DeMaMech 2007

- Report -

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2 Executive Summary

This report describes my experiences of my exchange to Takeuchi Laboratory, Osaka University, Japan. The exchange had a duration of five months: it started in April 2007 and ended at the end of September of the same year.

Takeuchi Laboratory is specialised in precision manufacturing, and one of the machines used for high speed milling is the HexaM 5-axis, Parallel kinematic Milling Machine. This machine had serious position error problems. The goal of my research was to find a method of error reduction using compensated NC-data. The fact that the milling machine had a parallel kinematic structure made my research extra challenging.

Complementary to my research work at Osaka university, I was able to discover a lot about the famous but often not understood Japanese Culture. The history, politics and daily life were very interesting and made my stay in Japan a experience to never forget. And due to some extraordinary friendships I made in Japan I learnt a lot about myself along the way.

This report wraps up with some conclusions and recommendations for anyone who is thinking of joining the DeMaMech exchange program. I leart a lot from former DeMaMach students and I hope that, in the same way, my experience will be helpful to future DeMaMech students.

The Report discussing the actual research is not included in this report, since it is an separate report, in paper format [Los07]. A summary of this research report is given in chapter 4, for those who would like a brief insight into what my research is all about.

3 Travel Schedule

Amsterdam – Osaka	14 April	2007
Osaka – Amsterdam	24 September	2007

4 Research

4.1 Introduction to the research summary

My research activities at the Takeuchi Lab finished with writing a research report. This Report discusses all the relevant aspects of the research done on the HexaM milling machine [Los07]. Because this report may be to elaborate to some readers, a brief summary is given here.

4.2 Previous research

My research was a continuation of the research carried out by an other DeMaMech exchange student from DUT - 3ME, Sander Pastoor. In his report [Pas05], he proposes a method for the improvement of the position error of the milling machine.

According to his research, the HexaM milling machine [fig 1] can be described by a kinematic model. This model can predict how an certain error source will effect the position error of the end effector of the milling machine. These predictions, together with the actual found errors in the workspace of the machine, can be used to identifying the actual error sources. After knowing what causes the position error, the NC-data describing the kinematic movements of the end-effector can be altered in such a way that the position errors are exactly compensated for.

4.3 Research summary

My starting point was more or less where S.Pastoor had ended his research on the milling machine. I was not obliged to continue exactly where Pastoor ended, but it is good to have some experience of others which you can use, avoiding reinventing the wheel.

The most important piece of research was the kinematic model of the machine. Pastoor had tried to use his model to compensate for position errors of the end-effector of the milling machine, with some promising results. The error of the machine was reduced by a factor tree, bringing the accuracy close to the desired value.

The greatest limitation of his approach was that the position errors were only measured by experiments and predicted by the model in two dimensions, the horizontal plane. My focus was to expand the error compensation method from two to tree dimensions, bringing it a step closer to being a practical tool.

In order to discover the actual error of the milling machine, I designed two standard work pieces, one for the horizontal error (X and Y) and one for the vertical error (Z). These work pieces can be seen in figure1and 2. Direct measurement on the end effector was not possible, so we milled work pieces first and measured them using a Coordinate Measurement Machine (CMM).

Figure 2: The HexaM milling machine

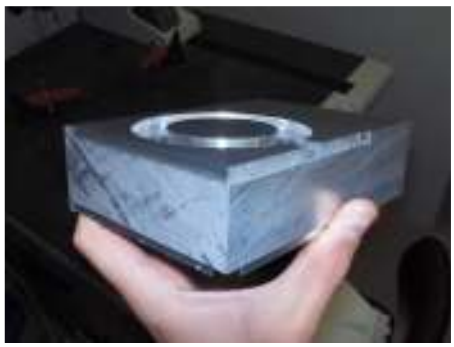

Figure 3: The Work Piece for XY error measurement

Figure 1: The Work Piece for Z-error measurement

All measurements together resulted in a 3+3 dimensional error space, as can be seen in [fig 3]. Three dimensions for the coordinate of the points in space, and three for the error direction in these points. Luckily, the kinematic model was already capable of predicting the errors in three dimensions, so modifying the model was not a big issue.

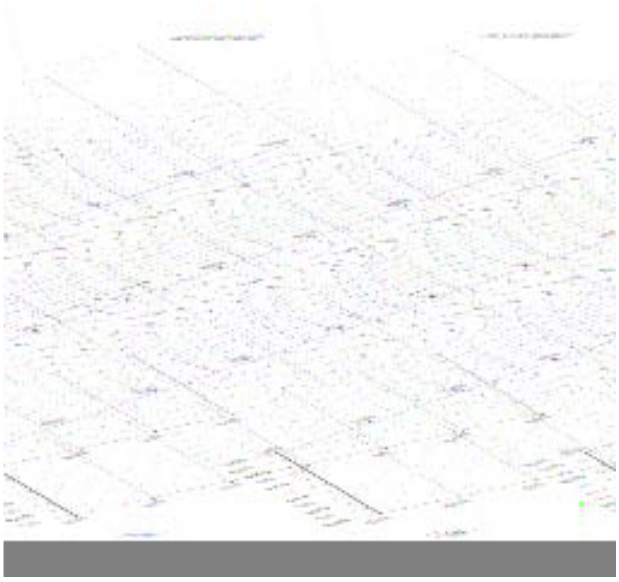

Figure 3: The interpolated tree-dimensional error field represented in a 9x9x9 mesh.

At this point, the error reduction was typically a factor two (from 15 um to 8 um) [fig 39 to 41]. Due to a bad reproducibility of the milling and measuring experiments, the deduced error space was not very accurate. None of the error patterns predicted by the kinematic model fitted nicely to the measured error patterns. Predicting the simultaneous effect of two or more error sources produced error patterns closer to the actual error field [fig 34 to 37]. But it is clear that the reproducibility should be significantly improved before reliable compensation of the error is feasible.

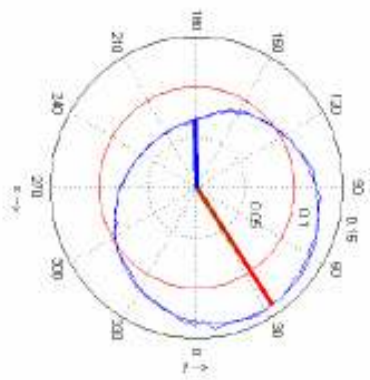

Illustration 39: Error pattern for the position 9,9,7 before compensating.

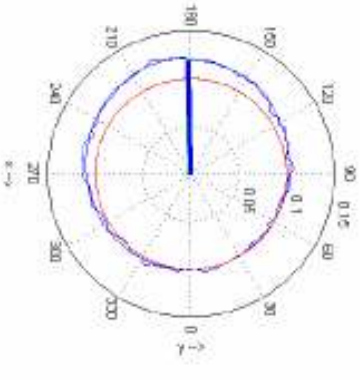

Illustration 40: Error pattern for the position 9,9,7 after compensating.

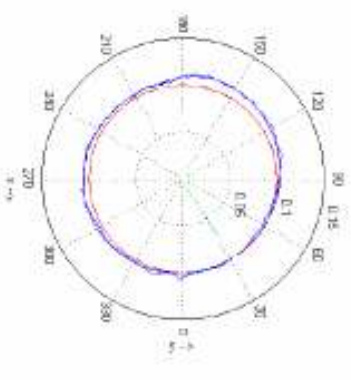

Illustration 41: The expected error pattern, the error data translated according to the compensation.

Improvements likely to deliver a gain in reproducibility and accuracy are, among others: direct measurement of the end effector position, a better control of the climate around the milling machine and including more error sources in the kinematic model.

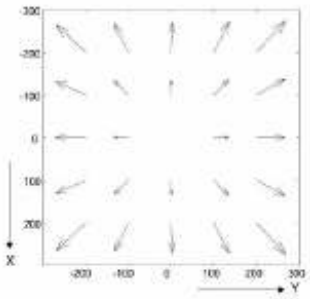

Illustration 34:
All 6 struts elongated with 8 mm.

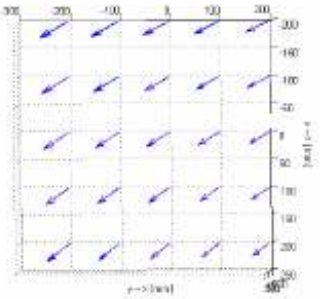

Illustration 36:
Struts 1,2 and 6 elongated with 1 mm.

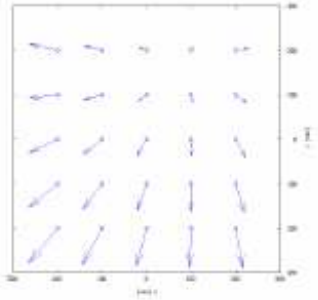

Illustration 35:
Struts 1,2 and 6 elongated with 1mm,
All 6 struts elongated with 8 mm.

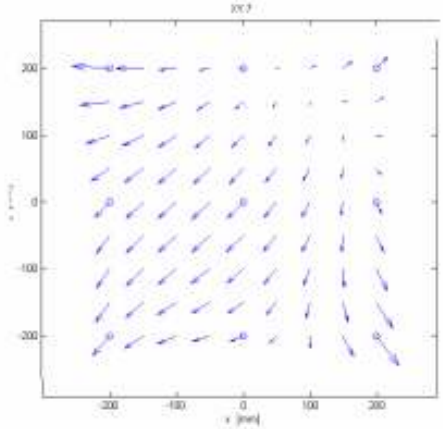

Illustration 37: The actual measured horizontal error field at a hight of z = 225 mm.

4.4 Field trips and factory visits

During my study time I was given the opportunity to go on several field trips to discover more about my research field.

I went to Toyoda Machine Works and J-Tect Manufacturing to discuss some problems encountered with the HexaM milling machine and to find possibilities for a more effective NC-code.

I also was able to visit a interesting Open House day at Mori-Seiki Machine Tools. Numerous state-of-the-art milling machines showed their great capabilities.

In Odaiba, Tokyo, the annual exhibition of MEMS technology was held, and I was invited by prof. Takeuchi to visit this exhibition, which, in fact, covers an part of my master specialisation.

These field trips and factory visits were a nice supplement to my research work.

4.5 Lectures

During my stay in Japan I did not only carry out research for the Takeuchi Laboratory, but attended some elective courses. In fact these courses were set up as a part of the OUSSEP exchange program at Osaka University. The OUSSEP program is a cultural exchange program for international students. It has a duration of two semesters, and is suitable for anyone with a particular interest in the Japanese culture, history and language. I attended two of the OUSSEP courses. 'Japanese Culture, Inside and Out' and 'Comprehensive Japanese Language Course – Beginners'.

The culture class was very interesting to me, because it dealt with the way Japanese see themselves and how foreign people tend to see the Japanese. The Lectures were given by a very good and knowledgeable 'Sensei' called Yamamoto-San. She is a British woman, married with a Japanese man. At times, it was a pleasure to be able to leave the dusty machine hall and soak up these interesting stories and anecdotes about Japanese culture. Ultimately, I did not pass the course due to time limitations, but that was not my goal in the first place.

The language course helped me to force myself into learning some Japanese Language and develop a better feeling of the Japanese Culture in general. It is very helpful to be able to speak some basic Japanese in daily life, and making some effort to speak their language triggers some genuine enthusiasm from the people you meet and acts as a good ice-breaker. It is eye-opening to discover how much of the Japanese culture is reflected in their language. Because the Japanese Culture is so ancient, the language had enough time to evolve in such a way that it reflects the traditions off social interaction, Japanese style.

I strongly recommend one of these OUSSEP courses to all DeMaMech students who are studying at Osaka University.

5 Exchange student life

NB: For pictures on this topic, please see the slide presentation.

Research in Japan

Japan has the reputation of being a very large economy and having the manpower and the eagerness to research in a fast pace, with a high quality. According to many, this would give Japan a great advantage among other Asian countries, making Japan the leading scientific power in the East.

This is only partly true. Japanese have a very positive attitude towards science and engineering. In The Netherlands for example, being a scientist or an engineer often is associated with being a 'geek' of a 'nerd' with poorly developed social skills. In Japan, engineering is one of the most prestigious fields and technology is seen as one of the most important economic activities. As some of my lab-colleagues said, “In Japan, only if technology fails, we look for other solutions to a problem”. This attitude gives Japan an advantage in engineering compared to Western Europe. A side effect is that, in my humble opinion, solutions for some social issues are searched for in strange places. The amount of research that is done to develop toys for kids, especially kids that had a serious lack of parental attention and love, is surprisingly large.

On the other hand, Japanese research students tend to work long hours and focus on “being busy”, not on how much time it takes to ultimately get there. This may result in a ineffective way of working. But when needed, they will not complain about having to work extra hard.

Lab Life

Compared to the Dutch system, the Japanese organisation of the Graduate Schools is different. At Osaka University, all students who wish to enter the Masters program, need to pass the obligatory entry test of the Lab they want to join. The difficulty of these tests is dependent on the status and the prominence of the Lab and its leading professor. As far as I could see, there is not many research exchange between different labs.

There is a noticeable difference between a corporate engineer and a research student in University. In Japan, during the primary and secondary school (High school) period, pupils are very much focussed on passing the entry-test of a University. This is one of the sources of the hard working and very competitive atmosphere. Many students start working at their jobs after finishing University, entering the famous long-hour working life.

The University life itself tends to be the complete opposite. Sometimes referred to as 'Leisure Land', many students have no shortage of time and freedom. Many Universities are not so strict in letting students pass exams, and there is not a great demand for fast and relevant research results. There are exceptions, and as I was told, the Graduate School of Engineering of Osaka University is one of them. Indeed, Students did work quite hard and appeared frequently in the Lab. No Leisure Land for us...

Daily Life

Dormitory

In most Japanese cities, space is limited and housing is not very luxurious. My dormitory was no exception, my room was approximately 11 m^2 and very basic. The rent and public services costs were very basic too, so that was a pro for a student on a limited budget.

I was lucky, because it was a dormitory for international students, so I had the pleasure of living among a lot of interesting Thai, Korean, European, American and Australian students. Some of these student eventually became very good friends of mine. Together we regularly went out down town and explored Japan on sight-seeing trips.

Furthermore, the dormitory was relatively liberal. There was no curfew for example, and having a party once in the while was no problem either. Hearing and experiencing the strictness of the other dormitories made us feel very privileged indeed.

Travelling

If you have some money to spend on transportation, Japan is the ideal country to travel around. There is a lot to see and discover. Whatever you are interested in, there will be something for your liking.

As for myself, I lived in Osaka, so I mainly travelled around western Honshu, the main island of Japan. A lot of beautiful history and culture can be found in cities as Nara, Kyoto and Kobe. A little further, but very much worth the effort of getting there are Hiroshima, Tokyo and Mount Fuji, the Northern Coast and Shikoku. My professor was proud of his country and encouraged me to not only stay in my lab, but get out and explore, which I certainly did.

Culture

Japanese people are very friendly and kind, they always try to make you comfortable and help you out when needed. It is very nice to experience people first thinking of others before thinking of themselves.

On the other hand, getting to know Japanese personally is a much greater challenge. From the outside, Japanese are very kind and open, but when you try to discover their personal life, opinions and way of thinking, you will encounter a 'wall' which they will not let you through very easily. After a while they will loosen up, and show more of their individual personalities.

Back in the Low lands

After nearly six months of living in Japan, it is very awkward to come back to The Netherlands. Upon arrival I immediately noticed a lot of typical Western-European habits I was less aware of than before. People seem to be very expressive and loud, cities are more quiet and relaxed and there are in fact flat pieces of land not used for buildings! It's good to be back home, but Japan will always be on top of the list of countries to visit again.

6 Summary

I had a marvellous time in Japan, and studying in Japan is a unique experience. It is not likely that I will have such a adventure again very soon. Japan is especially interesting because it is a country that is very well developed, and at the same time bears a unique ancient culture. For a engineering student like me, Japan was the ideal country to experience a totally different culture, combined with a high quality of engineering education.

The most challenging aspect of studying in Japan is to cope with the cultural differences. First of all there is the language barrier to overcome. For me, this was not a big issue, since my professor and my tutor were good at English. But language is only one aspect of communicating. The way of sharing thoughts, knowledge, experience and opinions is very different from what you are used to back home. Because of this, guidance and coaching needs extra attention, from both the student and the supervisors.

As for my research, five months is a very short time, and as always, planning is a important phase for your research. When starting a new research, it is easy to underestimate the amount of work to be done. In order to keep the research feasible and to avoid disappointment, take extra care in the planning phase, and consult more experienced researchers for a realistic planning.

In contrast to some previous experiences, my accommodation suited me very well. I was very pleased with the open, liberal, and international character of the dormatory, together with its cost effectiveness.

As a final remark I would like to encourage everybody to consider joining the DeMaMech program and have the time of their lives studying in the Country of the Rising Sun.

I would like to thank the DeMaMech supervisors for giving me the great opportunity to study overseas in the fascinating country of Japan. Special thanks go to my Delft supervisor prof. Tomiyama for offering me a place in the DeMaMech exchange, and for the administrative effort needed to get it happen. I would like to thank my Osaka supervisor prof. Takeuchi for giving me a warm welcome to his Lab, and for showing me a lot of the Japanese Machanical Engineering Industry. Many thanks go to Ueda-San, my tutor and friend, and to all the Master-2 guys from the Lab. It was great to have many helping hands during my research and great times during our other adventures. Last but not least I would like to thank Simon, San and Jochen, for being great company and good friends during my dormitory life.

7 References

[Los07] J.G.Los, Research Report, *Expanding the possibilities of position error compensation in CAM for PKM milling machines.* - 2007

[Pas05] S.Pastoor, Research Report, *Improvement of HexaM, a parallel kinematic machine tool, using error compensation in CAM.* - 2005