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ANALYSIS OF DEFECT AND QUALITY IMPROVEMENT FOR O RING PRODUCT THROUGH APPLYING DMAIC METHODOLOGY

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Abstract

To control the quality of a product to meet standards, a reliable measurable technique is needed with the company's business strategy. This research raises case studies identifying quality problems and effective ways of improvement of O Ring products using DMAIC (Define-Measures-Analyse-Improve-Control) quality control methods. Company X found the problem in the form of an average O Ring product defect ratio reaching 1.50% (the company's target is 1.30%). DMAIC is a systematic methodology that focuses on the key factors that control the performance of a process, set it at the best level and keep it at that level. Statistical tools combined with quality principles are applied to each of the DMAIC phases. The result of this DMAIC implementation was the O Ring products defect dropped to 0.83% and the sigma value rose to 4,363%.

Keywords: quality, DMAIC, O Ring, defect, sigma, standard

Abstrak

Untuk mengontrol kualitas suatu produk agar memenuhi standar, diperlukan teknik terukur yang dapat diandalkan dengan strategi bisnis perusahaan. Penelitian ini mengangkat studi kasus yang mengidentifikasi masalah kualitas dan cara yang efektif untuk meningkatkan produk-produk O Ring dengan menggunakan metode kontrol kualitas DMAIC (Define-Measures-Analyze-Impro-Control). Perusahaan X menemukan masalah dalam bentuk rasio cacat produk Ring O rata-rata mencapai 1,50% (target perusahaan adalah 1,30%). DMAIC adalah metodologi sistematis yang berfokus pada faktor-faktor kunci yang mengendalikan kinerja suatu proses, menetapkannya pada tingkat terbaik dan menjaganya pada tingkat itu. Alat statistik yang dikombinasikan dengan prinsip kualitas diterapkan untuk masing-masing fase DMAIC. Hasil implementasi DMAIC ini adalah cacat produk O Ring turun menjadi 0,83% dan nilai sigma naik menjadi 4,363%.

Kata kunci: kualitas, DMAIC, O Ring, cacat, sigma, standar

INTRODUCTION

Quality is a characteristic of product and services which is determined by user or customer and obtained by measurement process and by continuous improvement. Therefore, every company must control the quality of product or services delivered to customer. Quality control is defined as a technique and activity or planned action taken to achieve, maintain and increase of product and services quality to conform to standard was has been set and can fulfil a customer satisfaction. This research was raised from a case study faced by Company X as a manufacturer of heavy equipment spare parts that faced the problem of high defects in O Ring products. O Ring products (figure 1) are sub-parts of Floating Steel products (figure 2), where a very soft ring is made of synthetic rubber and functions as a static and dynamic seal for pressure of more than 5000 psi whose function is almost the same as a gasket. O Ring is obtained by printing rubber material at 180º. The O Ring product defect is found in the body part of the product and in the curing process. This defect cannot be repaired because the O ring product is made of rubber base material so that it is easily scratched and damages the surface of the product. In addition, the product also cannot be recycled and must be discarded. This causes financial and environmental losses problem that must be reduced by the company. That leads to the purpose of this research, that was conducted to help Company X to improve the quality of products that are sustainable with the DMAIC method and provide knowledge to companies manufacturing other heavy equipment spare parts to maintain the stability of the production process and quality.

Figure 1. O Ring product

Figure 2. Floating Steel product

LITERATURE REVIEW

Quality and DMAIC Methodology

DMAIC, which stands for define, measure, analysis, improve and control is a methodology that was originally developed from the Six Sigma principle (Ansari, Lockwood, Thies, Modarress, & Nino, 2011). Where Six Sigma itself is a concept approach introduced by Motorola with the aim of increasing productivity and quality, while reducing operational costs (Jirasukprasert, Garza-Reyes, Soriano-Meier, & Rocha-Lona, 2012). The five stages in DMAIC are more detailed process improvement steps compared to Deming's plan do check action cycle (Andersson, Eriksson, & Torstensson, 2006; Pande, Neuman, & Cavanagh, 2000). DMAIC is a structured methodology to improve processes focused on efforts to reduce process variances while reducing defects (products / services that are out of specification) by using statistics and intensive problem-solving tools (Koeswara & Ardianto, 2013; Pepper & Spedding, 2010). Stages in DMAIC can also use techniques and tools such as statistical process control, design of experiment and response surface methodology (Keller, 2004) which can improve accuracy in improving the quality of manufacturing processes. The Six Sigma Methodology is a customer focused continuous improvement strategy that minimizes towards defects and variation achievement of 3.4 defects per million opportunities (DPMO) in product design, production, and administrative processes (Brady & Allen, 2006; Valles, Sanchez, Noriega, & Nuñez, 2009). It is not easy to reach a defect rate of only 3.4 in one million products or it can be said to be almost defect free, this is what makes DMAIC a promising six sigma methodology and reliable business strategies to guarantee quality in the long run. This methodology is expected to become a rooted management philosophy of continuous improvement in every business process. Good quality control will provide certainty for consumers to be able to enjoy standard products continuously, which can improve the company's image (Kholil & Prasetyo, 2017).

DMAIC Tools

Critical to Quality (CTQ)

CTQ is a limit, characteristics and quality standards for quality dimensions that must be maintained from a product. The standard on this dimension can be input that comes from the customer / customer or is determined by the manufacturer or is a combination of both. CTQ also provides analysis on matters both inside and outside the company that have the potential to influence the quality dimensions of the product.

Voice of Customer (VoC)

VoC is a tool for knowing how consumers and customers perceive and express their products. In conducting VoC, surveyors are needed who have the spirit of change and the same spirit of continuous quality improvement as the company.

Run Chart

Run Chart is an image that maps data in the form of numbers based on the data period. Run Chart is a tool that is widely used and widely applied to various interests, both in strategic planning and in the field.

Cause Effect Diagram

Cause effect diagram is a graphic image that displays data about the causes of failure or non-conformity, to analyze the deepest sub of the factors that cause problems. The form of analysis on the Cause effect diagram is in the form of quantitative or qualitative data.

Check Sheet

Check sheet is a tool to ensure quality in real time, meaning that the contents on the check sheet will provide an actual and up-to-date description of quality. The truth of the data is very dependent on the person or officer who assesses the conditions in the field.

Why Why Analysis

Why why analysis is a root cause analysis tool to solve a problem. This tool helps identify the root of the problem or the cause of a discrepancy in the process or product.

Design of Experiment (DOE)

A procedure taken before the experiment is carried out so that the required data can be obtained, so that the analysis and conclusions can be objectively carried out. Based on statistics, experimental design techniques are very useful in the world of engineering to improve the performance of manufacturing processes and have broad applications in the development of new processes. By conducting experiments that have been designed, the engineer can determine a subset of process variables that have the greatest influence on the performance of the process.

RESEARCH METHODOLOGY

In this study, the data were collected through direct observation and collection of production report data, daily machine activity check sheet data, documentation and operator skills in the Open Roll, Rubber Cutting and Curing sections. This research is conducted in five stages in accordance with DMAIC methodology, namely:

1. Define. In this phase clarification of the critical characteristics of product quality desired by the customer by using the CTQ (Critical to Quality) method and describing the quality standards desired by the customer by using the VoC (Voice of

Customer) tools. The merger between CTQ and VoC techniques makes the uniqueness of this research. Because in general research uses direct CTQ data already available, while in this study the existing CTQ data is re-verified its suitability with customer requirements.

2. Measure. Researchers calculated the average O Ring defect ratio found, the sigma value based on the number of defects produced. And the type of defect is determined and the type of product with the largest number of flow-mark defects using pareto diagrams. In this study presented a detailed calculation method that allows the reader to understand it.
3. Analysis. In this stage an analysis of the causes of flow-mark defects is done using the Cause effect diagram method by analyzing the implementation factors (Man), methods (Method), machines (Machine), raw materials (Materials) and environment (Environment) and analyzing the causes in more detail with using “why-why analysis” tools.
4. Improve. In this phase a series of tests and experiments are conducted to test and prove that the causal factors that have been analyzed are correct and greatly affect the occurrence of flow-mark defects with the Design of Experiment (DOE) technique. After ascertaining the cause, then improvements were made based on the causes that had been found earlier.
5. Control. At this stage, revisions will be made regarding the standards of open roll process work and rubber cutting. As well as controlled using Gemba check sheet and stability measurement using a control chart, to ensure the stability of the width and the weight of the rubber cutting still meet the recommended size standards.

RESULT AND DISCUSSION

The results and discussion of this study will be described in accordance with the stages of the DMAIC methodology.

Define

The O Ring manufacturing process is described in Figure 3. Physical defect conditions in O Ring products include flow-mark defects, tear defects, Scratch (scratch) defects, and contamination (Table 1). The condition of the defect mentioned is a defect that occurs during the Curing process (rubber printing), which is then to be made in the determination of quality characteristics (Critical to Quality), as shown in figure 4. Physical defects in O Ring are found or identified by visual inspection throughout O Ring surface in the Body area and the Parting line area, whether done by the Quality Control or by the production operator.

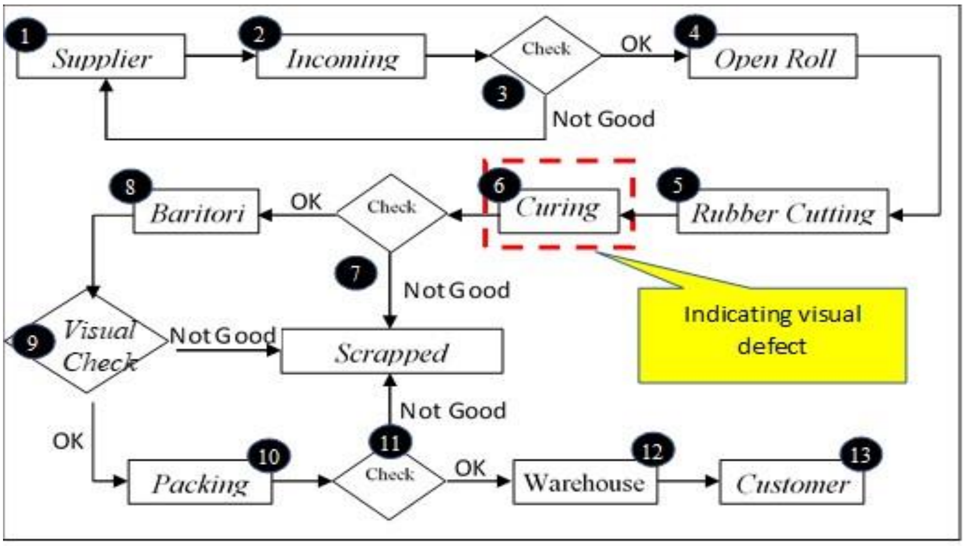
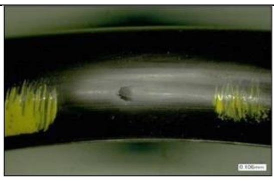
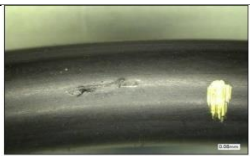


Figure 3. O Ring production process flow

Table 1. Type of Defect in O Ring Product

No	Type of Defect	Figure
1	Flow-mark	
2	Torn	
3	Scratch	
4	Contamination	

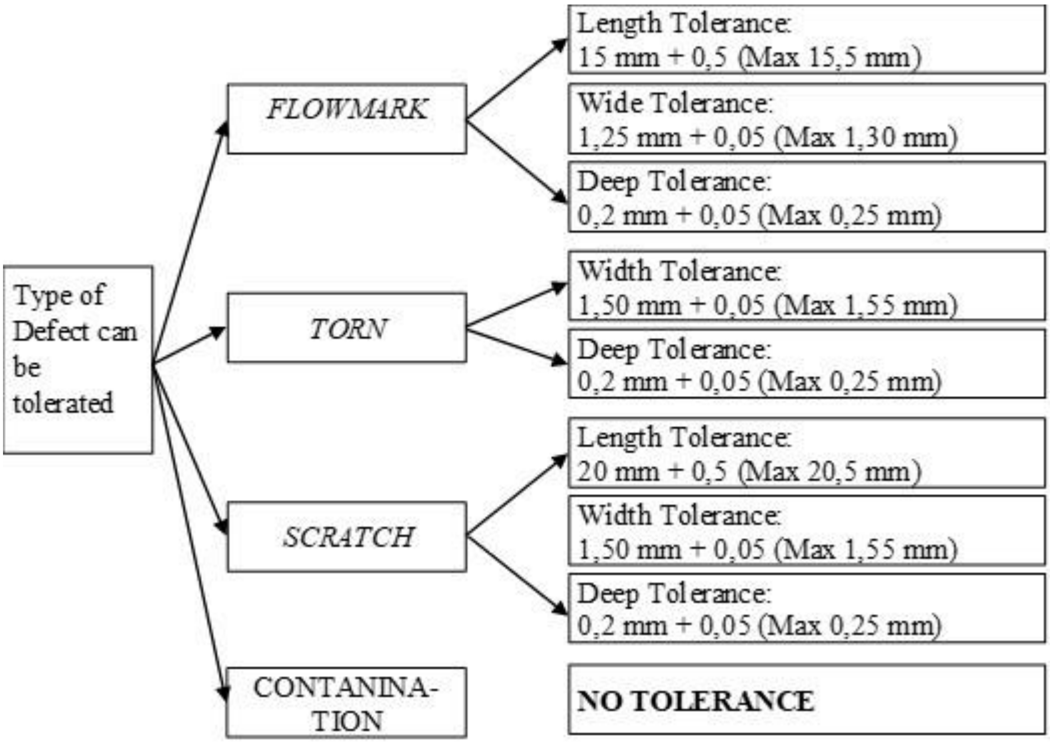


Figure 4. Critical to Quality Tree of product O Ring

This define phase ends with the determination of Voice of Customer, which is done by interviewing the Quality Assurance Company X and the customer requirement table is made with the limit sample method as in figure 5

Figure 5. Voice of Customer O Ring products with Limit Sample Method

Measures

In this phase the defective data is collected and mapped in a run chart from July to December 2017 as shown in figure 6. From the trend in figure 6 it is known that the average defect ratio (1.5%) is above the company's target (1.3%) The defect ratio is calculated by dividing the number of defects with the total amount of production produced.

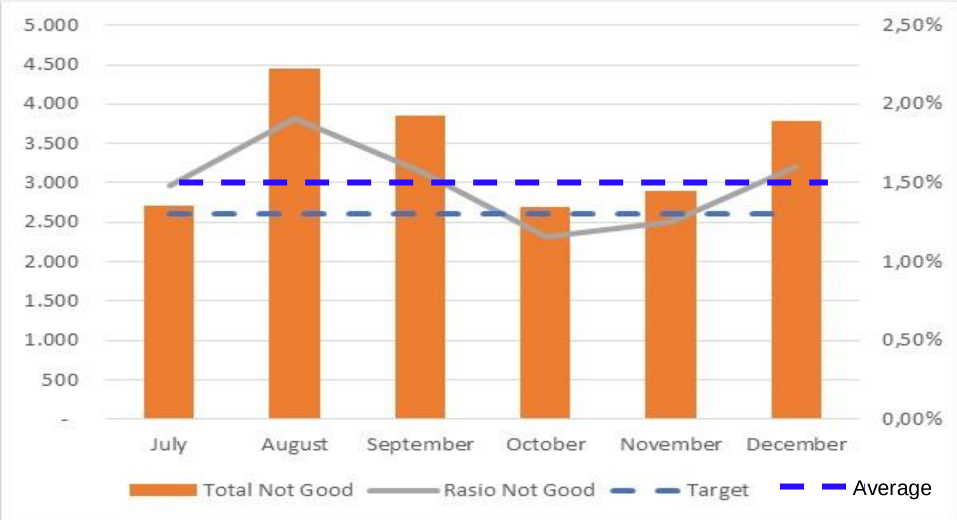


Figure 6. Defect product ratio July - December 2017

The next step is to measure the current sigma value as an indicator of the quality of the process.

Table 2. Number of Defect O Ring per Defect Type

Month	Scratch	Conta-mination	Torn	Flow-mark	Total Defect (D)	Total Production (U)
July	342	645	796	928	2,711	182,839
August	968	832	987	1,662	4,449	232,644
Sept	690	875	787	1,493	3,845	243,493
Oct	367	491	631	1,210	2,699	232,198
Nov	842	429	667	955	2,893	231,402
Dec	532	243	1,201	1,801	3,777	236,288
TOTAL	3,515	3,741	5,069	8,049	20,374	1,358,864

With D = 20,374 unit, U = 1,358,864 unit and OP (Opportunities – defect type) = 4, then

TOP (Total Opportunities) = U X OP (1)
= 1,358,864 x 4
= 5,435,456

DPO (Defect per Opportunities) = D / TOP (2)
= 20,374 / 5,435,456
= 0,0037

DPMO (Defect per million opportunities) = DPO x 1,000,000 (3)
= 0,0037 x 1,000,000
= 3,700

Calculating sigma values using Microsoft Excel with the formula:

$$\text{normsinv}((1000000\text{-DPMO})/1000000)+1.5 \quad (4)$$

and the result is 4,178. The target of the sigma value of the company is 4.5, so the next step is the priority of the defect that will be handled first by using tools in the form of pareto diagrams (Figure 7 and Figure 8). Based on the pareto diagram, the type of defect that will be overcome is the Flow-mark for Ring products) type ZZ00000123.

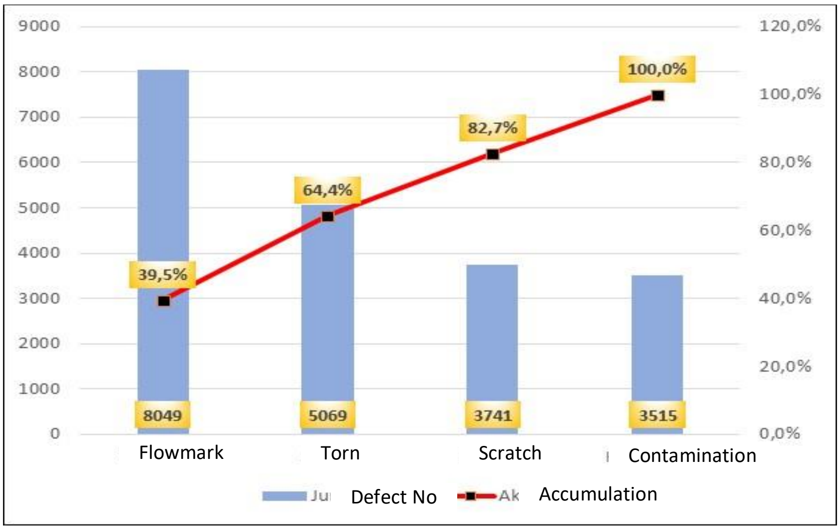


Figure 7. Pareto Diagram as a priority type of disability

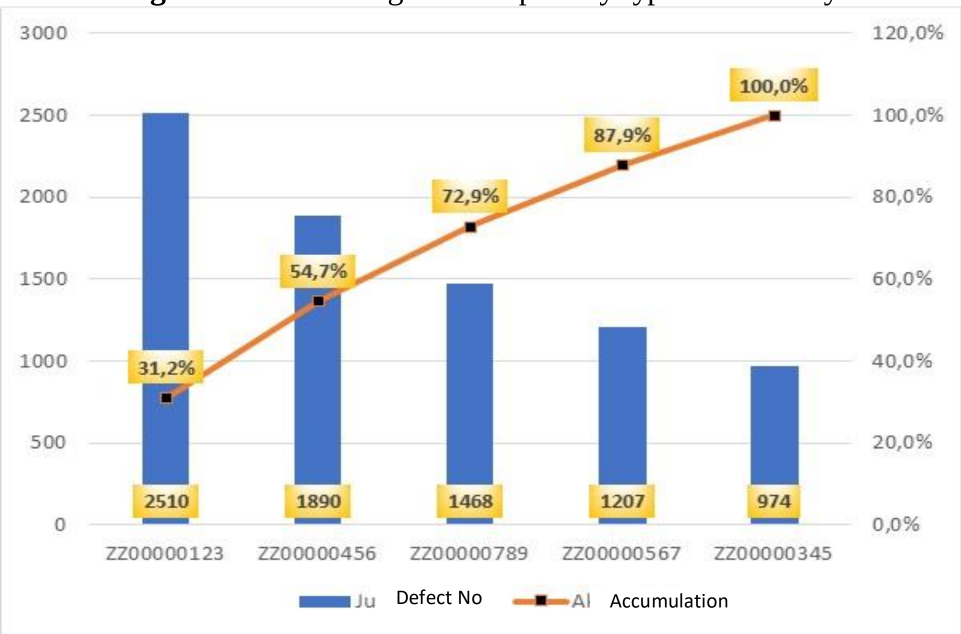


Figure 8. Pareto Diagram as a priority type of disability flow-mark

Analyze

This phase is done by combining the why-why analysis technique (Table 3) and cause effect analysis diagram (Figure 9) in a brainstorming process.

Table 3. The Mapping of Possible Root-Cause Using Why-Why Analysis

4M1E	Why-1	Why-2	Why-3	Why-4
Man	Lack of operator awareness about quality	Assuming quality is the task of the QC department	Production department member must produce quickly base on target time	Lack of understanding and education about quality
	It's not maximal in cleaning Bury's left with air gun	Operators are in a hurry since being pushed by targets	Unclear socialization about how to clean bury in the mould	
		Don't know if the air gun functions to clean the mould from the rest of the bury	The air gun is only used to remove the O Ring which is ripe from the mould	Less clear socialization from the leader
	Operators install rubber cutting in non-standard moulds	Operators are in a hurry since being pushed by targets	Lack of training and education regarding the quality and risk of operating errors	
		Done by senior operators and feel more experienced and know better		
Method	There are remaining bury on the mold	Mould is not visually checked or cleaned by hand	The cleaning method is only sprayed with air gun	
Material	Rubber hardness is hard (Hardness)	Rubber is stored for too long and is not processed immediately	Rubber cutting has been prepared 2 days before	Stock requirements for shipping
	The rubber cutting ends do not stick	Rubber cutting is less long	Standard measurement of rubber sheet width during the open roll process is only sampling every 10 sheets	
	Rubber cutting stands for when installed in a mould	Length is not measured during the rubber cutting process	The length of rubber cutting is measured during the open roll process.	The size of the rubber sheet width during the open roll process is too long size for rubber cutting
Machine	Vacuum machine settings are difficult to stabilize	Some parts are difficult to find	Used import machine	
	The mould temperature does not match the display settings	There are components that have been damaged and must be replaced		
Environment	Temperatures in the less cold curing area can cause rubber to become har	The cooling engine that is in the curing area is not proportional to the temperature of the heat coming out of the curing machine		

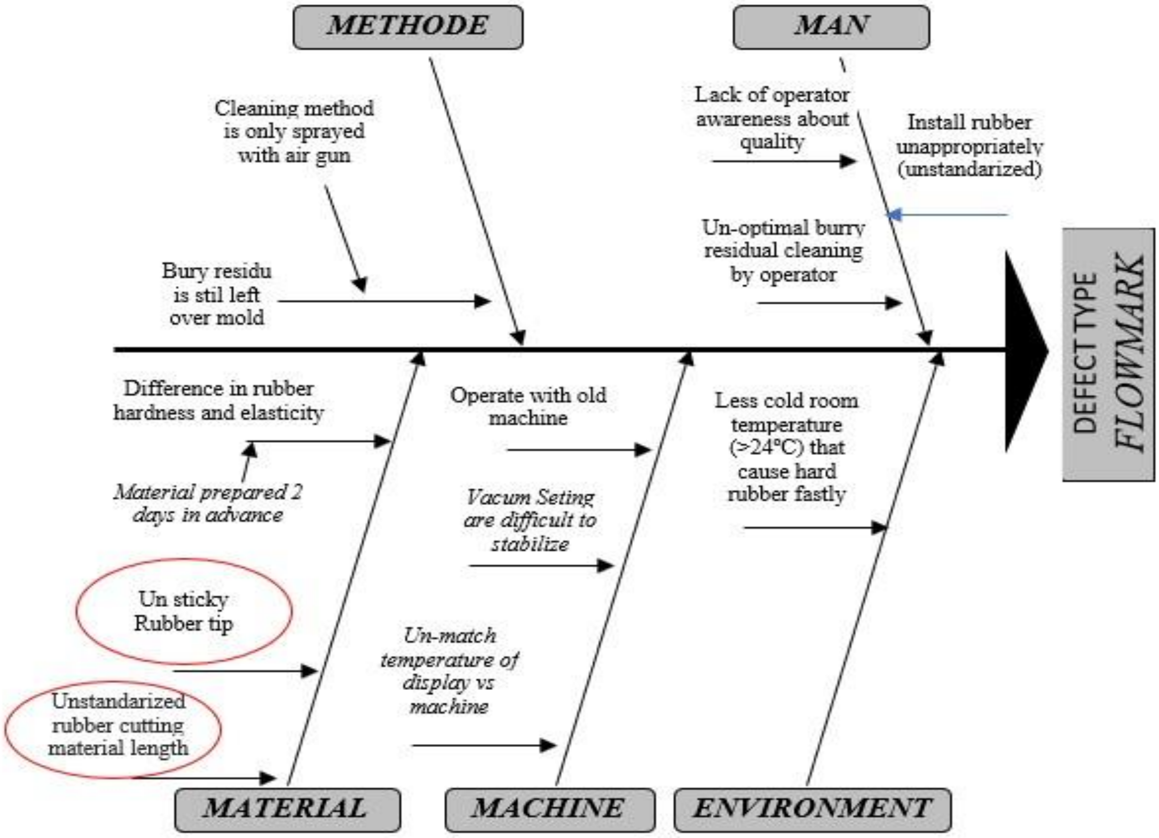


Figure 9. Cause Effect Diagram to find root causes of flow-mark defect

There are 3 analysis points that can be taken from those analysis tools, which are:

1. The long factor of rubber material can affect the occurrence of flow-mark defects on the O Ring type ZZ00000123. If it is too long, the installation method will overlap the attachment method and potentially cause flow-mark defects. So that rubber that is too short. When installed in the mold will form a gap between the tip and the tip of the rubber so that the flow-mark defects are potentially too.
2. Based on the analysis in the rubber cutting process, Measurement is done only once every 100 pieces of weight measuring and only once every 50 piece of rubber cutting width measuring. Therefore, it is necessary to measure the stability of the weight and width measurement results to ensure compliance with the specified specification standards.
3. The validation process of rubber cutting length measurements is happened in open roll processing, and the measurements are carried out only every time producing 10 sheet rubber. In this process it is necessary to monitor the width size stability which will be the length of the rubber sheet later.

Improve

As a follow-up of the analysis, improvements were made through testing with the Design of Experiment (DOE) technique, to test the truth that rubber sheets that are too long and too short will cause flow-mark defects in the O Ring type ZZ00000123. And it will also be tested that the appropriate rubber sheet (the tip with the tip of the rubber sheet attached) will not cause flow-mark defects.

Based on experimental data or experiments carried out from March 13 to March 2018 (Table 4), the rubber cutting factor was too long and too short when the research proved very influential in causing flow-mark defects. For the time being the width size is still according to the actual specifications produced and do not make changes. This is evidenced in the experimental data using a long rubber cutting that is still within the specified range of specifications that the number of flow-mark defects that do not have more than the experimental results-1 and experiment-2.

The determinant of the length of the rubber cutting is in the open roll process. As a suggestion for improvement, in the open roll process the width sheet should be measured on each sheet produced (not every 10 sheets). This is done to avoid the size deviation that is far enough, especially the width. The determinant of the width of the rubber cutting is the rubber cutting process. This process is referenced to remain in accordance with the actual specifications produced. After the cause of the flow-mark defect is known, the next step is to experiment in the production process for 3 months, starting from April to June 2018. The results can be seen in figure 10.

Figure 10. Defect ratio 3 months after implementation

Based on the data above, sigma values were measured after improvement, namely:
D = 6,497; U = 785,915; OP = 4;
then: TOP = 3,143,660; DPO = 0.0021 ; DPMO = 2,100 ; Sigma = 4.363

Table 4. Comparison Data Before and After Improvement

Research Object	**Before** (Average Jul-Dec 2017)	**After Improvement** (Average Apr-Jun 2018)
DPMO	3,700	2,100
SIGMA	4.178	4.363
Number of Defect O Ring	3,396	2,166
Defect Ratio O Ring	1.50%	0.83%
Flow-mark Number	1,342	305
Flow-mark Defect Ratio	39,5%	14,1%
Number of Flow-mark ZZ00000123	2,510	166
Defect Ratio of Flow-mark ZZ00000123	31.2%	18.2%

Control

There are three activities carried out to evaluate and control the results of the previous stages, namely:

a. Revise work standards, especially the open roll process and the rubber cutting process
   - Revise the implementation points in the width of the rubber sheet measurement process. The measurement is initially only done once every 10 sheets, so to improve this flow-mark defect, it is necessary to measure each sheet so that the stability of the size is maintained.
   - Revise weighing implementation points from the previous one every 100 pieces 1 time, to every 20 pieces. To control the weight of rubber cutting remains stable according to specifications.

b. Prepare the obervasi check sheet (gemba check sheet) every month

c. Use the control chart visualization tool to ensure the process is controlled.

CLOSING

Conclusion

The conclusions that can be drawn from this research are:

1. The flow-mark defect causing factor is the length of the Rubber Cutting which is less and excessive, because during the measurement process the weight and length are carried out by the sample and the stability is not controlled so that it passes to the curing process.
2. Improvements are made by reducing the measurement frequency that is shorter when measuring the width of the Rubber Sheet and the weight and length of the Rubber Cutting, and its stability is controlled (at this time every 2 days).
3. The Sigma value increased from the previous 4,178 to 4,363.
4. O Ring defect ratio per month fell from the previous 1.50% to 0.83%.

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