REDUCTION OF DEFECTS IN JEWELRY MANUFACTURING

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Abstract. The aim of this research was to reduce the defects of gem bracelet found during manufacturing process at a jewelry company. It was found that gem bracelet product has the highest rejects compared to the rejects found in ring, earring, and pendant products. Types of defect were classified by using Pareto Diagram consisting of gem falling, seam, unclean casting, impingé, and deformation. The causes of defect were analyzed by Cause and Effect Diagram and applied Failure Mode and Effects Analysis (FMEA) was applied during manufacturing processes. This research found that the improvement of manufacturing process could reduce the Risk Priority Number (RPN) and total of all defects by 48.70% and 48.89%, respectively.

1. Introduction
Currently, Thailand jewelry export is top 15 countries creating a great economic value to the country. Consumers in the ASEAN countries are interested in jewelry products. This results in overall jewelry business become active and jewelry export of Thailand is leap forward. Therefore, it is a great opportunity of Thailand to expand its jewelry export and supports the revenue of its population and tourism business. The study of Kasikorn Research Center found that export forecast in the year 2016 is expected to increase by 4% from the year 2015 with a total export value of approximately 286,000 million Baht and once AEC (Asean Economic Community) is opened, the competition will increase. It is necessary to improve the performance to get high quality products according to customer specifications of which will lower the cost and the defective products and subsequently result in high revenue.

The Failure Mode Analysis and Effect (FMEA) technique is a step by step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service [1]. The FMEA is a technique used to identify the associated something potentially going wrong such as creating a defect or out of specification in the production of the product. The FMEA identifies controls that are placed in the production process to detect any defect at various stages on the processing [2].

A case study of a jewelry company which manufacture various kinds of jewelry was carried out. The gem bracelet product was focused in this study since the highest number of defects (3.05% or 30,547 PPM) were found when comparing to other products. Therefore, the research aims to study the reduction of defective parts in gem bracelet because management level give the priority to reduction of defective parts in gem bracelet and has get a goal to reduce the defects to halve or as much as possible.

This research has focused on the revision of manufacturing process of bracelets, especially those inlaid with gemstone around the work piece. The principles of FMEA was used for the reason that this technique is useful to identify and eliminate failures and mistakes during design and manufacturing processes. It can select defects that should be fixed first and it is a technique widely used in the automobile industry. It is also can be applied to many other industries. The researcher therefore sees the possibility of applying FMEA techniques along with
studying and analyzing the real root cause of the problems in order to approach the solution permanently and to prevent the problem repeatedly occur; and to serve as a benchmark in terms of production and quality control in the jewelry industry in order to minimize the defects.

2. Methods and Result

2.1 Defining phase

The historical manufacturing data of gem bracelets from January 2015 to October 2015 was collected in order to determine types of defect by using Pareto chart. Five defect types account for 80 percent of all defects were then taken into consideration to find the cause. A Pareto chart is a bar graph. The lengths of the bars represent frequency or cost (time or money), and are arranged with longest bars on the left and shortest to the right. In this way, the chart visually depicts which situations are more significant [3].

Five defect types account for 80 percent of all defects were determined as follows gem falling off 25.32%, seam 18.68%, unclean casting 12.09%, impinge 11.47% and deformation 10.63% as shown in Fig. 1.

Figure 1. Pareto chart of defect (Source: Production data of bracelet from January 2015–October 2015)

2.2 Root-cause analysis

The Cause and Effect Diagram (Fishbone Diagram) developed by Ishikawa in 1968, help users to think through problem causes [4]. For that particular reason it is also termed as “Cause-Effect analysis”. In a typical fishbone diagram the main problem which is required to be resolved has been put on the head of the diagram and the causes are put as the bones and then smaller bones are created as the resemblances of the sub-causes. Ultimately after completion of the diagram it is a comprehensive evaluation of the causes of the main problems and also reveals the root causes as well [5].

The case study was brainstormed by expert team who are specialists in jewelry production process. The Cause and Effect Diagram or fishbone diagram was applied to this process to find the root causes of the problems.

Ten root causes of defect were determined by the Cause and Effect Diagram as shown in Table 1.

| Table 1. Root causes of defects |
|---------------------------------|
| Defect type         | Root cause                                                                 |
| Gem falling off     | 1. Water pressure used to clean the product is too high.                     |
|                    | 2. Operators make a wax-setting to repeat bezel                              |
| Seam               | 1. There is no equipment to help operators while pressing the rubber mold during wax injection |
|                    | 2. Incomplete rubber mold                                                    |
| Unclean Casting    | 1. Water pressure used to clean the casting tree is too low.                 |
| Impinge            | 1. Improper equipment to place the products                                  |
3. Analysis of defect by FMEA technique

From Table 1, it was found that the causes of problem occurred only during wax process comprising of wax injection, wax cleaning, wax setting, treeing and casting process, investment, burn out, casting, cleaning, black oxidation, cutting treeing processes. These are very important in the manufacture of jewelry. If defects can be reduced during these processes, a great number of defects will decrease also wax injection and casting process as shown is Fig. 2. This research therefore aims to study those 2 processes only.

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FMEA method is used all over industry for a sort of applications and this flexible method can be executed at diverse steps in the product life cycle. FMEA method can be used to carry design, development, manufacturing, service and other activities to get better reliability and enlarge efficiency. As an example, there is extensive use of both design and process FMEAs inside the automotive industry and documentation of this investigation is a general requisite for automotive suppliers. This technique is also generally used in the aerospace, medical, Nuclear and other manufacturing industries [6]. The FMEA table was applied to the jewelry
industry by adjusting severity (S), occurrence (O) and detection (D) Score is determined during the meeting between Production Department, Quality Assurance, Maintenance Department and workers to determine the criteria of scoring according to the level of effects as shown in Table 2. The score of each effect was recorded in the FMEA as shown in Table 3.

**Table 2.** Scores of severity Level (S), occurrence (O), detection (D) in jewelry manufacturing process

| Effect  | Severity Level (S) | Possible failure rate (O) | Detection failure (D) | Score |
|---------|--------------------|---------------------------|-----------------------|-------|
| Serious | Tendency of the defect severely impacts the quality of the product resulting in demolishing all the product | 1 in 20 | Uncontrolled process | 5 |
| Major   | Tendency of the defect severely impacts the quality of the products. Correction some of the products out of the production line may be required before acceptance. | 1 in 100 | Not easy detection (i.e. random) | 4 |
| Moderate| Tendency of the defect severely impacts the quality of the products. Correction all the products at the point of operation may be required before acceptance. | 1 in 1,000 | Detection after process by operator | 3 |
| Low     | Little problems occur to some manufacturing process at the point of operation | 1 in 10,000 | Detection after process auto | 2 |
| Minor   | No impact felt | <1 in 100,000 | Detection in process | 1 |

The risk priority number (RPN) can be calculated according to the equation below.

$$RPN = S \cdot O \cdot D$$

(1)

**Table 3.** FMEA table before and after improvement

| No. | Defect                                | Root cause                                                   | S | O | D | RPN Before | Action                                      | S | O | D | RPN After |
|-----|---------------------------------------|--------------------------------------------------------------|---|---|---|-------------|----------------------------------------------|---|---|---|-----------|
| 1   | Incomplete of rubber mold             | Failure to check the rubber mold before the trial wax-injection | 5 | 5 | 5 | 125         | Rubber mold inspection line was established | 5 | 3 | 3 | 45        |
| 2   | Improper Equipment to place the products | Use of plastic bags to transport the items to the next process will cause impinge | 4 | 5 | 5 | 100         | A new tray to place the product was designed | 4 | 3 | 3 | 36        |
| 3   | No equipment to help operators while pressing rubber mold during wax injection | Operators use his/her hands to press the rubber mold causing the stiffness | 4 | 5 | 5 | 100         | Equipment to hold rubber mold was designed | 4 | 3 | 5 | 60        |
| 4   | Operators repeat the setting          | Bezel and pave are deformed due to operators repeat the setting without fixing it first | 4 | 5 | 5 | 100         | Q-Point and pictures of defect were posted at the point of operation | 4 | 3 | 3 | 36        |
| 5   | operators stage products              | operators stage the products in basket                      | 4 | 5 | 4 | 80          | Design new basket to place the casing tree | 4 | 3 | 4 | 48        |
| 6   | Operator remove wax from the rubber mold too soon | There is no schedule to remove the wax from rubber mold in the work instruction | 5 | 5 | 3 | 75          | Details of schedule to remove wax from the rubber mold in work | 5 | 5 | 3 | 45        |
4. Conclusion
This research analyzes the manufacturing process of bracelets, pendants, earrings, and rings. The study found that there were 5 categories of defect of gem bracelets. Root causes of the problem were analyzed by the application of Pareto Charts, Cause and Effect Diagram, and Failure Mode and Effect Analysis (FMEA) together with the experts of the plant in order to find improvements and solutions. The study found 10 root causes of which has been improved by 1. Amendment of machines 2. Improvement of methodology 3. Staff training. After the correction and improvement it was found that RPN was decrease by 48.70% and resulting in a total number of defects decrease by 48.89%. This research can be used as a guide to improve processes, and to reduce defects during in manufacturing of jewelry and can be applied to other product of jewelry industry.

5. Reference
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