DeMaMech Exchange Student Report

Student: Kentaro WATANABE

Host University: Technical University of Berlin (3 months)
Technical University of Delft (2 months)
Home University: The University of Tokyo

1. Personal Data

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Supervisor: Prof. Dr.-Ing. Frank-Lothar Krause, Dipl.-Ing. Christian Kind

2. Executive Summary

I left from Japan to Holland and Germany on 28 August 2005 as a participant of DeMaMech student exchange program from The University of Tokyo. Since it was my first time to live alone in abroad, I had anxiousness feeling, but I was also excited by possibility to know totally different ways of thinking about something. And I knew this will be great experience to improve my technical viewpoint and personality.

I was belonging to the institute that is led by Prof. Dr.-Ing. Frank-Lothar Krause as an exchange student of DeMaMech program from The University of Tokyo. The period to stay was from 2 Nov 2005 to 2 Feb 2006. My research theme was “DESIGN IMPROVEMENT BY FMEA AND ITS INFLUENCES ON INCREASING THE RELIABILITY OF MECHATRONIC SYSTEMS” and I had felt great honor that I can be involved in this research.
This research theme was arisen from problem in product development process. To improve product reliability, designers use some methodologies such as FMEA, FTA and DR in early stage of the process. They can know how to improve reliability with these methodologies. But designers also need to know the influence of improving design process on increasing reliability of products.
We proposed a methodology to estimate improved product’s reliability by FMEA. We focused on failure rates of components and calculated reliability from failure rates before and after executing FMEA.

From my point of view, this exchange program was so great that I came to hope to live in these countries in future. I met many people and made many nice friends. They gave me a lot of precious things that changed a part of my view of life and I hope that I can keep in touch with them.

These great experiences were realized by this DeMaMech project. So I really appreciate all the help by organizers and supervisors and all the involved parties of this DeMaMech project.

3. Travel Schedule

28.08.2005 Tokyo / Narita airport → **Amsterdam** / Schiphol airport (Airline: KLM)

↓ **2 months**
At **TU Delft**

02.11.2005 Amsterdam / Schiphol airport → **Berlin** / Tegel airport (Airline: Air Berlin)

↓ **3 months**
At **TU Berlin**

02.02.2006 Berlin / Tegel airport → Frankfurt / Frankfurt airport (Airline: LH)
Frankfurt / Frankfurt airport → **Tokyo** / Narita airport (Airline: JAL)

4. Research Theme:

"DESIGN IMPROVEMENT BY FMEA AND ITS INFLUENCES ON INCREASING THE RELIABILITY OF MECHATRONIC SYSTEMS"

Introduction

Recently mechatronic products such as cameras, cars and cell phones which are integrated with mechanic and electronic are playing an important role in world wide market. In such circumstance companies need to optimize their product development process to save costs and time to design a new mechatronic product. FMEA is used in early stage of this process in order to find defects and to improve system reliability. FMEA makes the order of priority of failure mode to implement countermeasure by using indicators which is called as RPN. RPN is calculated by multiplying indicators, Severity(S), Occurrence(O) and Detection(D). But RPN itself means nothing but number and the methodology to assess improvement of reliability resulted from using methodology such as FMEA for design process is missed. In this research, we proposed a methodology for this problem.

Proposed Methodology

(1) Calculating Component's Reliability before Implementing FMEA

At first it is premised that each company has stored up data of various failure mode of each component and they can also know the reliability of component from that data. For example, suppose that 6 failures were observed within 10000 hours for component C_1 as the Fig.11 below shows.

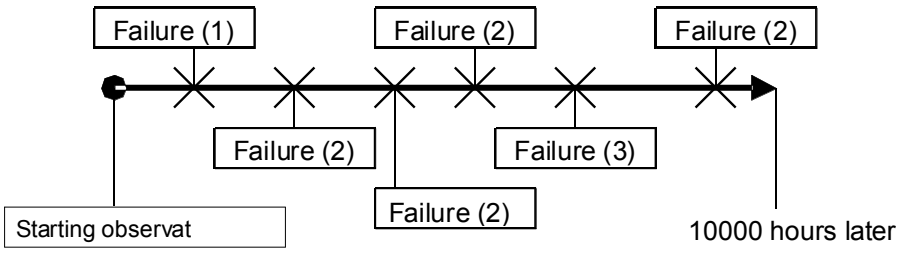

Fig.11 Failure Data of the Component C_1

Then the failure rate will be calculated as below:

$$\lambda = {}^{6}\!/_{10000} = 0.0006 \quad \text{[Number of time / hour]}$$

And this failure rate can be written as below:

$$\lambda = 0.06 \quad \text{[\% / hour]}$$

This means that this component C_1 has possibility 0.06% to be broken within 1 hour. Or it can be also said that failure rate is $\lambda = 6$ [% / 100hour].

And from this failure rate λ = 0.06 [% / hour], the reliability $R_{(t)}$ of this component C_1 can be calculated as below:

$$R_{(t)} = e^{-\lambda t} \quad \text{t: usage time [hour]}$$

If t = 1000 [hour], $R_{(t)}$ of this component C_1 will be

$$R_{1(t)} = e^{-0.0006 \times 1000} = 0.548$$

(2) Calculating System's Reliability before Implementing FMEA

Suppose that the system consists of 6 components in reliability diagram as Fig.2 shows, and company knows reliabilities of every components when usage time is 1000 hours from data of failure rate.

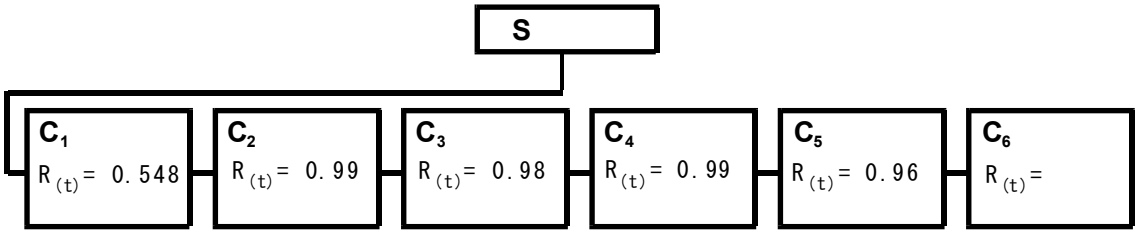

Fig.2 System's Reliability Diagram

The whole system's reliability which means the probability that the system can have worked without failure within 1000 hours can be calculated as:

$$R_{(t)} = 0.548 \times 0.99 \times 0.98 \times 0.99 \times 0.96 \times 0.97 = 0.49$$

So the whole system's reliability when usage time is 1000 hours is 49%.

To improve this reliability of the system, methodologies such as FMEA are executed.

(3) Implementing FMEA

Failure Rate of Each Failure Mode

For example, the component C_1 has 6 failures within 10000 hours but they all are not same failure mode. There are three failure modes, (1), (2) and (3). For failure mode (1) & (3), the failure rates are $\lambda_{(1),(2)}$= 0.01 [% / hour], and for failure mode (2), the failure rate is $\lambda_{(2)}$= 0.04 [% / hour]. If supposed usage time is 1000 hours, each failure rate becomes $\lambda_{(1),(3)}$= 10 [% /1000 hour], $\lambda_{(2)}$= 40 [% / 1000 hour].

Occurrence (O) of Each Failure Mode

Before starting FMEA, each company has to make table of Occurrence (O) of each failure mode and failure rate for ranking indicators of RPN. Usually Occurrence (O)

ranking is decided by own company's designer according to his experience and knowledge of data about the component and subsystem and generally indicated by 1~10 number. Table.1 shows an example. This table can vary by industry. This table assumes that usage time is 1000 hours. According to this table, failure mode (1) and (3) are ranked with Occurrence (O) = 7, and failure mode (2) is ranked with Occurrence (O) = 9. Suppose that C_1 stands for gas pipe which is a component of heating system of air-conditioner. FMEA sheet of this component is made in this way as Table.2 shows. According to this table, failure mode (2) & (3)'s RPN are the high. Thus, company has to adopt proper countermeasures for failure mode (2) & (3) to reduce failures.

Table.1 Occurrence and Failure Rate

Occurrence (O)	State	Failure rate λ[%/1000h]
10	Very high: Failure is almost inevitable	> 50, (greater than 1 in 2)
9		33, (1 in 3)
8	High:Repeated failures	12.5, (1 in 8)
7		5, (1 in 20)
6	Moderate: Occasional Failures	1.25, (1 in 80)
5		0.25, (1 in 400)
4		0.05, (1 in 2000)
3	Low: Relatively few failures	0.00667, (1 in 15,000)
2		0.00067, (1 in 150,000)
1	Remote: Failure is unlikely	<= 0.00067, (1 in 1,500,000)

Table.2 FMEA Sheet on The Heating System

No.	Subsystem	Component	Failure mode	Potential cause	Possible effect				(S)	(O)	(D)	RPN
					Subsystem	System	Function	Human				
1	Heating subsystem	1.1 gas pipe	(1). blem	1) contact	insufficient function	nothing	nothing	nothing	1	7	5	35
				2) defective material								
			(2). leakage of gas from pipe	1) defective preservation	does not work	possibility of detriment	cannot achieve	possibility of detriment	9	9	4	325
				2) corrosion								
			(3). leakage of gas from joints	1) defective weld	ditto	possibility of detriment	cannot achieve	possibility of detriment	9	7	4	252
				2) corrosion								

(4) Calculating Improvement of Reliability

Suppose that after the company adopted appropriate countermeasures, the failure rates of failure mode (2) and (3) declined up to $\lambda_{(2)}$= 0.5 [% /1000 hour], $\lambda_{(3)}$= 4 [% / 1000 hour]. In that case, the component gas pipe and the heating system's reliability can be calculated in this way. The failure rate λ of component gas pipe is

$$\lambda = 10 + 0.5 + 4 = 0.0145 \quad [\%/\text{hour}]$$

So the reliability $R_{1(t)}$ of this component gas pipe is

$$R_{1(t)} = e^{-0.000145\times 1000} = 0.865$$

And then the reliability of the heating system will be

$$R_{(t)} = 0.865 \times 0.99 \times 0.98 \times 0.99 \times 0.96 \times 0.97 = 0.773$$

So the reliability of this heating system was improved from 49% to 77.3% when usage time is 1000 hours. Fig.3 shows the proposed method conceptual diagram.

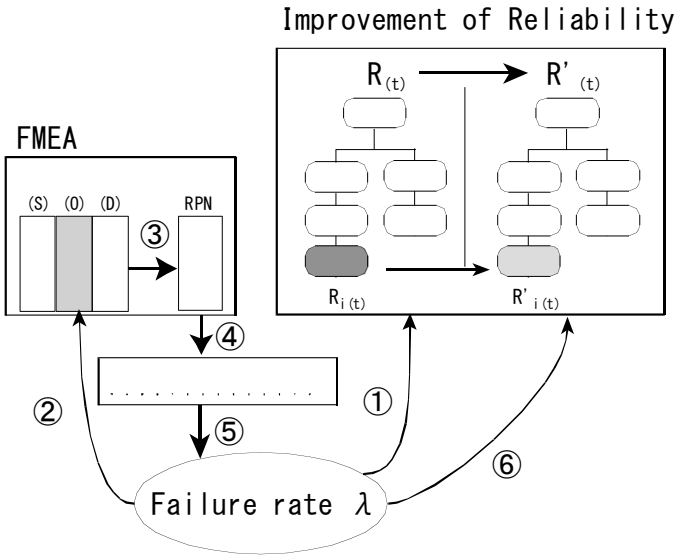

Fig.3 Proposed Methodology

Conclusion

Proposed methodology starts with estimating whole system's reliability by using failure rates of each component from data before executing FMEA. And after FMEA is done with using failure rate data as Occurrence (O), appropriate countermeasure is applied to the failure mode that is pointed out according to RPN as fatal effect's cause. To assess the influence of the countermeasure on the system reliability, whole system's reliability is calculated again and compared with the previous reliability.

According to this proposed methodology, the designer can figure out the improvement of whole system reliability after executing FMEA, which was indicated by decreasing of RPN.

5. Exchange Student Life

The Netherlands

Accommodation

My accommodation in Delft was located about 20 minutes on foot west of TU Delft. To settle down in this accommodation, I had to receive a key for my room from the dormitory-management company, DUWO. And payment for rent was 340 euro per month. The room had quite nice equipments such as own kitchen, shower, toilet, bed and chest. So it was relatively easier to start living abroad alone. But it was totally individual room and difficult to make friends through this accommodation.

Study

I took an English course and mechatronics design course. In English course, we had many nationality students such as Spanish, Polish, and Chinese. Our English teacher was quite nice man and helped us kindly. In mechatronics design course there were many students who asked the professor questions during the lesson. And professor also asked often students questions. I think this point is the biggest difference between Dutch and Japanese styles. Since my staying Delft was 2 months, I could not get any credits from these courses. But if you choose appropriate course, you can get it for 2 months.

Culture & Life

Dutch people: In the Netherlands, almost all people can speak English very fluently. Even in supermarket, staffs helped me kindly in English. People in Holland are open minded, kind, sociable to foreigners. I am sure that if you can speak some Dutch words, they will be very interested in you and in 10 minutes you will be friend of them.

Dutch student: Generally speaking students in European countries love to hold parties. And in Holland, of course students like to go to disco, to dance and to drink beers in weekends. But they are also so ambitious to finish their study they stay in corridor to study about lessons with their friends.

Germany

Accommodation

My dormitory was located far from the office. It took me 1 hour by bus to commute every morning and evening. And we shared kitchen with other students. So the payment was

cheap, it was only 200 euro per month. And I could get necessary things such as sheets with 10 more euros. This dormitory was so at home because every evening I could meet somebody at kitchen and could talk long time, sometimes all night. I made many friends here and they gave me a lot of precious wonderful memories.

University

The office was located 10 minutes by bus from main building of TU Berlin. People who works at this institute was so nice and have an inquiring mind and always gave me advice about research. The style of laboratory is very different from Japanese style. First they have own rooms for 2 or 3 working people, not large room like Japanese lab. And comparing with Japan they come to office earlier and go back home earlier. It is smarter way that they concentrate on their works during office hour.

Procedure

To enroll in TU Berlin and register as a foreigner resident in Berlin was so complicated that if I was alone I couldn't handle it at all. Because to find people who speak English in Berlin is difficult even though university students speak English very well. But fortunately I had a German "Buddy" who can speak Japanese fluently. He helped me not only in procedure but also in every aspect. To get visa was so difficult and the officer's attitude was so obnoxious because Berlin has so many foreigners that 90% of primary school students in Berlin are not German.

Culture & Life & Friends

As I had many friends in Berlin, I could spend very good time. They loved to hold parties in our dormitory so I was always there and had nice conversations and dances with them. And sometimes we went out to ice-skating link, museums and discos. These things are difficult without local friends. Although almost all my friends are not German, they can speak English and German very well. In Berlin it was not rare to find someone who speaks 3 languages. Or I should say "it's usual."

Sight Seeing

Thanks to cheap fees of airplane and bus, I went to Poland, Czech Republic, Belgium, Luxemburg, France, Spain, Italy, Austria, Slovakia, Hungary and Denmark during my staying in Europe. Comparing with Japan, European countries have old beautiful buildings even in capital cities. At the same time I re-realized that Tokyo is so big.

6. Summary

I stayed in Delft and Berlin for 2 months and 3 months. In Berlin I had accomplished my research theme: “DESIGN IMPROVEMENT BY FMEA AND ITS INFLUENCES ON INCREASING THE RELIABILITY OF MECHATRONIC SYSTEMS”. And in both nice countries, I had learned very important ideas and experiences which had changed part of my view of life through my new friends and cultures. Both Holland and Germany are so nice countries for Japanese student to live and study thanks to open minded people and culture. And at the same time, I re-found our culture and life in Japan are also wonderful.

Although I can’t speak Dutch and German, my fellows and friends kindly spoke to me in English and we could communicate each other. I re-realized the importance of studying foreign language and hoped the opportunity to speak English in Japan will increase. I also hope that foreign people in Japan can stay in our country comfortably and to that end I think we have to improve our English up to level that even supermarket’s staffs can explain in English.

This exchange program was very smoothly executed thanks to involved parties and I could spend great time in both countries. This experience gave me chances both of educational and personal aspects. I appreciate gratefully that I could be involved in this DeMaMech program as a participant.