

## 1. Personal Data

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## 2. Executive Summary

The first thing I was said from my teacher at K.U. Leuven was “think by yourself

and act by yourself". This was of course applied to my research activity, but was required all through my stay in Europe. Since I didn't have any friends in Belgium and this was my first time in Europe, I had to gather information all by myself. This means that if I didn't make any action to what I want to get, I would end up with nothing. It was very interesting to act in an environment where I couldn't use my mother tongue.

The research was operated in a team who had a similar topic for their researches. Since the topic of my research was new to me, I had to start from gathering information about the topic to understand what is done in the recent researches. I had to determine how to run my research by considering the remaining time and estimating what I could do from the research environment in that time. The most difficult thing was to understand and to adjust my research environment like reserving the experimental machines. It didn't work out first and I think I did waste some time. The problem was the lack of communication with the technicians in the workshop and the tight scheduling of my research which came from the unfamiliarity to the research environment there.

The life it self was very important during my stay in Europe too. The scenery and buildings were totally new to me and the culture in Europe was my first experience. I had very nice experiences by traveling a lot of places, by going to the party or pubs to drink Belgium beer, going out with my friends and etc. Since the time of my stay in Europe was limited, the most important thing I felt was to open myself and to challenge to various things to experience a lot efficiently.

### 3. Travel Schedule

2004/09/15 to 2005/01/02 Katholieke Universiteit Leuven, Belgium

2005/01/02 to 2005/01/31 Denmark Technical University, Denmark

### 4. Technical report

## Basic Study on Forming Cranial Implants

# by Incremental Sheet Forming

Yusuke Hosomi

## 1 Introduction

In recent years, the need for small lot production has arisen to satisfy the changing market demands. In case of sheet metal forming, the major current method is press working but it costs time and money to adopt in small lot production. To solve this problem, the forming method called incremental forming has been proposed to form sheet metal[1]. Incremental forming is a method to develop sheet metal into three-dimensional shapes, only by moving a tool relatively on the sheet metal. It doesn't need a die or specific tool during the production process and this characteristic enable to meet the market demands of small lot production from the view point of cost and time of the production process.

The demand of small lot production is not only from the industrial engineering, but also from medical engineering. There are demands of forming metal membranes for bone reconstructions. The metal membranes are custom made for each patient because the desired shape differs between the patients.

The aim of this study is to form the skull implant part by using existing technique of single point incremental forming, and to improve the accuracy of skull implant part by modifying its tool path. Several tests have been made to verify the usefulness of the tool path modifications.

## 2 CAD Model Design

The geometrical data of the skull part is shown in figure 1. In this study, two CAD models were created to create tool path in incremental forming. One is created by covering the outer shape of the model since the skull part is convex shape, and other is by NURBS surface from the point cloud. These two models are shown in figure 2. Table 1 shows the geometrical accuracy of the two CAD models compared to the original STL data. From table 1, CAD model using the wrap command was chosen

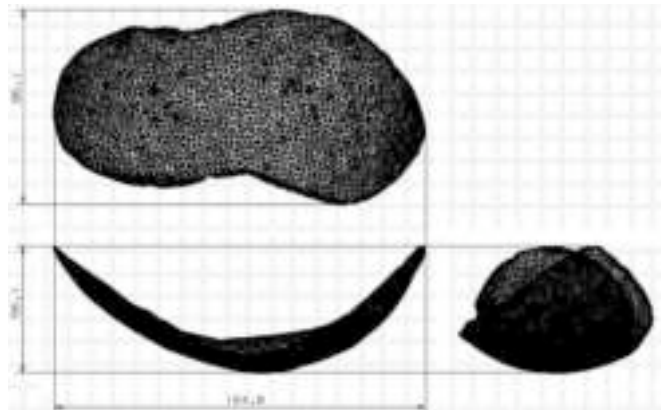
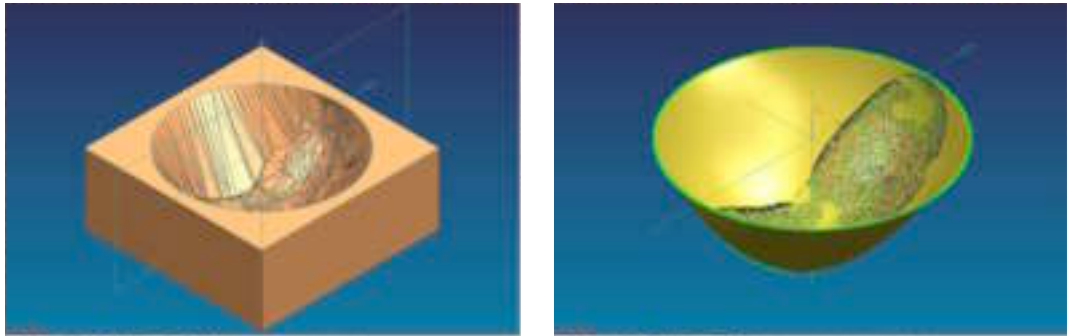


Figure 1. geometrical data of the skull part

to create the tool path.



(a) wrapping

(b) NURBS surface from point cloud

Figure 2. created CAD models

Table 1. Geometrical error of the two CAD models

	average [mm]	maximum [mm]
Wrap	0.091	0.38
NURBS	0.42	2.02

### 3 Tool Path Design

From the created CAD model, tool path was created. The 2D contour tool path was used. The spiral tool path was not used for the first tool path because it was difficult to control the vertical pitch of the tool path in this complicated model. In this study, 4 types of tool paths were tested to compare the geometrical accuracy.

- Type 1

Normal 2D contour tool path was created. This tool path is used to check the usefulness of other tool paths.

- Type 2

After the 2D contour tool path, spiral tool path was adopted. In type 2, the spiral tool path was created from the outer boundary to the center of the model.

- Type 3

After the 2D contour tool path, spiral tool path was adopted. In type 3, the spiral tool path was created from the center to the outer boundary of the model.

- Type 4

2D contour tool path was created according to the measured data formed by type 1 tool path. The correction algorithm is shown in figure 3. After the skull part was created by the 2D contour tool path, the shape was measured and “deviation vectors” pointing from a set of points

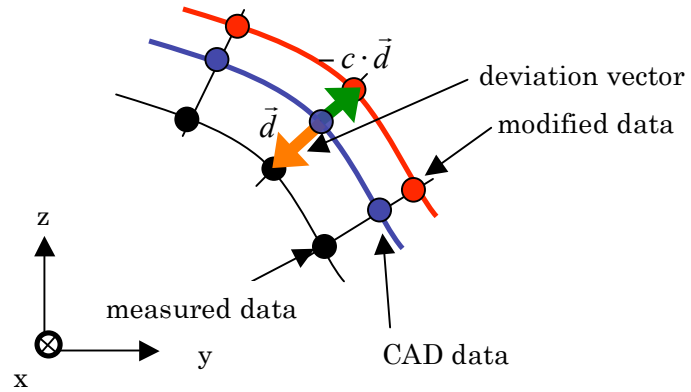


Figure 3. Correction algorithm

on the CAD data to the corresponding points on the actual geometry are determined. These vectors are inverted and scaled by a correction factor  $c$ , yielding a new trial tool path to produce a further part. In this study, the value of 0.7 was used for the correction factor  $c$  which was determined by the earlier studies[2].

#### 4 Results

The measured error considering only the skull part is shown in table 2 and the error map of the whole sheet is shown in figure 5. The positive and the negative error are defined in figure 4. The distance perpendicular to the measured data to the CAD data is defined as error. Especially when the CAD data is higher in  $z$  direction than the measured data, it is

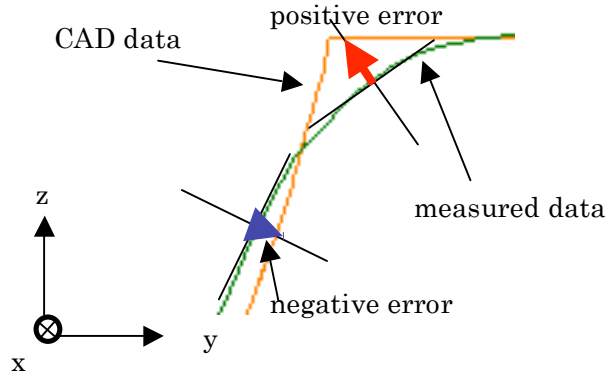


Figure 4. Definition of positive and negative error

defined as positive error, and negative error is defined when CAD data is lower than measured data in  $z$  direction. This is important for the error map shown in figure 5.

From the figure 5 and table 2, the most useful tool path considering only the skull part is the type 3 tool path. When considering the whole shape, type 4 tool path has the best result.

Table 2. Comparison of the geometrical error in the skull part

test type	average [mm]	minimum [mm]	maximum [mm]	range [mm]	RMS [mm]
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type 1	-0.288	-1.393	0.379	1.773	0.199
type 2	0.811	0.143	1.418	1.275	0.277
type 3	0.344	-0.293	0.909	1.202	0.138
type 4	0.407	-0.523	0.906	1.429	0.171

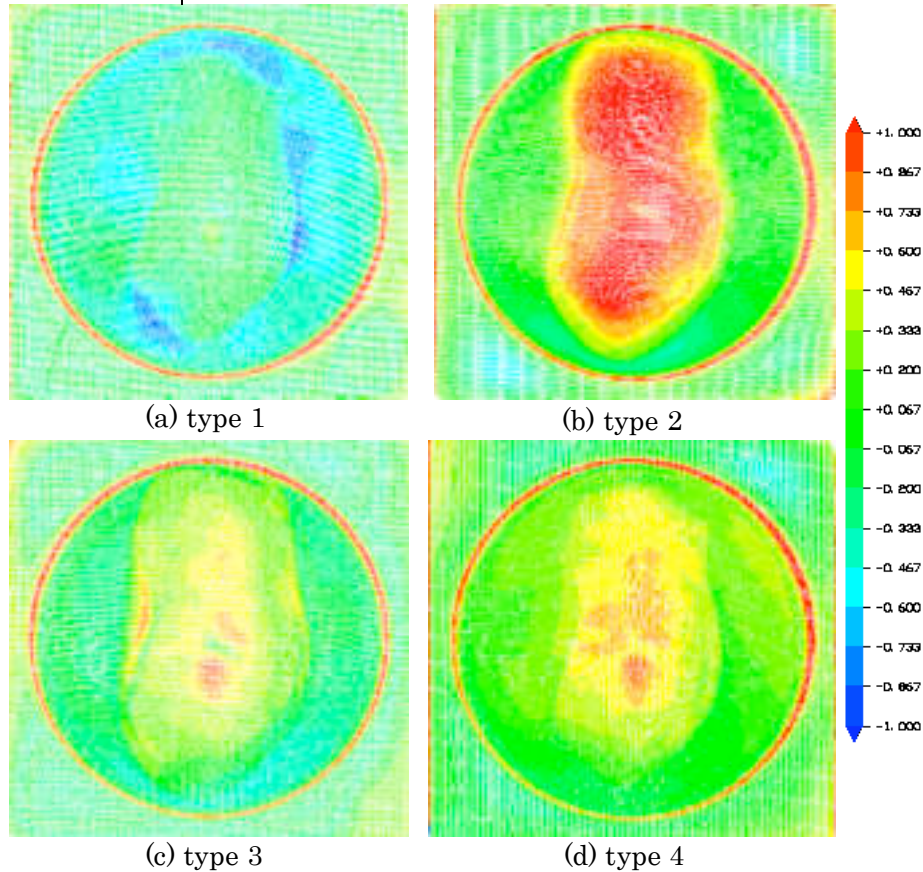


Figure 5. Results of the tool path modification

## 5 Conclusion

The main results achieved in this paper are summarized as follows:

1. The design method of creating a CAD model which includes the skull implant data was investigated in case of single point incremental forming.
2. Basic tests were carried out and the skull implant part was created by single point incremental forming.
3. Methods to improve the geometrical accuracy of the skull part was investigated and verified through tests.

## 6 Reference

1. Matsubara, S., A computer numerically controlled dieless incremental forming of a sheet metal, Proc. Instn. Mech. Engrs., Vol. 215, Part B, 2001, 959-966.
2. Pattijn, V., Samson, I., Sloten, J., Van Audekercke, R., Swaelens, B., De Buck, V.,

Medical image based, preformed titanium membranes for bone reconstructions: design study and first clinical evaluation, Proc. Instn. Mech. Engrs., Vol. 216, Part H, 2002, 13-21.

## 5. Exchange Student Life

This was my first time I went to Europe. The first city I stayed was Leuven, Belgium. The first thing I noticed was the good driving manners of the drivers. When I intended to walk across the street, the cars and even the trucks stopped to let me cross the street. The reason may be that Leuven is a small city and people are not so busy and crowded, compared to the big cities. Leuven is indeed not a big city but has everything inside. You can find almost everything you want in the main shopping streets. And since Leuven is a city where Katholieke Universiteit Leuven is located, the city has a lot of young people. There are a lot of bars where you can find very nice Belgium beer.

The first week was the orientation week. There were lots of events for the new students and international students such as party, day trip to the other cities and etc. The events of this week provided me a lot of chance to make new friends.

After the orientation week, my research started. It was a very new topic for me and I started from gathering the information about the topic. The most important thing was the scheduling of the research. I had to determine how to run my research by considering the remaining time and estimating the progress of my research. The largest problem was to adjust my research environment such as booking the experiment machines and materials I needed. It didn't work out first and I think I did waste some time. The problem was lack of communication between the technicians of the workshop and my tight scheduling of my research which I made myself. After the reason was clear, it was quite easy to solve but it needed some time to get use to the environment.

The time for the research was only about 3 months. Since the deadline of the submission of the report was fixed, I had to get some results through experiments and write the report during this period of time. It was very hard for me to start from learning a new topic to write a report in this time of period, but it was really good time for me.

In the weekends, the laboratory was closed. So I had some time to go out for a trip to look around some cities in Belgium and Europe. Since Leuven is located in the center of Belgium, and Belgium itself is not such a big country, it was easy to visit some cities in Belgium by train. And also Belgium is located in the center of the

west Europe, the big cities such as Paris, London, and Amsterdam was near by. I went to these cities by bus and train. The countries in Europe lays next to each other and this could not be imagined in the island country like Japan. Since this was my first time in Europe, I was curious about the difference between the countries in Europe. Even the boarder of the countries contacts one another, the type of people, language, food, customs, cultures, and types of buildings differ from north to south and east to west. It was very nice for me to have a chance to see these differences.

The second county I went was Denmark and stayed at Denmark Technical University at Copenhagen. The day length was only about 8 hours and this was my first experience. I took a 3 week concentrated course of simulation using FEM in casting and forging. Even though I had never done these productive processes, it enabled me to understand the principle and the flow of the process. FEM does consume time to acquire results, but from the term of its accuracy, I believe it is useful. My undergraduate research was about proposing a method of simulation in milling process and the main aim was to minimize the calculation time. So it was set up against the FEM analysis. Since I haven't actually studied the FEM deeply before, this was a good chance for me to study FEM and experience the advantage and the weak point of the FEM.

As mentioned above, my life during the exchange program consisted of mainly two factors such as research and student life. My time was meaningful since both of them were very new and precious experience to me.

There are two things I felt during this program. The most important thing to success my research in this short time of period, is to understand and be able to use the environment around me as fast as possible. And the most important thing for my life is that I should not hesitate to try new things and just do it. I believe this is most important to experience and feel a new environment.

## 6. Suggestions to the Project

I will mention about few things I noticed during my stay. I know this project has just started, but there are some points which should be modified.

- The information about the project was not announced equally to all the Universities. After I met some Japanese who belong to this program, we noticed that there was some gap in the information. This should be corrected before the announcement of this program next year.



- The accommodation was very difficult to find. In case of K.U. Leuven, Belgium, the minimum period of rent in most of the accommodation was 6 months. So the accommodation office could not be able to help me. I stayed in a hotel for few days to find the accommodation myself.
- It is quite difficult to make a research and get some results in such a short time like 3 months. The schedule is quite tight. So I think it is nice to have an option to stay in one country to make a research during their whole stay, or to stay in two countries to experience several environments.

## 7. Summary

I joined the short term program. It was actually not a long time to do the research. Even the long term program, it only allows 5 months for the research in one university. So I think this program is not so good for a participant who wants to focus only on the research. But since there is a chance to see two universities in two countries, there is a chance to see and experience the education system based on their culture. Since this was my first time in Europe, everything was new to me and exiting. From the viewpoint of experience new things, joining this project was meaningful to me since I believe I could not have experienced such a lot of things if I stayed in my home university during the same period of time. And since the period of time of my master course is limited, my aim is to grab the chances which are open for the master course students to experience many things as possible. When I first heard about this program, I felt it will match my aim and it actually did. I believe this program will satisfy the demand of students who wants to experience various of things during their master course. Since Japanese is an island country, it will be a good chance to compare the Japanese culture and education system and Japan itself to European countries.