QUALITY CONTROL ANALYSIS USING SIX SIGMA (DMAIC) METHOD TO REDUCE POST PIN ISOLATOR RIJECT IN PT XYZ (FIRING SECTION)

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***Abstract*: This study aims to find the type of defect, along with find the main causes and providing suggestions for improvements in reducing the number of failed products in production processes of firing sections. This study uses a *Six Sigma* methodology approach with tools such as *Fishbone diagrams, Pareto diagrams, Brainstroming and Histograms*. This research is a quantitative descriptive exploratory method. The results of this study indicate the types of product failures, namely Skirt Lip Crack, Inner Skirt Crack and Broken Body. Then there are several causes of product failure is : the auger in the pugmill machine is worn, the dimensions of the Honggote (HG) shape in the forming and seizure sections are not matching, vaccum finishing is not stable, and there is no measurement of the twist of the Yobigote (YG) twist. Then, corrective actions were taken in the form of repairing the extruder and finishing machines, training the operators, making new SOPs, making checksheets and checklists for control. The conclusion of this research is that quality control using the six sigma method can reduce the rejection level and increase the six sigma level. The suggestion is the need for further research to be able to increase the six sigma level.**

Keywords*: *Six Sigma, Quality Improvement, Fishbone* Diagram, and *Ceramic Insulator

I. INTRODUCTION

The company is one of the industries in the manufacturing sector engaged in medium voltage ceramic insulators, namely the production of 12.5 kN pin post insulators and 70 kN suspensions. In April 2020, the company targets a rijek level in the firing is 2.5 % while the failure rate for pin post in the finishing sections is 10.12%. Thus it is necessary to control the quality of production so that production defects can be reduced and product quality is maintained.

Researchers chose quality control using Six Sigma because "Six Sigma is a new management tool used to improve Total Quality Management, very focused on quality control by exploring the company's overall production system which aims to eliminate production defects" (SHIFT Indonesia, 2017). Six Sigma is considered better than other methods such as Total Quality Management (TQM), TQM is a method for implementing and managing overall quality improvement activities in an organization (Usman).

Many researchers have previously researched quality control using the Six Sigma (DMAIC) method in various industries but only a few have researched quality control using the Six Sigma method in the ceramic insulator industry. Previous researchers explained the application of Six Sigma in the water industry (Didiharyono, Marsal & Bakhtiar, 2018), the application of six sigma in the electronic goods industry, namely the Blue-Ray Disc Player (Dony Arief Widiatmoko), the application of six sigma in the car painting industry (Mohhamed A Rahman, AKM Mohiuddin & Hanani Abdullah, 2015), the application of six sigma in the construction industry (Molly Thomas & I.Porcia, 2017).

This study will analyze any failures in the production section of pin post ceramic insulators, as well as find the main causes of the failure of the product and provide suggestions for its repair. This research is also to determine the value of SQL (Sigma Quality Level) in the production section of pin post ceramic insulators.

II. LITERATURE REVIEW

A. *Control*

Control is an activity carried out to monitor activities and ensure that the actual performance carried out is as planned (Vincent Gasperz, 2005).

B. *Quality*

Quality is a philosophy that involves all elements of activities carried out by all people in the company that are continuous to achieve a degree of quality and achieve consumer expectations (Achmad.H.S, 2003).

C. *Defect*

Defect is a condition in which a product is declared to have failed or does not meet the requirements set by the company or customer (Burhan, 2015).

D. Six Sigma-Introduction and overview

At the end of 1970, Dr. Mikel Harry, a senior engineer at Motorola's Government Electronics Group, started an experiment to solve the problem using statistical analysis. Using Motorola's GEG is starting to show dramatic improvements: products are designed and produced faster at less cost. He then wrote this method in a paper entitled "The Strategic Vision for Accelerating Six Sigma Within Motorola", Dr. Mike Harry was then assisted by Richard Schroeder, a former Motorola executive, to develop a data-driven change management concept. The result of this collaboration is a simple quality measurement tool, which later became a philosophy of business progress, known as Six Sigma.

Six sigma is a management tool used to replace Total Quality Management (TQM) which is very focused on quality control by exploring the company's overall production system (Achmad Sutawijaya & Lenny Nawangsari, 2019). The six sigma method has been widely applied in order to improve performance, such as the manufacturing industry (Linderman, et al., 2003), health and safety (Rimantho & Cahyadi, 2016; Sanjit, et al., 2011), environmental management systems (Calia, et al., 2009).

III. RESEARCH METHODOLOGY

The research methodology used in this research is a case study research with the aim of describing the application of Six Sigma to the ceramic manufacturing industry. Case study-based research engages facilitators to study and work with case study companies.

This study uses primary data and secondary data. Primary data is data that is directly obtained and collected in the research area, such as: the condition of the materials used, work instructions and data of employees who work in the production department. Meanwhile, secondary data is data obtained from indirect sources that have been previously prepared and used for the research process, such as process flow data and employee competency matrices.

Data collection techniques using interviews, observation (direct observation) and documentation. The samples in this study were all internal reports on the production section of pin post ceramic insulators. In analyzing the data using the help of the Minitab 18 application and the Six Sigma calculator.

IV. RESEARCH RESULTS

1. Define Phase

This phase defines the project by identifying critical customer needs and linking them to business needs.

a. Process Flow

A process flow diagram is a diagram showing the general flow of plant processes and equipment. Figure 1 shows a flow diagram of the pin post ceramic insulator production process.

b. SIPOC Diagram

The SIPOC (Supplier, Input, Process, Output and Customer) diagram is a tool for identifying the flow of raw materials, machinery, production processes, finished product output until the receipt of goods by the customer. Figure 2 shows a SIPOC diagram for a pin post insulator section firing.

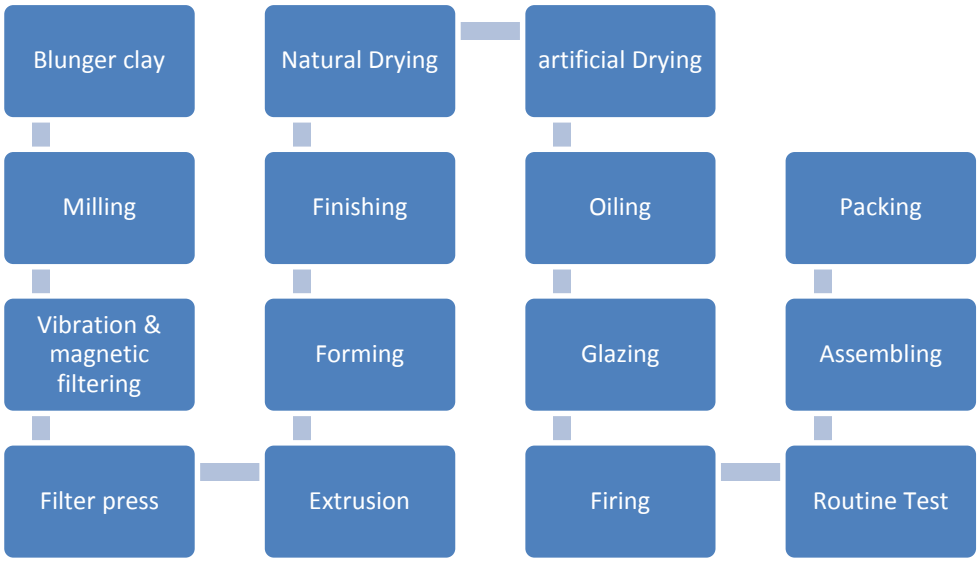

Fig 1: Process Flow of Making Ceramic Pin Post Insulators

c. Critical to Quality (CTQ)

In the Critical To Quality (CTQ) production process, namely the requirements / judgments from QC to achieve customer satisfaction so that there are no complaints from the previous process. Table 1 shows the Critical to Quality (CTQ) production of ceramic post pin insulators in part and Table 2 and Figure 3 show the definition of the type of product defect.

d. Identification of Problems

At this stage the researchers collected data and identified problems that occurred in the quality of the pin post product. Table 3 shows the data for April 2020, there were products that failed in pin post production in finishing section by 10.12% and the target company value for rejuvenation level. Thus it is necessary to control the quality of production so that production defects can be reduced and product quality is maintained.

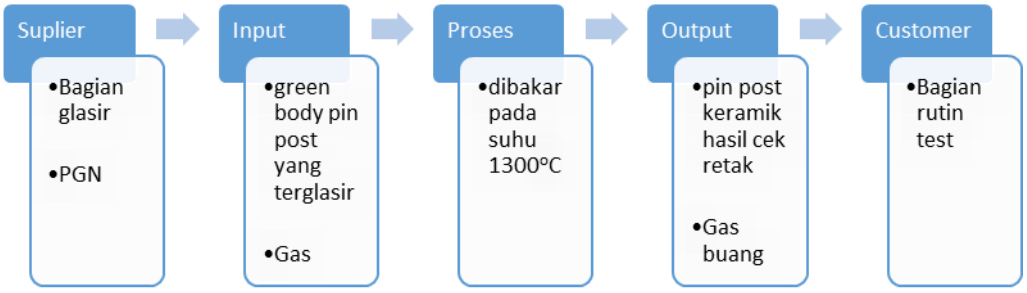

Fig 2 : SIPOC diagram produces Pin Post ceramic insulator

Table 1: CTQ section

Firing Section		
Quality characteristics	Performance Requirement	Type of defect
Compatibility of visual conditions	Nothing cracked	RA RL1 RL2 RD1 RD2 RBR RDR RRT RK TB PB LM RRA
	Brown color and glaze defects according to standard provisions.	C.GLZ

Table 2 : Defect Definition Table

No	Code	Name Reject	Definition
1	Form	Reject form forming	The flak from forming because the shape does not match the image on the leg (tilted leg / dent)
2	Slip	Slip	When it is formed by the finishing machine, the finishing knife stops halfway when it forms.
3	RA	Cracked Head	Cracks at the edge of the upper leaf for the marking part of the pin post
4	RBR	Cracked Lip Skirt	The crack in the middle arch in the skirt from the pin post
5	RRT	Crack Middle Skirt	The crack in the center of the radius in the skirt.
6	RRA	Top Radius Crack	The crack in the first neck from the top of the pin post
7	RK	Cracked Legs	Crack the base of the leg of the pin post
8	KTR	Dirt	Dirt sticking to the pin post surface but the dirt comes from the burning kiln.
9	RD1	1st Leaf Crack	That is, the cracked edge of the first leaf
10	RD2	2nd Leaf Crack	Namely the crack at the edge of the second leaf
11	RL1	1st Neck Crack	The crack in the first neck from the top of the pin post
12	RL2	2nd Neck Crack	The crack in the second neck from the top of the pin post
13	PB	Broken Body	That is, the pin post is split in two, between the leg and the body or between the first neck and the second neck with the feet
14	RDR	Crack In Skirt	Cracks in the radius in the skirt, into the body (sideways and not in the middle of the radius)
15	LM	Laminate	Cracks in the body of the pin post. The fractions looked twisted
16	SOMPEL	Sompel	That is a small fraction in a certain part of the pin post
17	PUNTIRAN	Twist	The twisted fracture of the leg due to the forming / pugmill
18	TB	Paste Material	The remaining material that sticks during the forming process (usually attached to the inside of the pin post skirt)
19	PK	Broken leg	The pinpost leg was broken with the body and skirt
20	PL1	1st neck fracture	Fracture of the first neck from above the pin post as a result of mechanical stress
21	PL2	2nd neck fracture	Fracture in the second neck from the top of the pin post as a result of mechanical stress
22	C.GLZ		Spot without glaze or insert small objects on the glaze layer and small holes. Where the provision is that the total glaze defect area in each insulator unit must not exceed: $100x\frac{D\ X\ F}{2000}$ mm2 And every single glaze defect must not exceed: $50x\frac{D\ X\ F}{20000}$ mm2 D = largest diameter of the insulator F = The creepage distance of the insulator So for pin posts, the total glaze defects must not exceed: 100 x 170 x 534/2000 = 4539 mm2 And every single glaze defect must not exceed: 50 x 170 x 534 / 20000 = 226,95 mm2.

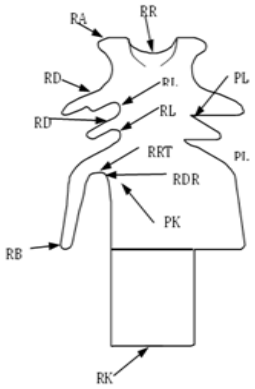

Fig 3 : Types of Pin Post defects

Table 3 : Production data of pin post insulators in April 2020 and company defect target.

Bagian Proses	April 2020			Target Rijek
	Total produksi	Rijek	% Rijek	
Finishing	20.750	232	1,12	0,40%
Natural Drying	21.556	532	2,47	0,50%
Oiling	21.013	1.767	8,41	3,50%
Firing	19.152	0	0,00	2,50%
Rutin Test	15.830	147	0,93	0,80%

e. Project Chapter

In making a project chapter, the most important thing is to make a goal statement. The objective statement must be specific and measurable, because it becomes the basis for improvement efforts (Desai et al., 2014). Then the goal statement is seen in table 4.

2. Measure Phase

The measure phase consists of finding and executing the data that has been collected to establish the basics of improvement and measuring the CTQ as the target process and calculating the sigma level value.

a. Production Control Chart

To create a control chart and binomial capabilities of each production section, researchers used the help of the Minitab 18 application. Figure 4: shows the control chart and capabilities in the finishing, natural drying, oiling, combustion and routine test sections.

Table 4 : Project Chapter

PROJECT CHAPTER	
BUSINESS CASE	OPPORTUNITY STATEMENT
Production rejects in April 2020 in several parts of the production did not reach the target set by the company, in section :	The production reject in April 2020 in several parts of the production did not reach the target set by the company, as a result, production in April lost as much as:
• Finishing section reject is 1.18% while the target is 0.4%	• finishing section: 149 pcs (0.78% of April 20 production)
• Natural drying section reject is 2.46% while the target is 0.5%	• natural drying section: 424 pcs (1.96% of April 20 production)
• Oiling section reject is 8.4% while the target is 3.5%	• oiling section: 1,029 pcs (4.9% of April 20 production)
• Firing section reject is 10.1% while the target is 2.5%	• firing section: 1,130 pcs (7.6% of April 20 production)
• Routine Test reject is 0.92 while the target is 0.8%.	• routine test section: 19 pcs (0.12% of production April 20).
GOAL STATEMENT	PROJECT SCOPE
"Reducing the pin post production flux in the finishing section from 1.12% to 0.4%, the natural drying portion from 2.49% to 0.5%, the oiling portion from 8.41% to 3.5%, the combustion portion of 10.21% to 2.5% and the routine test portion from 0.93% to 0.8%, at the end of semester 1 ".	Scope : Production in the finishing section, natural drying, oiling, firing and routine tests

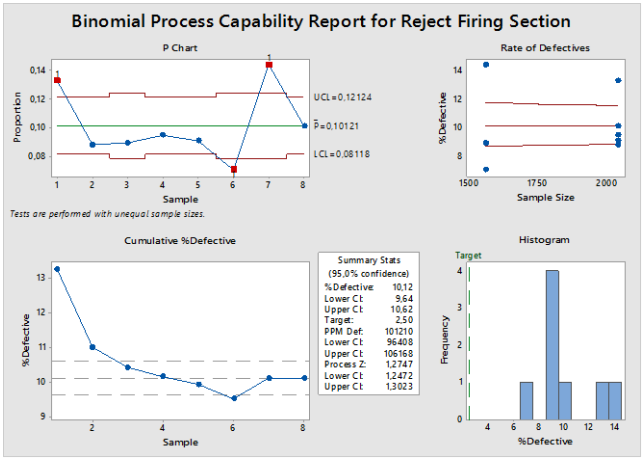

Fig 4 : control chart and capabilities in the finishing, natural drying, oiling, combustion and routine test sections.

b. Calculating the Sigma Leve

In calculating the value of DPO and DPMO using historical data for April 2020, which shows the capability of the process before repair. Measurement of the six sigma level with the help of the six sigma calculator application. Table 5. shows the results of the calculation of DPO, DPMO and six sigma level.

Table 5 : The six sigma calculation results table

Proses	DPO	DPMO	Level Sigma
Finishing	0,011180723	11180,723	3,78
Natural Drying	0,024679904	24679,904	3,47
Oiling	0,084090801	84090,801	2,88
Firing	0,101209677	101209,677	2,77
Rutin test	0,009286166	9286,166	3,85

3. Analyze Phase

In the Analyze Phase, the root cause of the problem is determined using the Pareto diagram from the QC data and fishbone diagrams.

a. Pareto Diagram

The Pareto chart is a tool that can determine which improvements need priority.

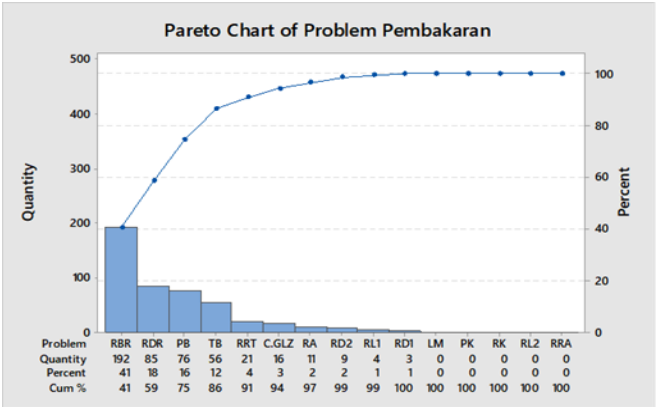

Fig 4 : Pareto diagram parts of finishing, natural drying, oiling, burning and routine tests.

b. Fishbone Diagram

In finding the source of the cause of the defect, this study conducted direct interviews with sources who were considered to be experts to obtain information about the causes of potential defects, then a Fisbone Diagram was made to be able to determine the causes of the defect. After that, from the possible root cause fishbone diagram, discussions and field observations were made to obtain the root cause. The figure in the appendix 1 shows a fishbone diagram by section.

4. Improve Phase

At the Improve phase, an analysis of corrective actions will be carried out to overcome the problem of reducing pin post insulator pressure, then calculating the back using the 5W1H concept (Why, When, Who, Where, What and How). Table 6 shows 5W1H to solve the root cause.

5. Control Phase

The control phase in the DMAIC approach is about maintaining the changes made in the improve phase. Table 7 is a control to maintain the changes made in the problem improvement phase.

a. Analysis capabilities

Capability analysis is a comparison of process performance after repair with specified requirements and before repair. Appendix 2 shows the analytical capabilities of each section.

b. Calculates the six sigma level

After getting the data from the results of the improve, the DPMO calculation is done again to determine the next performance. Table 8 shows the results of the calculation of the six sigma level after the improve phase.

Tabel 6 : Table 5W1H

No	Penyebab	Why	What	Where	When	Who	How
1	Vaccum in the finishing part is not stable (too big or small)	Because the vaccum duct is clogged with residual dirt	Vacuum lines cleared and operator finishing at briefings	in the finishing section	18-May-20	Maintenace	Vaccum finishing line cleaning and routine maintenance checks
2	The auger pugmill or extruder has worn more than 5 mm	Because 45,597 km have been used, it needs maintenance	Repair of the auger and maintenance standards were established	in the extruder	08-Jun-20	Maintenace	Repair of the auger by patching worn augers and making a pugmill wear checkset that converts from pcs to m for periodic maintenance
3	Operators in entering the feeder into the mold forming as long as it is not perpendicular.	Because the going in forming is not perpendicular because the pugmill operator is in a hurry to put the going into the lorry.	Pugmill operators are trained to put the going so as not to tilt.	on the pugmill section	08-Jun-20	Operator pugmill	Pugmill operator training for laying down and consistent monitoring of work by the Head of Formation.
4	Between the HG in the forming section and the seized part in the finishing section, the dimensions don't match	By checking the results of the forming form are placed in seized, the result is that the lip of the skirt does not reach the confiscated stoper.	Repairs are carried out for confiscation and standards are made for maintenance.	in the finishing section	25-Jun-20	Finishing and maintenance operators	Use the checksheet for use of HG and confiscated molds and check the similarity of dimensions of confiscated and HG after each use of 20,000 pcs for maintenance
5	There is no torsional measurement for YG mold results	Because the most recent measurement is sufficient as a reference for checking the measured measurements.	Dilakukan pengecekan untuk puntiran YG dan operator diberi training.	in the forming section	23-Jun-20	Forming operator, Head of forming and QC	Making a check sheet for YG measurement and setting the rotation standard for YG, namely 90 degrees.

No	Control	Tool	How to often	Checking	Who
1	Vaccum	Maintenance checklist	Monthly	Vaccum duct	Maintenance
		Production checklist	Daily	Work consistency	Head of Forming Section
2	Auger	Extruder usage checksheet	Monthly	Length x production pcs	Maintenance
3	Consistent insertion of going into mold forming	Production checklist	Daily	Work consistency	Head of Forming Section
4	HG compatibility with sita	Production checklist	Weekly	Number of production	Forming operators, finishing and forming technicians.
5	YG twist	YG checking checksheet	Daily	Degree of twisting	Forming operator, Head of forming and QC

Table 7 : Table control after improvement

Table 8 : The table is the calculation result of DPO, DPMO and six sigma level after the upgrade stage.

Proses	DPO	DPMO	Level Sigma
Finishing	0,002962963	2962,963	4,25
Natural Drying	0,003800601	3800,601	4,17
Oiling	0,031134374	31134,374	3,93
Firing	0,018872549	18872,549	3,58
Rutin test	0,002576828	2576,828	4,3

From the table, it is found that the results of the improvements that have been made can reduce the DPMO value, in the firing section from 101209.67 to 18872.54. Meanwhile, there was an increase in the sigma value, in the firing section from 2.77 to 3.58.

V. CONCLUSIONS

Based on the results of the research that has been done, it can be concluded that:
In the firing section, rijek occurs: RDR (inner skirt crack), RBR (skirt lip crack) and PB (broken body). With the main causes, namely: the pugmill machine is worn out, the dimensions of the Honggote (HG) shape in the forming and seizure sections are not matching, vaccum finishing is not stable, and there is no measurement of the twist of the Yobigote (YG) twist. The reasons for this were repaired as follows: cleaning the vaccum ducts in the finishing section are kept clean from material impurities, auger repairs by patching worn augers and periodic maintenance, repair of Sita and HG to match the radius and periodic maintenance and routine checking twist of YG and making new SOPs.

Using the Six Sigma method has a positive effect on the quality of the products produced. This is shown by increasing the six sigma level.

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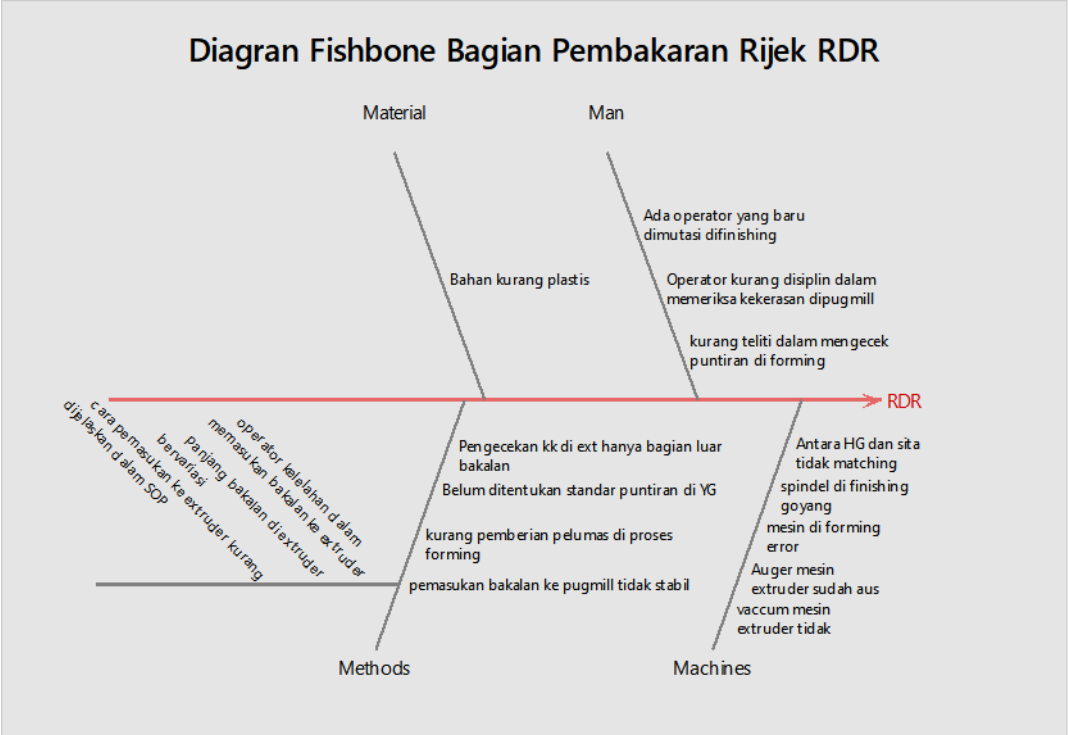
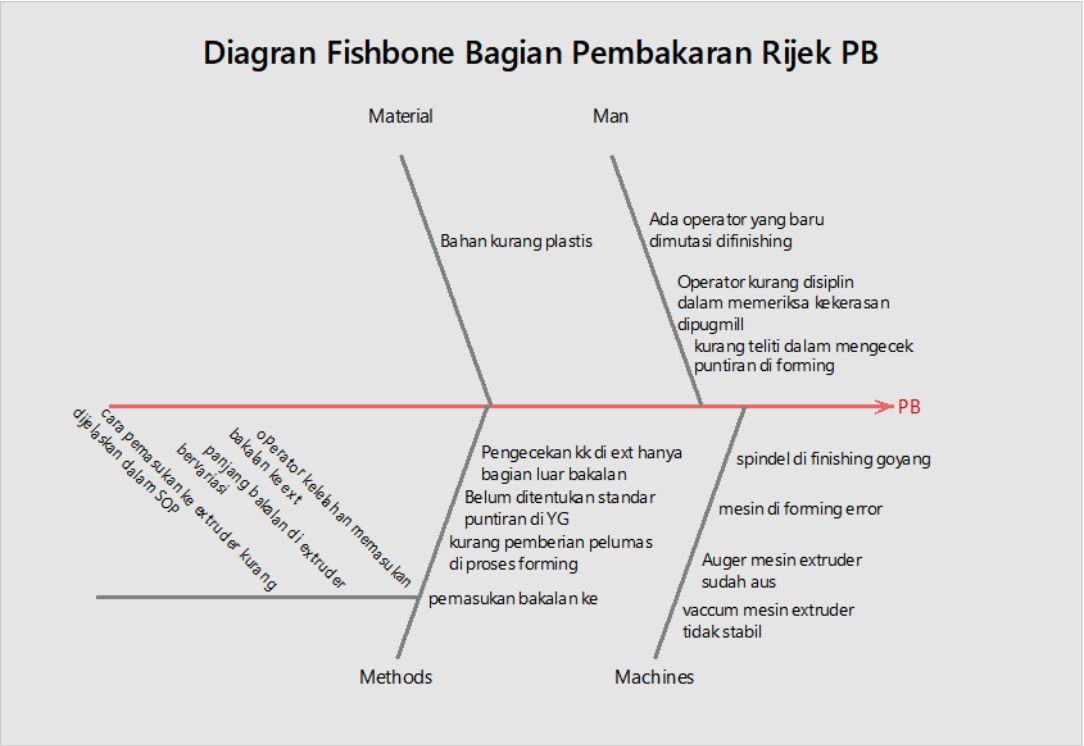
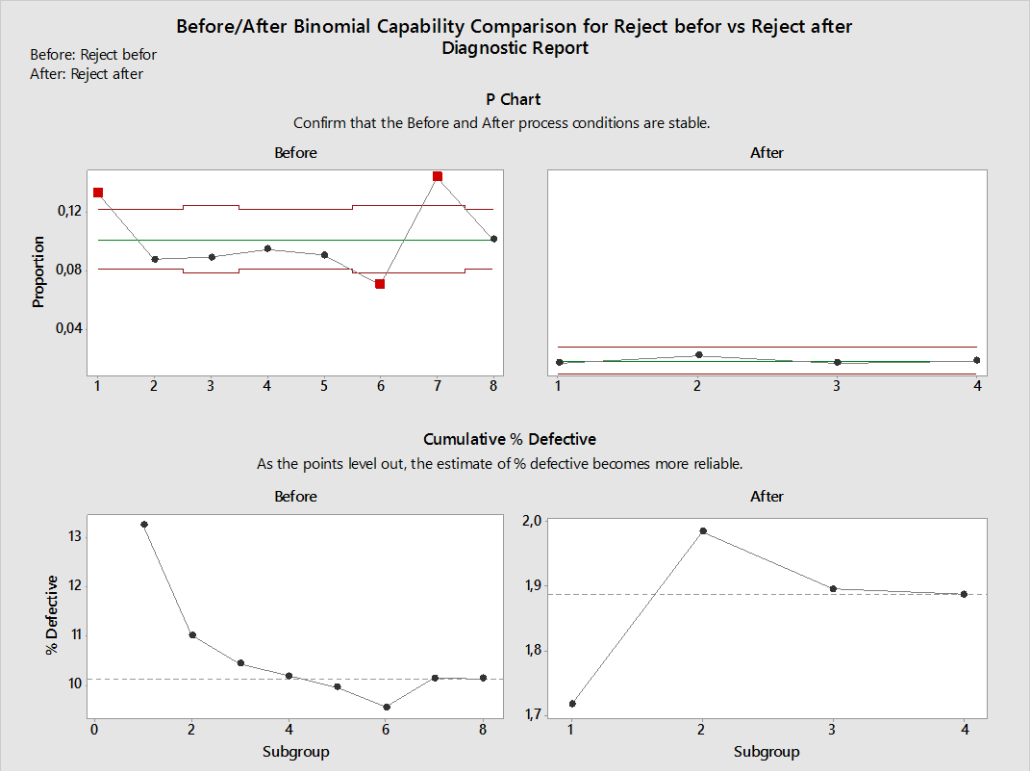
APPENDIX 1

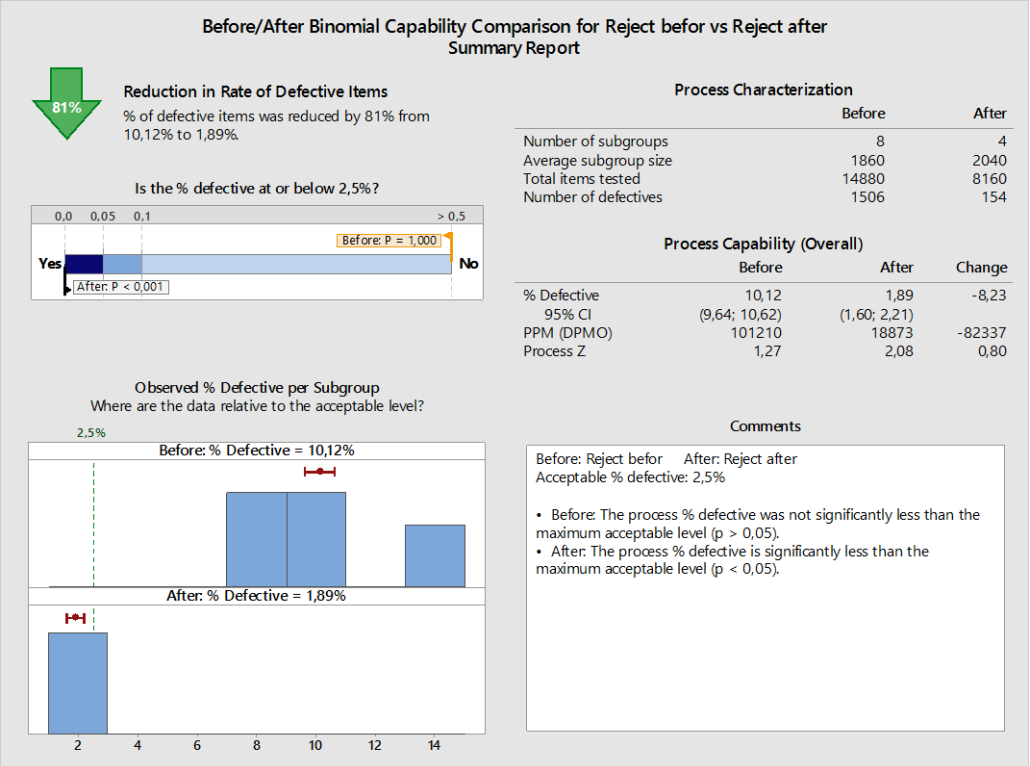

Diagran Fishbone Bagian Pembakaran Rijek RDR
Material
Man
Bahan kurang plastis
Ada operator yang baru dimutasi difinishing
Operator kurang disiplin dalam memeriksa kekerasan dipugmill
kurang teliti dalam mengecek puntiran di forming
RDR
Cara pemasukan ke extruder kurang dijelaskan dalam SOP
operator kelelahan dalam memasukan bakalan ke extruder
panjang bakalan di extruder bervariasi
Pengecekan kk di ext hanya bagian luar bakalan
Belum ditentukan standar puntiran di YG
kurang pemberian pelumas di proses forming
pemasukan bakalan ke pugmill tidak stabil
Antara HG dan sita tidak matching
spindel di finishing goyang
mesin di forming error
Auger mesin extruder sudah aus
vaccum mesin extruder tidak
Methods
Machines


Diagran Fishbone Bagian Pembakaran Rijek RBR
Material
Man
Bahan kurang plastis
Operator kurang disiplin dalam memeriksa kekerasan diforming
Operator kurang disiplin dalam memeriksa kekerasan difinishing
kurang teliti dalam mengecek puntiran di forming
Operator kurang disiplin memasukan ke sita dengan
Ada operator yang baru dimutasi difinishing
RBR
trayek dryer terlalu cepat
Penyeponan di mesin finishing kurang basah
kurang pemberian minya untuk forming
pengecekan kk di forming hanya di samping
cara pemasukan bakalan ke sita finishing
Cetakan HG dibagian forming masih kasar
Daya vaccum di finishing terlalu besar
Spindel finishing goyang
Radius HG forming kurang bulat
Methods
Machines


Diagran Fishbone Bagian Pembakaran Rijek PB
Material
Man
Bahan kurang plastis
Ada operator yang baru dimutasi difinishing
Operator kurang disiplin dalam memeriksa kekerasan dipugmill
kurang teliti dalam mengecek puntiran di forming
PB
cara pemasukan ke extruder kurang dijelaskan dalam SOp
operator kelelahan memasukan bakalan ke ext
panjang bakalan di extruder bervariasi
Pengecekan kk di ext hanya bagian luar bakalan
Belum ditentukan standar puntiran di YG
kurang pemberian pelumas di proses forming
pemasukan bakalan ke
spindel di finishing goyang
mesin di forming error
Auger mesin extruder sudah aus
vaccum mesin extruder tidak stabil
Methods
Machines

APPENDIX 2


Before/After Binomial Capability Comparison for Reject befor vs Reject after
Diagnostic Report
Before: Reject befor
After: Reject after
P Chart
Confirm that the Before and After process conditions are stable.
Before
After
Proportion
0,12
0,08
0,04
Cumulative % Defective
As the points level out, the estimate of % defective becomes more reliable.
% Defective
Subgroup
Subgroup


Before/After Binomial Capability Comparison for Reject befor vs Reject after
Summary Report
81%
Reduction in Rate of Defective Items
% of defective items was reduced by 81% from 10,12% to 1,89%.
Process Characterization
Before
After
Number of subgroups 8 4
Average subgroup size 1860 2040
Total items tested 14880 8160
Number of defectives 1506 154
Is the % defective at or below 2,5%?
Yes
No
Before: P = 1,000
After: P < 0,001
Process Capability (Overall)
Before
After
Change
% Defective 10,12 1,89 -8,23
95% CI (9,64; 10,62) (1,60; 2,21)
PPM (DPMO) 101210 18873 -82337
Process Z 1,27 2,08 0,80
Observed % Defective per Subgroup
Where are the data relative to the acceptable level?
2,5%
Before: % Defective = 10,12%
After: % Defective = 1,89%
Comments
Before: Reject befor After: Reject after
Acceptable % defective: 2,5%
• Before: The process % defective was not significantly less than the maximum acceptable level (p > 0,05).
• After: The process % defective is significantly less than the maximum acceptable level (p < 0,05).