

Improving Quality of Shoe Soles Product using Six Sigma

Athalia Jesslyn Wijaya, Wildan Trusaji*, Muhammad Akbar, Anas Ma'ruf and Dradjad Irianto

Faculty of Industrial Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia

E-mail: wildan@mail.ti.itb.ac.id

Abstract. A manufacture in Bandung produce kind of rubber-based product i.e. trim, rice rollers, shoe soles, etc. After penetrating the shoe soles market, the manufacture has met customer with tight quality control. Based on the past data, defect level of this product was 18.08% that caused the manufacture's loss of time and money. Quality improvement effort was done using six sigma method that included phases of define, measure, analyse, improve, and control (DMAIC). In the design phase, the object's problem and definition were defined. Delphi method was also used in this phase to identify critical factors. In the measure phase, the existing process stability and sigma quality level were measured. Fishbone diagram and failure mode and effect analysis (FMEA) were used in the next phase to analyse the root cause and determine the priority issues. Improve phase was done by designing alternative improvement strategy using 5W1H method. Some improvement efforts were identified, i.e. (i) modifying design of the hanging rack, (ii) create pantone colour book and check sheet, (iii) provide pedestrian line at compound department, (iv) buying stop watch, and (v) modifying shoe soles dies. Some control strategies for continuous improvement were proposed such as SOP or reward and punishment system.

Keywords: Six Sigma, DMAIC, Delphi Method, FMEA, 5W1H

1. Introduction

A make-to-order (MTO) manufacture produces some based-rubber products i.e. trim, rice rollers, shoe soles, etc. The manufacture has been rapidly growth since 1995 characterized by an increasing number of production, labours, and product types. The manufacture has a vision to be the number one in Indonesia's market shares. One of its strength is that it has entered the Original Equipment Manufacturing (OEM) market. In 2015, this manufacture created a contract of shoe soles product with a loyal customer who implements tight quality control. Based on secondary data, defect level of this product was 18.08% that needed to be reworked. The rework process caused the manufacture experiencing loss in time of 18.3 days of work and money about 49 million rupiahs.

To reduce the number of rework, the manufacture implement various quality improvement efforts for example recruiting new personnel who expert in quality to perform hardness test, quality analysis, etc. Moreover, this proposed research is also an effort to improve the shoe soles products in the manufacture by implementing six sigma methodology to improve the product quality continuously. This method was chosen because the root cause of higher reject rate was higher variability of product. Therefore, six sigma method which can reduce process variance is suited implementing in this kind of quality problem.



Although six sigma is possible to be implemented in high variance process, but the key factor of this method is the involvement of all stakeholder related to the project [1]. Six sigma methodology implements DMAIC (define, measure, analyse, improve, and control) cycle that is often used for continuous improvement strategy [2].

Six sigma methodology has been successfully implemented in many world class manufacture in the world such as Samsung, Kodak, General Electric, IBM, DEC, Sony, Texas Instrument, Nokia, Philips Electronic, and LG [3]. Six sigma methodology can be also implemented in industry with low level production or service sector. We also found a research which implement sig sigma to improve quality of seal leak test product in a manufacture [5].

2. Methodology

We follow DMAIC cycle to generate quality improvement on shoe soles product. Many tools are possible to be implemented in each phase of six sigma. SIPOC (supplier-input-process-output-customer) diagram, CTQ (critical to quality) matrix, or stakeholder analysis are some tools that can be used in defining of quality project. While statistics quality control such as descriptive or process capability is rapidly used in measure phase of six sigma. There are many usable tools in analyse phase such as cause and effect diagram, FMEA, value stream map, ANOVA, design of experiment, etc. Then, creative technique, 5S, or theory of constraint (TOC) are feasible implemented in improve phase. Finally, in control phase, project documentation or control chart are important tools [4].

In the define phase, our target is to get the quality project aiming to reduce the number of specific reject condition. We interview an expert from the manufacture and get secondary data to identify the product reject history. After discussing, we choose a critical product as an object of this research and characterize its specification e.g. size and colour. SIPOC and flowchart diagrams are used for understanding the production process of the product chosen. In addition, we classify the product reject condition and focus on some critical rejects that contribute to at least 80% of the reject number using Pareto diagram. Finally, we collect critical to quality (CTQ) information by implementing brainstorming and Delphi method to the experts of the manufacture.

Generally, process stability and capability are computed in measure phase of sig sigma. The process stability is mapped using fraction of nonconforming control chart. If the process is not stable, we must find and reduce some assignable causes so the process variance can fulfil the normal assumption. On the other hand, the capability process is used to state the sigma level of the process which can be computed after getting the defect per million opportunities (DPMO) value. If the sigma level is lower than six, some improvements must be applied to the production process.

Finding the correct root cause is the most important thing in the analyse phase. We implement brainstorming method for 4 rounds to identify some critical factors that cause the reject cases. Then, these factors are mapped using fishbone (cause and effect) diagram on several aspects i.e. man, machine, material, method, and environment resulting some root causes. After that, failure mode and effect analysis (FMEA) is applied to rank between the root causes. We choose some root causes to be tackled based on the risk priority number (RPN) that is resulted from FMEA.

To solve the chosen root causes, we design some improvement in the improve phase. Firstly, we generate some solution alternatives considering time and resource constraints. Then, with the experts, we chose the best alternatives as the improvement strategy. The implantation schedule is created in the form of gantt chart. Finally, we implement 5W1H (what, why, who, when, where, how) to make the detail of the solutions.

In control phase, control mechanism is designed to assure that implementation execution is aligned to the implementation plan. We also develop standardization process to make the solution will be implemented continuously. The detail of DMAIC cycle used in this research could be seen in Figure 1.

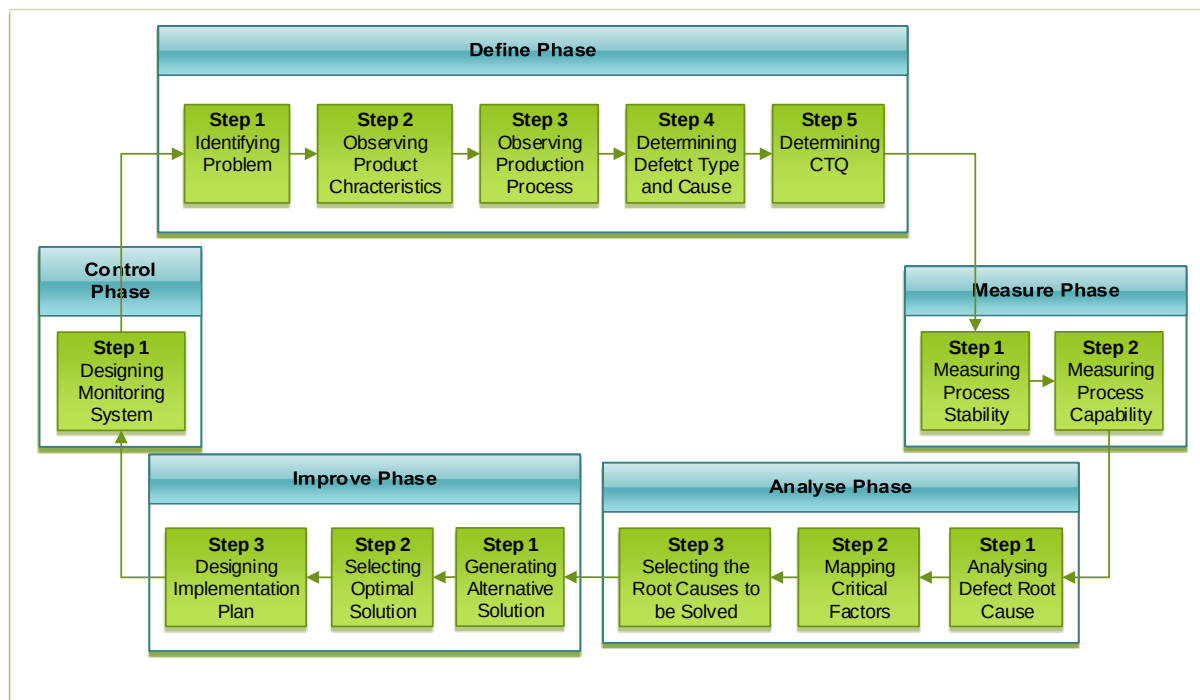


Figure 1. DMAIC Cycle

3. Implementation

This research was conducted at TRC, a manufacture located in Bandung, that produce rubber-based semi-finished and finished products i.e. shoe soles, vulcanization tires, spare part, etc. In the design phase, we chose shoe soles as the research object because the product was requested by the manufacture. It is known that the shoe soles had the second highest of demand with 36.4% of the manufacture's turnover. The customer with highest demand was chosen despite it had the highest number of returned product of 18.08%. The expected loss because of the returned product was about IDR 50 million from December 2015 to Mei 2016. The product characteristics discussed in this study was shoe soles colour (white, gum, and black), size with range of 38 – 44 using European standard, thickness between 0.8 – 1 cm, and hardness between 45 – 50 sore. We also defined supplier, raw materials, and process needed to produce the specific shoe soles ordered by specific customer using SIPOC diagram. We found at least 7 type of defects i.e. (a) contaminated by unwanted colour – 91 cases, (b) hardness is not appropriate – 17 cases, (c) surface eroded – 14 cases, (d) inconsistent colour – 13 cases, (e) contaminated by unwanted objects – 10 cases, (f) deformation – 7 cases, and (g) unsmooth surface – 5 cases. Then, we used Pareto diagram resulting this study only focused on the six first of the defect to tackle 96.82% of all reject cases (Figure 2). From these rejects, we analysed the critical factors by using 4-round Delphi method which delivered 5 CTQ i.e. (a) raw material, (b) operator, (c) press machine, (d) procedure, and (e) work environment.

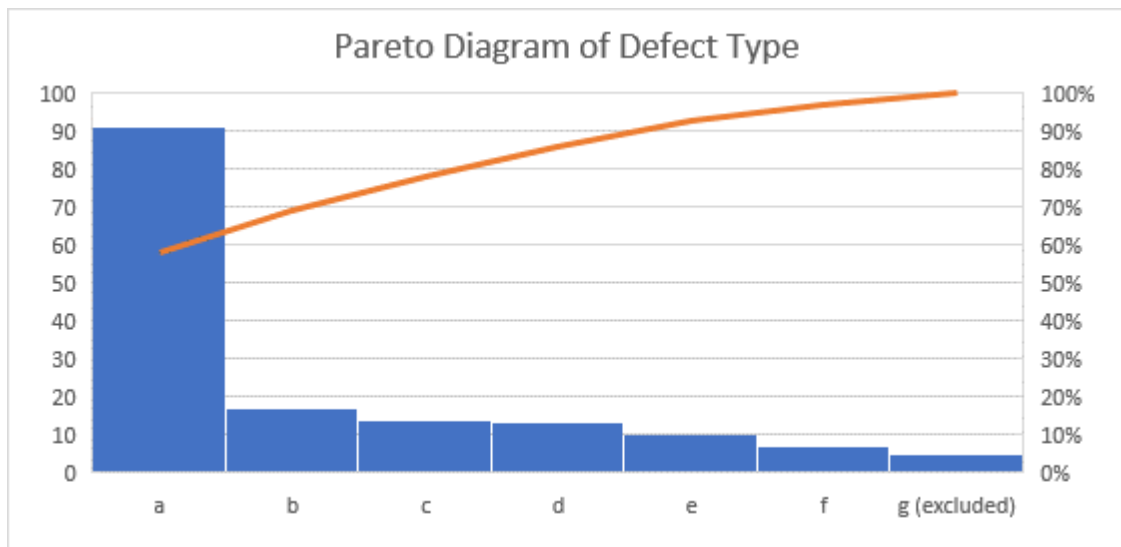


Figure 2. Pareto Diagram of Defect Type

After CTQ had been known, shoe soles production process performance was measured using defect fraction and DPMO to get process stability and process capability respectively. The mapping process was done to two important process linked to all reject types i.e. vulcanization and pressing process. It can be known from historical data that there were some out-of-control events as seen in Figure 3 and the experts identified those as false alarm events resulting the processes can be assumed as normal condition. DPMO of vulcanization and pressing process respectively were 89411.76 and 10359.96 with the sigma score respectively of 2.84σ and 3.81σ . This result shown that some improvement processes were needed to both processes. Moreover, we also computed sig sigma score based on product returns number which was still 3.3σ .

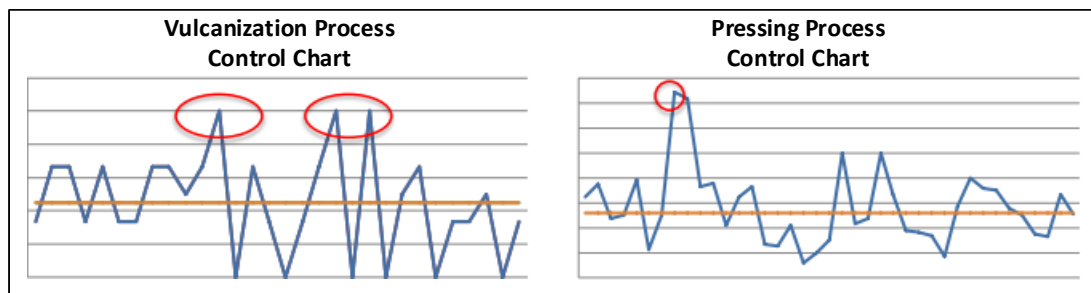


Figure 3. Fraction of Defect Control Chart

In analyse phase, we used brainstorming and Delphi method to find 15 root causes of the six defects. Then, we mapped it to the fishbone diagram for each defect as shown in figure 4. Using FMEA, we computed risk priority number (RPN) considering severity, occurrence, and detectability of each root causes and select the root causes with the RPN score more than 600. So, there were 7 critical root causes to be tackled in this study i.e. (a) hanging shelf near open mill machine, (b) composition of colour pigments, (c) operator on open mill machine, (d) raw material inspection procedure, (e) ripeness inspection process on pressing process, (f) operator on press machine, and (g) shoe soles mould. From these root causes, in improve phase, we generated 6 solutions to be applied at TRC using 5W1H method i.e. (a) hanging shelf modification, (b) pantone colour book, (c) drawing pedestrian line at rubber compound department, (d) make check sheet of pantone colour, (e) buying and using stopwatch, and (f) shoe soles mould modification. Those solutions needed about IDR 15 million to be implemented. The relationship between the root causes and the solutions is shown at Table 1.

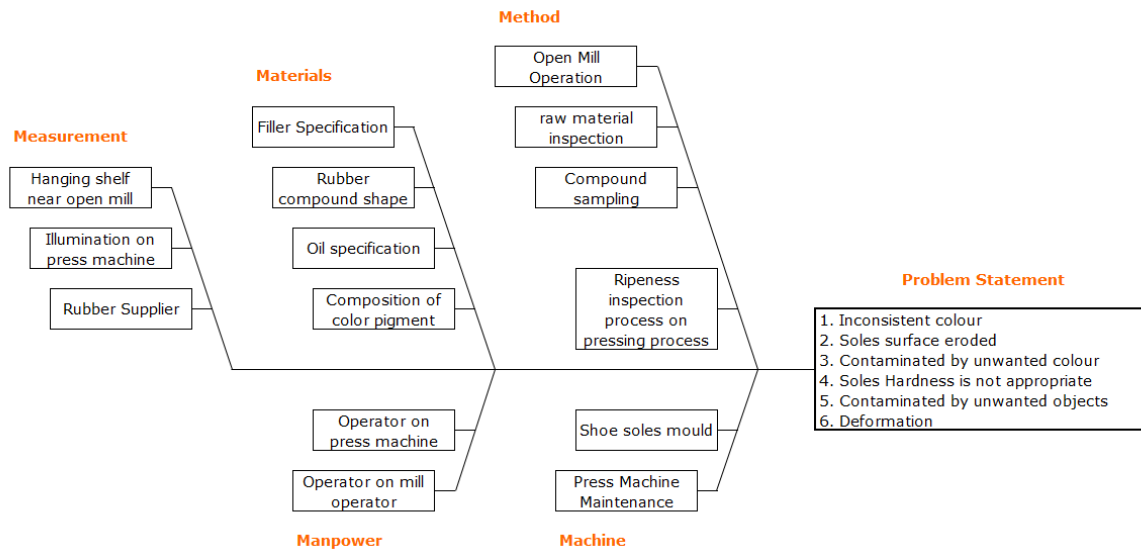


Figure 4. Fishbone Diagram

Table 1. Root Causes and Solution Relationship

Root Causes	Solutions
hanging shelf near open mill machine	hanging shelf modification
composition of colour pigments,	pantone colour book
operator on open mill machine	drawing pedestrian line at rubber compound department
raw material inspection procedure	make check sheet of pantone colour
ripeness inspection process on pressing process	buying and using stopwatch
operator on press machine	shoe soles mould modification
shoe soles mould	

To assure the continuity of the improvement, some monitoring and evaluation strategies in control phase has been proposed which were (a) reward and punishment system for some department heads and open mill machine operator, (b) implementing operator ID card containing pantone colour information, (c) putting warning board near press machine, (d) create SOP of plastic sheet allocation at the bottom of rubber compound, (e) create SOP of raw material inspection and ID card making regulation, (f) create SOP on press machining, and (g) data frequency recording of reject caused by operator on press machine.

4. Conclusion

Shoe soles got the second number as the most reject product at TRC manufacturing. The customer with highest demand of this product with the number of returned product reach 18.08% resulting expected loss about IDR 50 million. To overbear this problem, six sigma methodology consists DMAIC cycle was used. Seven defects were found in the define phase, but we only focus to 6 defects that contributed to 96.82% of cases. There were 5 CTQ that caused the defect i.e. (a) raw material, (b) operator, (c) press machine, (d) procedure, and (e) work environment. In measure phase, DPMO of vulcanization and pressing processes were measured respectively by the value of 89411.76 with the sigma value of 2.84σ and 10359.96 with the sigma value of 3.81σ . After analysis phase, 6 solutions were chosen to tackle 7 critical root causes that had RPN number higher than 600 i.e. (a) hanging shelf modification, (b) pantone colour book, (c) drawing pedestrian line at rubber compound department, (d) make check sheet of pantone colour, (e) buying and using stopwatch, and (f) shoe soles mould modification. Those solutions needed about IDR 15 million to be implemented. To assure the continuity of the improvement, some control strategies were submitted i.e. (a) reward and punishment system for some department heads and open mill machine operator, (b) implementing operator ID card containing pantone colour information, (c) putting warning board near press machine, (d) create SOP

of plastic sheet allocation at the bottom of rubber compound, (e) create SOP of raw material inspection and ID card making regulation, (f) create SOP on press machining, and (g) data frequency recording of reject caused by operator on press machine.

Acknowledgment

This research was conducted at the Manufacturing System Research Group, funded by P3MI research grant of ITB

References

- [1] Kubiak, T., Benbow, D. 2009. *The Certified Six Sigma Black Belt Handbook, 2nd Ed.* Milwaukee: American Society for Quality.
- [2] Montgomery, D. C., 2009. *Statistical Quality Control: A Modern Introduction (7th ed.)*. Hoboken: John Wiley & Sons.
- [3] Park, S. H., 2003. *Six Sigma for Quality and Productivity Promotion*. Tokyo: The Asian Productivity Organization.
- [4] Lunau, S., John A, Meran R., Roenpage, O., and Staudter, C. 2006. *Six Sigma+Lean Toolset*. Springer: Berlin
- [5] Malik, A.L., Akbar, M., Irianto, D. 2016. IOP Conference Series: Materials Science and Engineering. 114 012054.