DeMaMech Exchange Student Report

From 1st September to 31st January

Student: Hiroki Tanada

Home University: Osaka University

Host University: Delft University of Technology
Technical University of Denmark

1. Personal Data

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Home Institute:

Institute: Measurement Engineering on Production Subarea,
Department of Mechanical Engineering and Systems,
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Host Institute 1

Institute: Precision Manufacturing and Assembly,
Faculty of Mechanical Engineering, Marine Technology and Material Science,
Department of Precision and Microsystems Engineering,
Delft University of Technology

Address: Mekelweg2, 2628 CD Delft, the Netherlands

Host Institute 2

Institute: 33 Department of 33 of Micro and Nanotechnology
Technical University of Denmark

Address: Anker Engelundsvej 1 Building 101A 2800 Kgs. Lyngby, Denmark

2. Travel Plan

25th August 2005 Arrived at the Netherlands

2nd September 2005 Started Research at T.U.Delft

22nd December 2005 Finished Research at T.U. Delft

31st December 2005 Arrived at Denmark

2nd January 2006 Started 3-week course at DTU

20th January 2006 Finished 3-week course at DTU

3. Executive Summary

I stayed in the Netherlands for four months, from September to December 2005. During that period, I have done 1 small project and 2 lectures.

The project was done with my supervisor, Marcel Achtsnick. My research steps were as follows: literature survey on abrasive blasting (one and a half month), experiments (one and a half month), analysis of the experimental results written down in a scientific report (one month). Details are described in section 4.1.1.

I took one technical course and one English course. The contents and style of lectures are described in section 4.1.2.

I stayed in Denmark for one month, in January. I took three-week course there. This course included a use of simulation software. That was my first time to use that kind of software.

I performed this project with one French and one Danish. This 3-week project became a precious experience for me because this was my first time to use simulation software and do group work with foreign people

About an exchange student life, I went to university in everyday and traveled in weekends. Details are described in section 5.

4. Research and lectures

[T.U.Delft]

At Delft University of Technology, I have done one project and two lectures. The project was done with my supervisor at T.U. Delft. Two lectures were one regular lecture and one English lecture.

4.1.1 Project at T.U.Delft

A brief overview of my research was as follows:

First one month, I learned how to use experimental and measurement apparatus. And then I performed some basic experiments.

In the 2nd and 3rd month, I had progressed research operating experiments and searching literatures.

Last one month, I analyzed data and wrote a small report.

Research theme

"Improvement of the machining performance of micro abrasive blasting"

Background and Objective

Micro abrasive blasting (MAB) is a non-conventional machining process. This dry etching technique became established about 10 years ago as low-cost manufacturing process to structure three-dimensionally brittle materials such as glass, silicon and ceramics. Because of its low-cost, high accuracy and high productivity, this technique is expected to be applied on micro-electro-mechanical-system (MEMS), for instance machine parts for semiconductors, micro fluidics and Microsystems Technology (MST) applications, and on other various fields.

Figure 1 gives a schematic drawing of the principle of MAB. Two dimensions are named in Figure 1; l_d, the depth of the micro-feature and l_w, the width of the mask at the place where it is attached to the substrate the aspect ratio is calculated from these two dimensions.

$$aspect\ ratio = \frac{l_d}{l_w} \qquad (1)$$

The imaging quality and the shielding capability of a mask determine the tolerances of the micro-feature and enable the generation of deep structures with high aspect ratios.

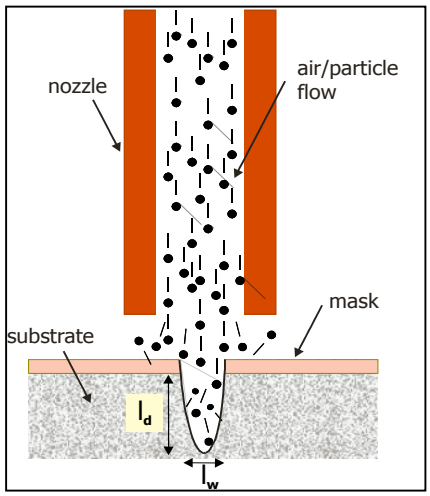

Figure 1: State of the art of micro abrasive blasting.

There are many models to represent erosion behavior and one of these models relating to hardness consider substrate material properties in the form

$$E_{rate} \propto K_C^{-1.33} \cdot H_{sub}^{0.11} \qquad (2)$$

Up to know the reachable structure depth is limited to shallow cavities. To answer the industrial demand of producing structures with high aspect ratios, an improved blasting strategy is required. The purpose of this research is to improve machining performance and to clarify the removing process of micro abrasive blasting on ceramics. Recently ceramics attracts attention for various applications on MEMS because of its superior solid state properties such as burning, corrosion, decay and abrasion resistance as well as its insulation.

Conclusion

I performed experiments with some different scan trajectory and with some kinds of particle (SiC and WA). Here I give conclusions drawn with the aid of the obtained results and possible reasons for observed phenomena.

1. Erosion rate decreases dramatically as scan speed increases. So lower scan speed is effectual in MIB.
2. When scan direction is perpendicular to mask image, there sometimes remains blast lag on the bottom of channels even after cleaned with ultrasonic cleaner carefully. Therefore larger aspect ratio will be achievable with scan direction that is parallel to the mask image.
3. As I had expected, aspect ratio (erosion rate) decrease as the impact angle decreases from 90 degrees and the aspect ratio decrease rapidly on the part where the impact

angles are over 45 degrees. If we need a large aspect ratio channel, we should make a vertical particle flow to the substrate surface. However it is reported that oblique particle flow can make monolithic structures in MIB. So if we need complex monolithic structures, oblique particle flow can be useful.

4. Erosion rate increases with increasing particle size for both SiC and WA particles up to certain value because of kinetic energy growth. Generally speaking, the particles become more elongated and less circular as the size of SiC and WA particles increases and the shape of particles have a strong effect on erosion. This phenomenon may be explained with rake angle. The rake angle is defined as the angle between the perpendicular to target surface and the leading edge of impacting particle, as shown in Figure 2.

Figure 2: Rake angle for particle impacting on a target surface.

a spherical particle will always impact the target surface with a large negative rake angle (See left of Figure 2) so that ploughing is the only plausible mode of deformation. How ever, an angular particle may impinge with either positive or negative rake angle. Considering random impact orientations, angular particles should be expected to produce both microcutting and ploughing. Furthermore, the rounder the particle, the greater will be the likelihood of ploughing in comparison to microcutting. Hence angular particle, that is to say large particle can erode more effectively.

4.1.2 Lectures in T.U.Delft

Control Theory

Control engineering: basic theory. State space description of linear dynamic systems. Realization of transfer function models by state space models. Controllability, observability, minimal order. Parallel and series connection, pole-zero cancellation, relationship with controllability and observability. Controllability and observability canonical forms. Jordan canonical form. Stability theory, frequency domain analysis. Dynamic response, relationship with pole and zero locations in the complex domain.

Loop shaping for dynamic response, robustness indicators. Multi-input and multi-output systems. Pole assignment, design of state feedback. Linear observers, Kalman filter. Design of observer. Control design and separation principle. LQ regulator and LQG theory. Algebraic Riccati equation, choice of performance criteria. Asymptotic analysis, LQ control system design, dynamic compensation. Disturbances and reference signals, modelling of exogenous variables. Internal model principle, design of tracking control systems, servomechanism design.

Lower-Intermediate English

This course is designed to help students to improve their English to the point where they are able to survive in an English-medium university environment. This includes listening to lectures, being able to participate in discussions, and writing basic reports and documents.

The course is based on a series of specially selected texts covering a wide range of topics. These texts form the basis for a variety of discussions and debates, as well as short written assignments. Grammar issues will be dealt with as needed, but the focus of the course is effective communication. In the second half of the course, each student are expected to give a brief presentation and to write a short report.

5. Exchange student life

The Netherlands

I stayed in the Netherlands for four months, from September to December 2005.

I lived in a student dormitory near the university with 13 Dutch students and 1 Norwegian. Although my English skill was terribly poor, they were all very kind to me. It was fantastic to stay with Dutch people, and in this way, I got to know their culture and enjoyed the Dutch food. Furthermore, they took me to bars, discos and parties to have fun and to make new friends there.

However, I often got into trouble due to my poor English. For example, when I was in the living room with my roommates, they talked in Dutch though they could speak English well. I could not follow their conversations and felt lonely. I am sure that if I could speak English very well, they would have a conversation in English. Now I regret bitterly that I haven't practiced English enough in Japan.

On weekdays, I spent almost all the time on projects and lectures.

I did the project with the help of my supervisor in the Netherlands. At first we had a trouble in communicating because of my bad English, especially in technical terms, but we managed to understand each other somehow. He recommended me to submit reports every week, and to tell him how my research was going.

Unfortunately, I had to share my experimental instrument with another student for the first two months. I could conduct my experiments only two days a week, and it was definitely not enough and efficient. But in the last two months my experiments progressed more effectively and I wrote a small report with some conclusions in the end. To my regret, I didn't discuss with my supervisor very often because I was not completely satisfied with my results. Surprisingly, in the Netherlands the POT laboratory does not have student rooms. So I did not have an opportunity to discuss with other students or ask them about the basic rules, such as how to use the lab, or where the experiment stuff is, and etc.

I took one technical course-Control Theory. Since I did not have the background knowledge and the lecture was given three times a week, it was very difficult for me to follow the teacher at the beginning.

But later it turned out that the lectures were very enlightening and I did study hard. Eventually, I passed the exam with a satisfying grade.

I took an English course as well. But it was a little bit stupid-around half of the

students were Japanese since all of us expected to practice English by taking that course. I wrote some reports, gave a short presentation and took an exam in that class.

Most of the students go to school before 9:00 and come back home before 17:00 in T.U.Delft. Such a schedule is completely different comparing to the situation in Japan where students go to school around 10:30 and come back after 20:00 or later. I think this difference arises from the cultural disparity, thus Japanese students are not like European students in this term and vice versa.
As I expected, in T.U.Delft many courses demand group works but I did not take any one of them. In the faculty building, there were many places for group work and students usually discussed intensely. I think we need to have more group works in Japan that are efficient and creative.

On weekends, I traveled around. The Netherlands is a very beautiful country and is especially attractive to me because I had never been to European countries before. Amsterdam, Den hag, Rotterdam, Kinderdaik, Paris and etc…. The Netherlands is such a fascinating place that 4 months are too short to travel all around. Since the main task for me to stay there is studying, I traveled only on weekends.

Denmark
I stayed in Denmark for one month, January 2006.

I lived in the campus village with many other exchange students. Staying in Denmark was really nice, because all my neighbors were very friendly and all conversations were in English, which gave me a great chance to practice English.

I took a 3-week course in Denmark about micro gripper actuated thermally. This course included a use of simulation software. That was my first time to use that kind of software, so it was really hard to understand it.
I performed this project with one French and one Danish. This 3-week project became a precious experience for me because this was my first time to use simulation software and do group work with foreign people.

6. Summary

I gained really valuable experiences through this exchange life abroad, which means I could get to know many foreign people who had totally different ideas, languages and cultures. So now, I can see Japan at a different point of view and my self as well. I think I could have a precious time period before getting job.

As I described above, many troubles I had were mostly from my poor English. So I will study English continuously in Japan and hope I can go abroad again.