2. Executive summary

### Technical University of Berlin

Studying of Design Methodology and Designing of a Fixture and a Tool

Downsizing devices is one of the most interesting themes in engineering field because it is expected to reduce environmental impact, to realize small space and high efficiency. Therefore, components in micro or nano accuracy are necessary in order to build these devices. In this work it will be focused on the manufacturing process to make a micro chip which is used for analyzing the DNA and so on, and tried to develop the micro processing machine for that. In this research the design methodology was studied and a fixture and a tool for micro processing machine with help of the design methodology was designed.



Designing process

## Technical university of Denmark

Investigation of Lubricants and Extreme Pressure Additives in Ironing

Pick up and galling due to lubricant film breakdown is a severe limitation in cold forming of difficult metals like stainless steel and aluminum. This is leading to investigations in how changes of additives in lubricants influence lubricant film breakdown on the several conditions. It was found that the viscosity effect has a great influence for lubricant. In addition, it was also found that the lubricant including chlorine as a compound in a mineral oil lead to a longer threshold drawing length at the high temperature before galling occurred. This matter implies that there are some effects in the lubricant film which could be explained as an effect made by the chemical additive at the high temperature.

I studied not only researches but also English, culture and the way of living strange country. And I made many friends not only European but also American, Asian and Japanese.

I went to ten countries and around thirty five cities to do sightseeing. This exchange program was very good experience for me. If I have a chance, I'd like to go again.

## 3. Travel schedule

September 13th 2004 Departure from Japan to Berlin

| | |
|---|---|
| September 15th 2004 | Start of studying in TU Berlin |
| December 23rd 2004 | Completion studying in TU Berlin |
| January 1st 2005 | Transfer to Denmark |
| January 3rd 2005 | Start of studying in DTU |
| January 20th 2005 | Completion studying in DTU |
| January 31st 2005 | Arrival in Japan |

**4. Technical research** in TU Berlin

**Studying of Design Methodology and Designing of a Fixture and a Tool**

# for Micro Processing Machine

## I. Introduction

Downsizing devices is one of the most interesting themes in engineering field because it is expected to reduce environmental impact, to realize small space and high efficiency. Therefore, components in micro or nano accuracy are necessary in order to build these devices. And MEMS (Micro Electro Mechanical System) technology is focused and actually used. On the other hand, the analyzing system called micro TAS (Micro Total Analyze System) with a very small device is focused, and MEMS technology is also made available to build up this device. However, it needs much time to make it and unconventional/heavy equipments or tools to build a microscale structure are required because conventional processing method puts to use institute unique technology. In my research, it will be focused on the manufacturing process to make it, and tried to develop the micro processing machine for that. Especially the emphasis targets in this paper are that the fixturing device and the cutting tool for the micro processing machine were designed with help of the design methodology.

## II. Design methodology [1]

A design process can be divided into four stages, such as "Clarification of the task", "Conceptual design", "Embodiment design" and "Detail design". Figure 1 shows this process step by step. Every process can be fed back and it can return to previous steps as described figure 1.

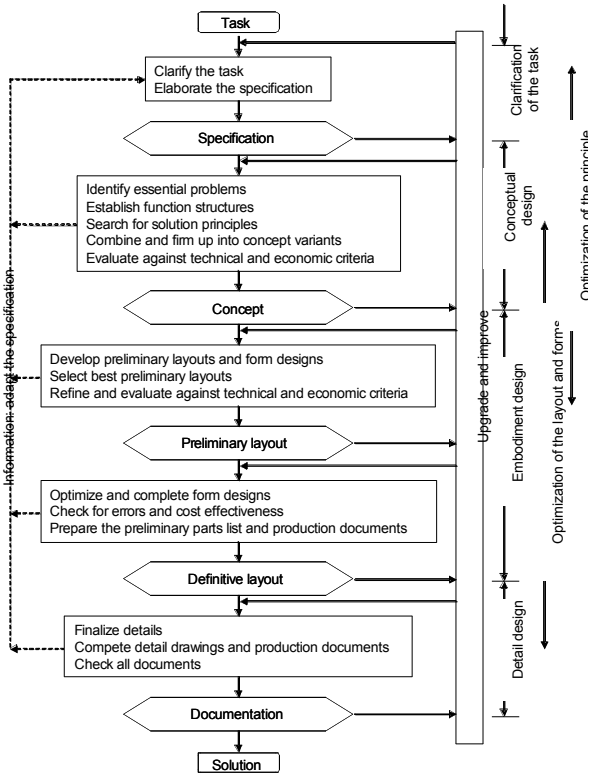



Figure 1 Steps of the design process

### 1. Clarification of the task

The designer's work starts with a particular problem. Every task must be fully understood whether the optimum solution is to be found. Therefore, the task must be defined as fully and clearly as possible so that amplification and corrections during designing can be confined to the most essential. To realize the clarification, a specification (requirements list) should be drawn up and consulted. In requirement list, only the

required function with the appropriate inputs and outputs and the task-specific constraints should be specified at the start because the solution of the task or concrete ideas often have an adverse effect on the final outcome. Therefore, it is essential to state whether the individual items are demands, which are requirements that must met under all circumstances, or wishes, which are requirements that should be taken into consideration whenever possible, when making a requirement list.

2. Conceptual design

Conceptual design is that part of the design process in which, by the identification of the essential problems through abstraction, by the establishment of function structures and by the search for appropriate solution principles and their combination, the basic solution path into concept variants is laid down through the elaboration of a solution concept. A successful solution is more likely to spring from the choice of the most appropriate principles than from exaggerated concentration on the finer points.

① Abstracting to identify the essential problems

The clarification of the task with the help of a specification will have helped to focus the designer's attention on the problems involved and will have greatly increased his particular level of information.

② Establishing the function structures

We need a system with a clear and easily reproduced relationship between inputs and outputs (See figure 2).

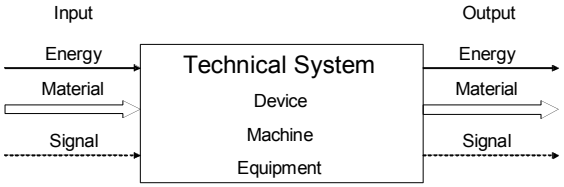



Figure 2 Task or function described on the basis of inputs and outputs

Depending on the complexity of the problem, the resulting overall function will be more or less complex. Just as a technical system can be divided into sub-systems and elements, so a complex or overall function can be broken down into sub-functions of lower complexity. The combination of individual sub-functions results in a "function structure" representing the overall function (See Figure 3).

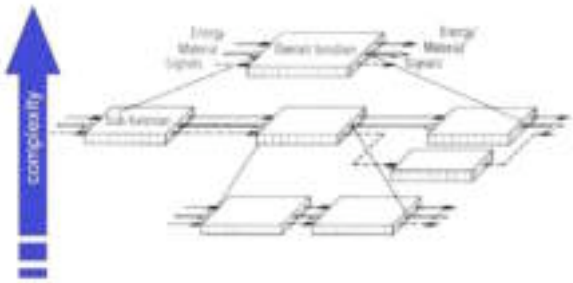



Figure 3 Establishing a function structure by breaking down an overall function into sub-function

③ Searching for solution principles to fulfill the sub-function

Solution principle has to be found for the various sub-functions. It should be important that the step of searching for solution principles is intended to lead to several variants in each sub-function (a

solution field).

| Sub-Functions \ Solutions | | 1 | 2 | ... | j | ... | m |
|---|---|---|---|---|---|---|---|
| 1 | $F_1$ | $S_{11}$ | $S_{12}$ | ... | $S_{1j}$ | ... | $S_{1m}$ |
| 2 | $F_2$ | $S_{21}$ | $S_{22}$ | ... | $S_{2j}$ | ... | $S_{2m}$ |
| ⋮ | | ⋮ | ⋮ | | ⋮ | | ⋮ |
| i | $F_i$ | $S_{i1}$ | $S_{i2}$ | ... | $S_{ij}$ | ... | $S_{im}$ |
| ⋮ | | ⋮ | ⋮ | | ⋮ | | ⋮ |
| n | $F_n$ | $S_{n1}$ | $S_{n1}$ | ... | $S_{nj}$ | ... | $S_{nm}$ |

Figure 4 Basic structure of a classification scheme with the sub-functions of an overall function and associated solutions

In order to seek for solution principles, conventional methods like Literature, textbooks, journal, magazines, internet, solution catalogues, professional information, patents, analysis of natural system, analysis of existing technical system, analogies, measurements and model tests, heuristic operations, are available. In addition, methods with an intuitive bias or with discursive bias are much helpful.

④ Selecting and combining solution principle

After searching solution, it is necessary to select suitable solution principles from function structure and to elaborate overall solutions from the combination of principles. The basic of such combination is the established function structure which reflects logically and/or physically possible or useful associations of the sub-function.

⑤ Firming up into concept variants

The principles elaborated in ③ and ④ are usually not concrete enough to lead to the adoption of a definite concept variant. Before concept variants can be evaluated, they must be firmed up which, as experience has shown, almost invariably involves a considerable effort.

⑥ Evaluating the concept variants

In the next step, the solution proposals must be evaluated so as to provide an objective basis for decisions. There are special evaluation procedures to fill this need. One of them will be introduced.

The first step in any evaluation is the drawing up of a set of objectives from which evaluation criteria can be derived. Then we must first assess their relative weighting to the overall value of the solution. A weighting factor is a real, positive number. It indicates the relative importance of a particular evaluation criterion. The next step is the assessment of values and hence the actual evaluation. These 'value' derive from a consideration of the relative scale of the previously determined parameters, and are thus more or less subjective in character. The values for every variant having been determined, the overall value must be calculated.

3. Embodiment design

During this phase, the designer, starting from the concept, determines the layout and forms and develops a technical product or system in accordance with technical and economic consideration.

4. Detail design

This is the phase of the design process in

which the arrangement, form, dimensions and surface properties of all the individual parts are finally laid down, the material specified, the technical and economic feasibility re-checked and all the drawings and other production documents produced.

## III. Designing of a fixture and a tool

A fixture and a tool for micro processing machine are actually designed with the help of the design methodology. The followings are results of conceptual design.

- A workpiece is put into a micro processing machine manually before processing and removed from there manually after processing (according to the requirement list).
- The machine is not equipped with any sensor to recognize the workpiece shape.
- The machine has a locating point which is defined by three locators. Locating method is "2:1 locating system".
- Two clamper moves the workpiece to the locating point which is defined by the locators.
- The clampers were located on the opposite side of the locators, and positioned between the locators.
- The processing stage can move in the ±X and ±Y direction (according to the requirement list).
- The tool can move in the ±Z direction (according to the requirement list).
- Process technology is "water-jet".

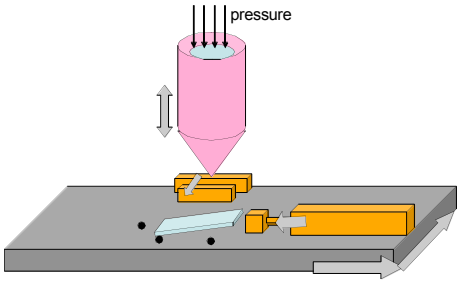



Figure 5 Designed fixtures and a tool

## IV. Conclusion

The design of a fixturing device and a tool for micro processing of glass or plastic was performed through the design methodology. The result is a conceptual design. Through evaluation of solutions, Figure 5 was the best overall solution. However, the control method of cutting depth is necessary to realize the require process by the water-jet technology.

## V. Future works

It is necessary to finish the design work with the embodiment design and the detail design. A prototype model should be build up. Moreover, the arrangement, form, dimensions and surface properties of all the individual parts should be finally firmed.

## VI. Reference

[1] G. Pahl, W. Beitz, Edited by Ken Wallance (1984), " Engineering Design", The Design Council, pp.41-132

## 4. Technical research in DTU

# Investigation of Lubricants and Extreme Pressure Additives in Ironing

## I. Introduction

Sheet material processing is one of the most interesting themes in the engineering fields because sheet materials are available in car industry, cans making industry and so on.

In the sheet material processing, ironing is one of the tribologically most severe processing owing to the high surface expansion and normal pressure at the tool-workpiece interface. Therefore, lubrication between tool and workpiece is very critical when forming metal parts. A major problem in this processing is the tendency to lubricant film breakdown resulting in pick up of workpiece material on the tool surface and subsequent scoring of the workpiece surface, the phenomenon normally referred to as galling. This problem is especially pronounced in deep drawing at the die entry radius, in draw beads in drawing as well as in stretch forming operations and in ironing. In order to avoid galling, chlorinated Paraffin oils normally have to be applied. However, these oils are expected to be abandoned in near future because of environmental problems. Therefore, implying that substitute lubricants needs to be developed and tested. For this reason, knowledge regarding the sustainability of a lubricant is very vital which means that prediction of when a lubricant fail is very important. The parameters which have the largest influence on the failure of breakdown of a lubricant are known to be the ones which relate to the tool/workpiece interface:

- Contact pressure (Reduction)
- Temperature of contact point

Thus a lubricant film breaks down earlier in a process if either contact pressure or temperature (or both) increases.

Earlier studies have shown that the breakdown of a lubricant can be predicted by identifying a critical temperature by preheating the tool to different temperatures. At this critical temperature the lubricant has reached a viscosity which thins the film to such a degree that the tool and workpiece topography come in close contact leading to direct metal-to-metal contact and subsequently total lubricant failure.

As mentioned above, the lubricant film break down is a problem in industry and the method to predict when the lubricant film breakdown occurs has been developed. But how the characteristic of lubricants influences on the lubricant film breakdown is not still clear. Then in this paper, the influences have been investigated by conducting the strip reduction test.

## II. Experiment condition

In the present work the limits of lubrication have been studied applying a strip reduction test, simulating the tribological conditions in ironing (See figure 1).

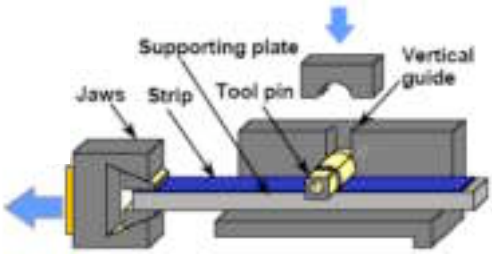



Figure 1 A strip reduction test

The following test procedure has been applied in this experiment.

①The tool is disassembled. ②All tool parts are cleaned thoroughly in an ultrasonic bath with naphtha. ③The equipment is also cleaned to remove the lubricant that is used for the previous experiment. ④A thin lubricant film is applied to the workpiece with a hand. ⑤If necessary, the top plate to adjust the reduction is changed. ⑥The workpiece with a thin lubricant is set on the supporting plate and the tool is assembled in the vertical guide. ⑦In the case of pre-heating experiment, the tool is heated with a heater. And tool temperature is measured. When the temperature is reached to the wished one, the heating is stopped. ⑧ The strip reduction test is conducted. ⑨ The workpiece is removed from the equipment and cleaned. ⑩Steps ①-⑨ are repeated with a new test workpiece. ⑪The length of drawn workpiece surface before any visible scratches appear on the surface is taken as a measure of the threshold sliding length before the onset of pick-up and galling.

## III. Result

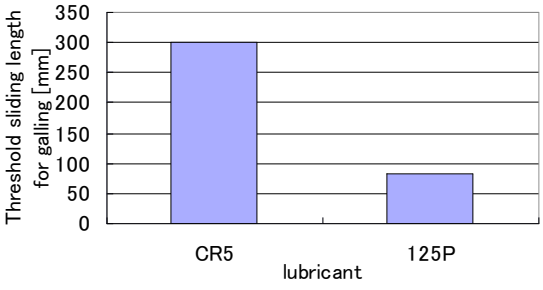
1. The influence of viscosity

First, the experiment for investigating viscosity dependence on lubricant film breakdown has been conducted. Lubricant samples are described in Table 1. The experiments have been carried out on the following condition; reduction-30%, tool temperature- 20℃. The results are shown in Fig 2.

Table 1 Code and description of the tested lubrication

| Code | Description | Viscosity [cst] (40℃) |
|---|---|---|
| CR5 | Pure Mineral Oil | 660 |
| 125P | Pure Mineral Oil | 125 |

Figure 2 Comparison between CR5 and




125P

It is found that the threshold sliding length for galling of CR5, which has higher viscosity than 125P, is longer than that of

125P in Fig 2. Both of CP5 and 125P are pure mineral oil. Only the viscosity is different between these two lubricants. Thus it is found that the lubricants that have higher viscosity show better results.

2. The influence of additives

Next, the influence of containing additives has been investigated

2-1. Difference of additive

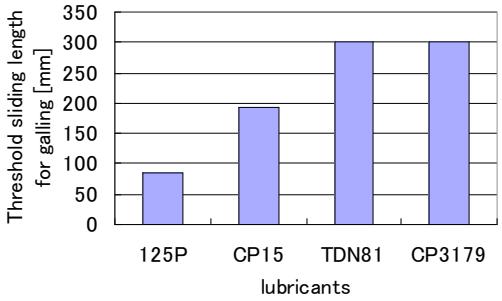
Table 2 is a detail of sample lubricants to investigate the influence of additives. Viscosity of these lubricants is almost same.

Table 2 Code and description of the tested lubrication for

| Code | Description |
|---|---|
| 125P | Pure Mineral Oil |
| TDN81 | High additive mineral oil with chlorine based EP additive. [Containing Chlorinated Paraffin consisted of 40% Cl] |
| CP15 | 125P (85%) + CP3179 (15%) [Containing Chlorinated Paraffin consisted of 7.5% Cl] |
| CP3179 | Pure Chlorinated Paraffin consisted of 50% Cl |

TDN81 is most widely used in industry and it is known that TDN81 contains Chlorinated Paraffin composed from 40% chlorine as an additive. Therefore especially the experiment for investigating influence of Chlorinated Paraffin containing chlorine has been conducted. The experiments have been carried out on the following condition; reduction-30%, tool temperature- 20℃. The results are shown in figure 3.

Figure 3. Comparison among 125P,CP15, TDN81 and CP3179




It is found that the threshold sliding length for galling becomes longer according to the following order: 125P, CP15, TDN81 and CP3179. The percentages of chlorine in 125P, CP15, TDN81 and CP3179 are 0%, 7.5%, 40% and 50%. Thus the pure Chlorinated Paraffin and the lubricants containing more chlorinate as an additive show better results. It is obvious that chlorine contained in Chlorinated Paraffin in lubricant influences the threshold sliding length for galling strongly.

2-2. Investigation of CP15

CP15 is the appropriate lubricant to investigate the effect of Chlorinated Paraffin

containing chlorine on the several conditions because CP15 includes only the Chlorinated Paraffin (7.5% of chlorine) as EP additive and shows a lubricant film breakdown at the above condition in Figure 3. That's why the characteristic of CP15 has been investigated.

The experience in the following condition: reduction-20%, 30% and 40%, preheated tool temperature-20℃, 40℃ and 80℃ was done. The result is shown in Figure 4.

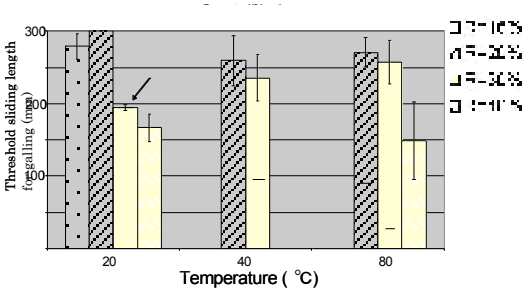



Figure 4 The result for investigation of CP15

Compared with the CR5 result [1], the same result is found in the case that reduction is focused. However, in the case that initial temperature of tool is focused, the different result from CR5 one is found when the reduction is 30%. Therefore, it could be said that some chemical effect on the workpiece or the tool surface works actively with this lubricant when the initial temperature is high. It means that the additive included chlorinated paraffin leads some chemical effect easily on the workpiece or the tool surface (or both) in high temperature and prevents occurrence of pick-up (See Figure 5).

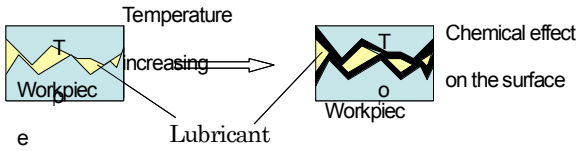



Figure 5 The sketch of chemical effect on the surface

## IV. Conclusion

Different mineral oil lubricants with different viscosity were compared and it was found out that the higher viscosity oil works as the more effective lubricant.

EP additive has an increasing effect on the possible drawing length in ironing. Since there is only one additive in CP15, It can be said that the improvement of the lubricant is due only to the effect of the Chlorine Paraffin and not to a synergic effect between different EP additives.

## V. Future work

It is found that high viscosity lubricants work more effectively than low viscosity lubricants in low temperature. In addition, it is also found that chemical additives make quality of a workpiece surface better in high temperature. Therefore, it is expected that a high viscosity lubricant with some chemical additive works effectively in any temperature conditions.

## VI. Reference

[1] D.D. Olsson, N. Bay, J.L. Andreasen "Prediction of limits of lubrication in strip reduction testing".

## 5. Exchange student life

I was not good English speaker before I went to Berlin. That's why I was afraid of going there as an exchange student. After I was selected as an exchange student, I studied English very hard. Of course I don't think I can speak English frequently now. However, I could get courage that I am not afraid of speaking English and strange places.

I studied not only English, research and culture but also the way of living strange country, which mean that there are not any people whom I can be counting on like family and friends. And I made many friends not only European but also American, Asian and Japanese.

**Germany**:

I got many culture shocks in Germany. I will describe some of them.

One of the most surprising things is that there are some people who can't speak English. And people who live in German don't like to speak English. Before I came to Berlin, I heard from my seniors in my laboratory who went to Germany (not Berlin but Hannover) last year that they never used German. Therefore I had thought that I only studied English. However, if I tried to talk to somebody in English, I got a cool reception. For example, when I went shopping to buy foods for dinner and asked a shop assistant where the articles are in English, he spoke to me in German. But I couldn't understand German. After all, I had to seek them by myself. Everybody talked to me in German in spite of my appearance is not German. Therefore, I studied German and I felt that I had better study German before I came to Berlin.

One month ago before Christmas, Every city in Germany became hot city like Japanese Festival. It called "Weihnachtenmarkt". A Vienna sausage was very good. And Illumination of trees, streets and houses were very beautiful. However, Every shops were closed in December 24th and 25th and Everybody went to a church. Christmas is sanctity for

Weihnachtenmarkt in Stuttgart

European.

The institute staffs in KTEM were very kind. They helped me not only in the advice about my research, but also in my private life. Every coffee break and lunch time, they asked me whether I go to café or restaurant together. I really appreciate their help.

Farewell party in TU Berlin

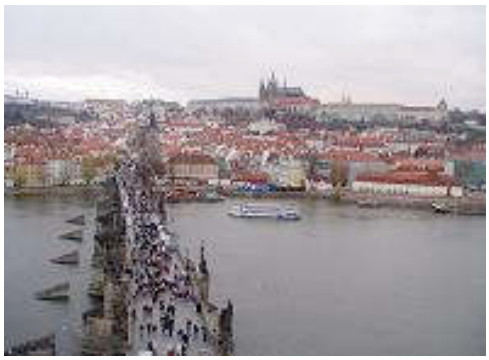
**Denmark:**

In Denmark, I could speak English. That is the most different point. And Prices were very expensive. So everyday I made lunch box and dinner.

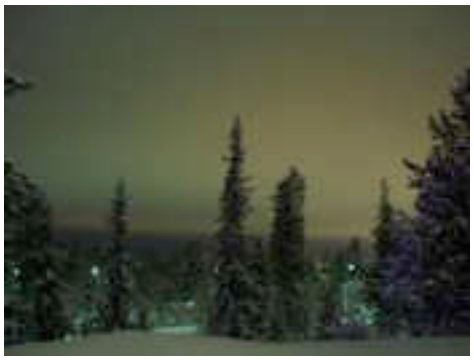
The research in DTU was for three weeks. I thought firstly that this class was only lecture because of shot time. However, it was study including making a report and presentation. Therefore, the class was hard schedule and we could not get the desired result. Moreover, I could not manage the research procedure.

The last lecture in DTU

I went to ten countries and around thirty five cities to do sightseeing. In the travel, I could see many old buildings and natures. They were very beautiful.



Charles Bridge in Praha



Aurora in Rovaniemi

This exchange program was very good experience for me. If I have a chance, I'd like

to go again.

## 6. Suggestion

・I went to two institutes in spite of short time exchange program. Therefore, I could not finish and satisfy my researches, especially in DTU because of only three weeks lecture. I think that it is better to go only one institute in the case of short time study.

・I had a problem that I could not get a student ID card first because of rack of a paper in TU Berlin. In the guide book for an exchange student, it was not said that we need the paper. I asked to send the paper to International office, and finally I could get ID card. I thought there were too many steps to get something in spite that I went studying. I wanted a condition to study smoothly.

・I think it is better to study German before if we go to the Germany. I went there without studying German. Thus I could not understand at all. We need a marginal skill for daily life before we go there.

## 7. Summary (acknowledgement)

"Studying of Design Methodology and Designing of a Fixture and a Tool" was done while I belonged to Department of Mechanical Engineering and Transport System in Technical University of Berlin. And "Investigation of Lubricants and Extreme Pressure Additives in Ironing" was done while I belonged to Department of Manufacturing Engineering and Management in Technical University of Denmark. Prof. Dr. –Ing Lucienne Bressing who gave me a great opportunity in TU Berlin and Assistant Prof. David Dam Olsson who gave me it in DTU are thanked heartily.

This exchange program was very good experience for me. I really appreciated anyone who helped me. Thank you very much.

At last, I appreciate Prof. Dr. Tojiro Aoyama in Keio University and his laboratory staffs, and my parents who permitted my invaluable studying abroad.