

Application of Reverse Engineering Technique to Designing Manufacturing Process of Open Clamp Type Bone Fastening Device

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ABSTRACT

The aim of this research is to develop a manufacturing process for an open clamp bone fastening device, using reverse engineering techniques, suitable for the standard of tools and machines available in Chiang Mai and Lamphun Provinces. An open clamp is an external bone fastening device which is used to treat broken bones. Presently, the Orthopedic Surgery Department at Maharaj Nakorn Chiang Mai Hospital uses a large number of these items; however, they are expensive as they have to be imported, leading to the need for research to be carried which aims to design an open clamp manufacturing process, using reverse engineering techniques, so as to create an item that has a size and quality similar to those being used at present, and suitable for and consistent with the tools and machines used in Chiang Mai and Lamphun Provinces.

Keywords: Reverse Engineering, Design Manufacturing Process, Open Clamp, Bone Fastening, Device External

INTRODUCTION

Reverse Engineering for Thai Medicine: At present, most imported medical supplies are very expensive in Thailand, and so, given that domestic technologies have continued to advance, a reverse engineering technique has been employed to examine technologies from abroad, so as to adapt them for domestic use and thus remove or lower the costs of having to import machines and equipment. This has already been achieved in other applications, such as the development of a Freeze Dryer, which is used to produce vaccines and serums through a freeze-drying process in order to effectively maintain the quality of products (Thailand Institute of Scientific and Technological Research and National Blood

Center, Thai Red Cross Society. 2009). Another example is the development of a continuous passive motion (CPM) device for the knee, which is nearly 50% cheaper than the imported version. The CPM device is used to gently flex and extend the knee joint after knee surgery, thus facilitating a quick recovery of the knee joint, lowering recuperation times and reducing the need for physical therapy (Thailand Institute of Scientific and Technological Research. 2009). According to previous research on the modeling of a prototype car, reverse engineering techniques are suitable for the production of complex work pieces with high levels of convexity and concavity, and for replicating work pieces to be used for further examination and development. For less complex work pieces with definite values however, the application of computer-aided design is more effective, as it helps to save time (Naradet, K. 2003, Nimityon, S. 2001).

When carrying out a literature review of such techniques, the researchers had an interest in studying the open clamp bone fastening device manufacturing process, in order to use the results to help develop a production process for use by manufacturers in Chiang Mai and Lamphun Provinces, based on reverse engineering techniques, which will lower future import costs. The open clamp bone fastening device used as a prototype in this research consists of eight parts, as shown in Figure 1. The design study was carried out for only six parts of the eight, as the other two, springs, are standard components.



Figure 1. Shape and Component Parts of an Open Clamp Bone Fastening Device.

METHODOLOGY

Study and Data Collection: A study and data collection exercise on the use of medical instruments and equipment was conducted at the Department of Orthopedic Surgery, Faculty of Medicine, Maharaj Nakorn Chiang Mai Hospital, in order to examine the details of the open clamp bone fastening device, based on original work pieces. The results showed that the material used to produce the screws is 316L stainless steel, a material commonly used and widely accepted

in the medical field. For this research, data was obtained from the actual work pieces, which was then used in the design of a prototype, since the item normally has to be imported - providing few details or specific physical information.

Size and Dimensions - Measurements and Characteristics: The device was dismantled in order to measure the size of each part, with each position on the part marked by a symbol. Measurements were taken using basic mechanical measuring instruments, comprising a vernier caliper, a micrometer, a depth gage, a bevel protractor and a screw pitch gauge. The size data was then employed to create a work piece model, using a computer-aided design (CAD) program, which was later transformed into CAD data in order to be used in the production process and to compare sample work pieces. The sample designs, in CAD data format, are shown in Figure 2.

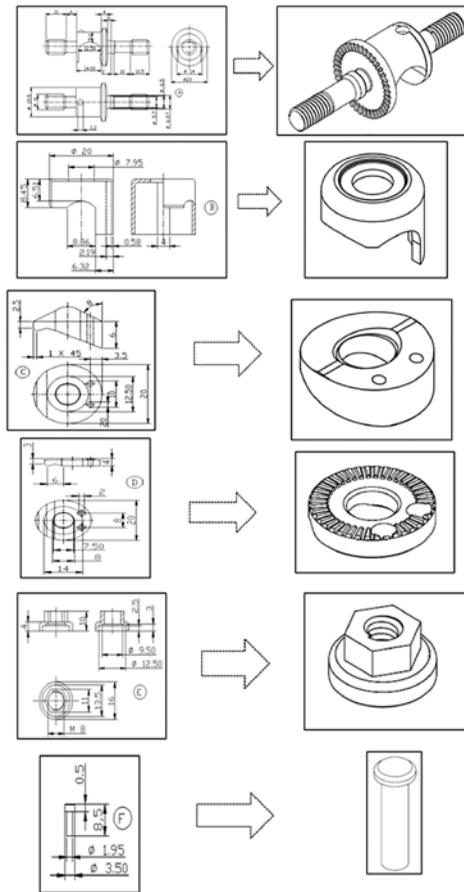


Figure 2. Prototype Measurement Positions in 3D Format.

Selection of a Work Piece Production Process: The study and selection of an open clamp bone fastening device production process was based on the properties of the materials used and the production processes available.

Type and Properties of Material Used: The material used in this study was

316L austenitic stainless steel, the same type for the prototype, a material which has a low carbon contents and non-magnetic properties. This material can thus be used in corrosive environments.

Selection of a Production Process: Prior to carrying out an experimental production process for each part, a production process for all six parts was jointly determined by production experts, on the basis of the steps used for designing each part, and with an emphasis on the use of basic machines to save time and cost.

Sample Production Experiment: The study into the production and design process for the six parts found that each part requires different production process steps. As a result, the design process had to be conducted separately for each part, based on the design specifications obtained from the size and dimension measurements and characteristics, as shown in Figure 3.

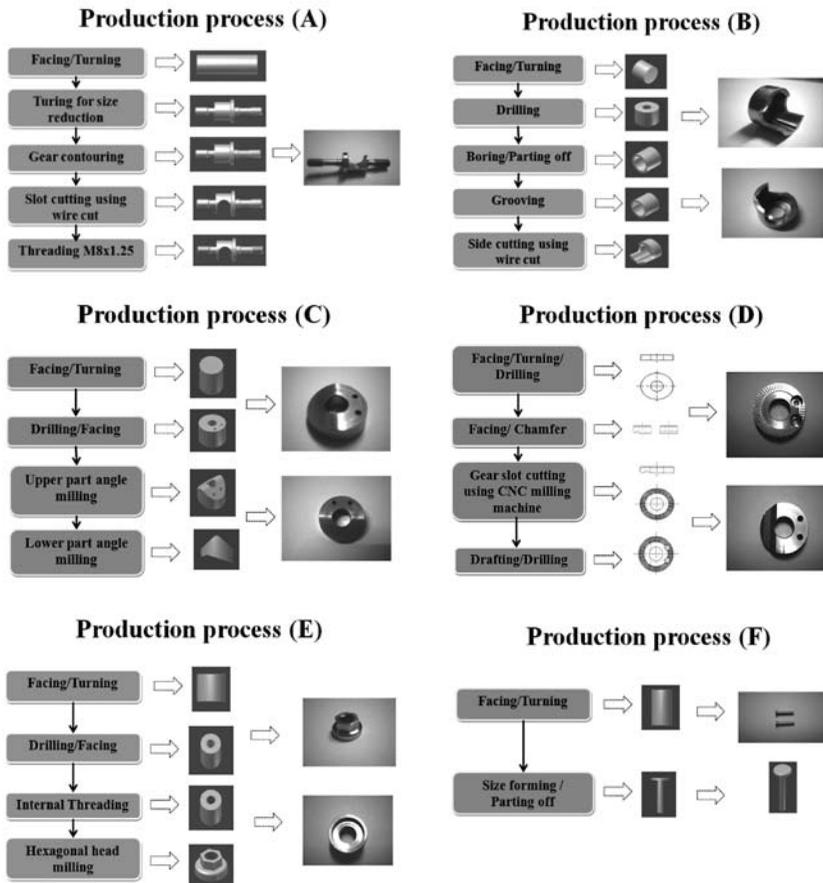


Figure 3. The Design and Production Process for each Part.

After the separate production of all six parts, they were then assembled into one work piece, as shown in Figure 4.



Figure 4. Characteristics of the Assembled Work Pieces.

Sample Inspection/Assessment: An evaluation of the four assembled work pieces obtained from the experimental production processes, each of which comprised six parts similar to those of the prototype, these being A, B, C, D, E and F, was carried out using the following steps:

1. Comparison of the prototypes' average size at each position
2. Test of the hardness of the prototypes and processed work pieces
3. Assessment of the processed work pieces conducted by experts in materials and mechanical tools, and by users (doctors).

Economic Cost Assessment: An assessment of the production cost per unit was carried out, as compared to the cost of importing the items.

Survey of the Competency of Manufacturers in Chiang Mai and Lamphun Provinces: A survey of manufacturer competency was carried out based on the availability of materials, the equipment and machines, and their production capability.

RESULTS

Size and Dimension Measurements and Characteristics: The results of the measurements - the averages of the six parts for each prototype, were employed to create new work pieces using a CAD program. The data was then transformed into CAD data in order to be used in the work piece production process.

Selection of a Sample Production Process: The results suggest that the most suitable process is a combination of two production processes, one using a manually operated machine (semi-automated) and one using a fully automated process; whereby the fully automated machine is used to form those parts of high levels of detail and complexity, those which cannot be produced by a manually operated machine.

Experiment with a Sample Production Process: By employing the selected production process, the results showed that a production process had been developed which allowed for all six parts to be assembled into a work piece.

Sample Inspection/Assessment: The samples obtained from the experimental production process were compared with the average sizes of the prototypes at each position, shown in Table 1.

Table 1. Comparison between Sizes of the Prototype and the Processed Work Pieces.

| Code | Position | Error (compared with the sizes of the prototype) | | Percentage error (%) |
|------|----------|--|--------------------|----------------------|
| | | Higher (millimeter) | Lower (millimeter) | |
| A | A02 | - | 0.25 | 4.16 |
| B | B08 | - | 0.03 | 5.17 |
| C | C06 | 0.15 | - | 1.50 |
| D | D01 | 0.09 | - | 3.00 |
| E | E09 | 0.08 | - | 0.5 |
| F | F03 | 0.02 | - | 1.1 |

From the tables it can be seen the maximum percentage error of the processed work pieces at each position, when compared with the actual error, was low and within acceptable levels.

A comparison of hardness between the prototype and the work pieces found that the maximum percentage error was 0.38%, meaning the hardness of the work pieces was 0.3 HRB lower than that of the prototype, and had an average value similar to that of 316L Austenitic stainless steel, which is equal to 79 HRB. As a result, the work piece production process did not have an adverse impact on hardness when compared with that of the prototype.

An evaluation of the assembled work piece, a joint assessment conducted by experts in materials and production, plus doctors from the Orthopedics Department, showed that the level of satisfaction with the size and shape, strength during use, compatibility with other instruments and practicality, was high, while the level of satisfaction with the item's physical appearance and burrs on some positions of the work piece was at a moderate level.

Economic Cost Assessment: The results of an assessment using a production cost per unit analysis showed that the open clamp bone fastening device production process incurred a cost per unit lower than the cost of importing the items.

Competency Survey of Manufacturers in Chiang Mai and Lamphun Provinces: The results of a competency survey of manufacturers in Chiang Mai and Lamphun Provinces, in terms of their readiness to use the materials, their equipment and machines, and their production capability, are shown in Table 2.

Table 2. Results of the Manufacturer Competency Survey in Chiang Mai and Lamphun Provinces.

| No. | Code | Production capability of manufacturers (15 manufacturers in each area) | | | | | | Total percentage of production capability (%) |
|------------------|------|---|-----------|----------------|---------------|-----------|----------------|---|
| | | Chiang Mai (No.) | | Capable (%) | Lamphun (No.) | | Capable (%) | |
| | | Capable | Incapable | | Capable | Incapable | | |
| 1 | A | 11 | 4 | 73.3 | 13 | 2 | 86.6 | 79.95 |
| 2 | B | 11 | 4 | 73.3 | 13 | 2 | 86.6 | 79.95 |
| 3 | C | 15 | 0 | 100 | 15 | 0 | 100 | 100 |
| 4 | D | 12 | 3 | 80 | 13 | 2 | 86.6 | 83.3 |
| 5 | E | 15 | 0 | 100 | 15 | 0 | 100 | 100 |
| 6 | F | 15 | 0 | 100 | 15 | 0 | 100 | 100 |
| Total percentage | | | | 78.76 | | | 93.3 | 90.53 |

From Table 2, the average competency of the manufacturers in Chiang Mai is 87.76%, whereas the competency of those in Lamphun is 93.3%. The total average competency for the two areas is 90.53%.

DISSCUSION

This research on the production of open clamp bone fastening devices, those used with patients, still requires input from experts and doctors, so as to improve the production process and to come into line with user requirements. In addition, this research did not carry out any experiments using the items with patients, as it only focused on the design of the production process. Therefore, any further studies on other medical instruments and equipment should include an experiment on their actual use.

CONCLUSION

The open clamp bone fastening device production process employed two different processes based on the type of machine used, one being a manually operated machine and the other a fully automated machine.

The results of the study show that the selected production process can produce work pieces similar to the prototypes in terms of size and shape, and incurs a cost per unit approximately 3.9 to 26.1% lower than when importing the items. In addition, the level of satisfaction among doctors and experts with the work pieces is at a high level. In terms of the competency of manufacturers in Chiang Mai and Lamphun provinces, this was high on average, at 90.53%. When comparing the competency of manufacturers in both areas, those in Lamphun have the advantage of having more expertise in the use of the machines, thus can produce higher quality products, while those in Chiang Mai have the advantage of having a greater variety of and more modern machines

and equipment.

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REFERENCES

- Naradet, K.2003. An Application of Reverse Engineering for modeling of a prototyped car, Mechanical Engineering department, Faculty of Engineering, Kasetsart University.
- Nimityon, S. 2001. An Overall Picture of Reverse Engineering: A Workshop on Metal Product Reverse Engineering for New Product and Substitute Component Creation. National Metal and Materials Technology Center.
- Thailand Institute of Scientific and Technological Research and National Blood Center, Thai Red Cross Society. 2009. A Development of a Freeze Dryer for Vaccine and Serum Production.
- Thailand Institute of Scientific and Technological Research. 2009. A Development of Knee CPM Machine for Physical Therapy.