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Quality Control And Improvement For Process Printing Of The Product Packaging Using Integration Of Fmea-Triz

Sherva Rafsanjani

[a]Bahaudin Mudhary University of Madura, Sumenep, Indonesia

A B S T R A C T

In this research, Product packaging has played an important role in a storage container product. One of the barriers in product quality packaging is common defects in the production process of the package. defects of Packaging will cause complaint from the customer. A way to reduce defects that occur is the quality control at the level of the process. This research uses the Six Sigma process improvement as a reference using the stages of DMAIC. The step of definition object, include define manufacturing operation process chart, identification of defects, critical process, critical to quality as well as determine priority defects using the pareto chart. Phase measure using the Capability process and DPMO to know the performance of the process. The step of analyzing use FMEA to get priority causes failure of the products in the process, then improve used by integration the method of TRIZ to get suitable recommendations. Then apply the control mechanism. The results showed the process of printing is a critical process with the value of the DPMO 18372 Sigma Level, level sigma for the plant is 1.58 sigma and the capability of the process is 1, 19. As for the results of FMEA, for critical defects miss print caused by the component of the cylinder, imprecision of gear and bearing, for color defects caused by the composition of ink and line defects caused by great mixed dried ink. Based on the analysis of contradiction matrix and 40 inventive principles, recommendations to repair defects miss print that is cleaning component of the gearbox using a vacuum cleaner, help tool vibration tester and the addition of the lock nut, for Defects the colors apply training to measure the viscosity and the development strategy of the supplier. Line defects adding CCTV in station printing and periodic cleaning of the ink pump.

Keywords: DMAIC, Operation Process Chart, Pareto Chart, FMEA, TRIZ

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1. Introduction

In Currently product packaging has played an important role as a product storage container. The presence of a container or wrapper can help prevent damage and protect the products contained therein from the dangers of pollution and physical disturbance (friction, impact, vibration). Nearly all manufactured or processed goods require packaging in facilitating product storage and protecting product content to maintain its quality (Lamb et al., 2004).

This study uses X Plant as a case study where becomes one of the big players in the packaging industry or product packaging to serve food and beverage industry from other company's customers. In serving customers of other companies, X plant includes companies that use the Make to Order system with mass customization production. In this study, the object observed is in the Printing Division. Printing Division is in charge of making plastic bags packaging products from other company's customers and original products made by X Plant. One of the obstacles is the frequent errors in the packaging production process resulting in defects in the packaging product. Supervision of defects that occur in product packaging in the printing division becomes the responsibility of the Quality Control department. Based on the data in the field, the percentage of defect packaging always exceeds the maximum target defect target set by the company so that the production of packaging that pass the QC stage decreases. Because the packaging of defective products will be returned to the original process (reprocess) to the recycle material or discarded depending on the material raw materials used. Another impact if the product packaging reaches the hands of the customer (another company) cause complaints from the customers.

With the average product return, the company needs to reduce the defect on the packaging of products that occur to achieve a good production system so that the output produced in accordance with the specifications and complaints can be reduced. Based on data in the company, priority problems about the number of defect cases found in the printing process. Then the way to reduce the defect that occurs is with the improvement and quality control at the process level. Appropriate production performance measurement is a major factor in the success of the production process. Factors that are very important and determine whether or not a business success is the quality, reliability, price and delivery. Of these four factors, quality is the most important factor (Oakland, 1993). When a company focuses on quality there will be an increase in performance. Quality also

* *Corresponding author.* Phone : +6281333191201
E-mail address: sherva@unibamadura.ac.id

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has a big role in determining a company's reputation when a company is known for its reputation of good or bad product quality

It is expected that with the improvement and quality control it can reduce the defect that happened. Therefore it is necessary to process the quality control of products in this case product packaging, so the company can anticipate the defect of the product by doing improvement measures for the next production.Various types of methods are developed by the company to produce products with better quality. One uses Six Sigma as one of the quality control and improvement efforts created by Motorola Company that emphasizes process improvement for the purpose of reducing variability and making general improvements. Six Sigma is also the process of all sustainable improvements, such as the continuous deterioration of each period. Six Sigma quality improvement process includes Define, Measure, Analyze, Improve, Control or (DMAIC) stages. Where in Control stage applied Control Mechanism used as a form of application in production process to facilitate detect problem, in this case, is defect product.

This study will discusses how to reduce the defect that occurs in the product packaging in the production process that experienced a critical defect that is the printing process by performing quality control in the application of Make To Order in companies that follow Mass Customization (MC) system as a quality control tool so as to meet the expectations and customer wishes. The use of quality control model is done to overcome the problem of quality defect with Six Sigma method covering process stages of Define, Measure, Analyze, Improve, Control or (DMAIC) so that solution can be found to reduce the defect that happened. Analysis of the causes of defects in critical processes through the Failure Mode and Effects Analysis (FMEA) table and proposed improvements through Theory of Invention Problem Solving (TRIZ) solutions and process mechanisms to benefit from quality control.

2. Literature Review

2.1 Definition of package

Packaging may be defined as all activities of designing and producing containers or packs or packaging of a product. Packaging includes three things, namely the brand, the packaging itself and the label. the original packaging function just as a place or container to protect a product. But now the packaging function shifts beside to protect the product from damage as well as promotional tools in supermarkets and supermarkets. (Basu, 1996). Other packaging functions are to provide superior protection, introduce a new way of opening, giving certain indications of products and companies describing the particular quality of the product or company or some other function (Philip, 2002). From the opinion above, the packaging function in addition to maintaining and protecting the product and must be able to provide new information from producers to consumers. Packaging should also be able to provide comfort to the consumers good convenience in bringing, opening, closing and storing the product.

2.2 Six Sigma Concept

Six Sigma is a business improvement strategy to eliminate waste, reduce costs because it produces poor quality, and improve the effectiveness and efficiency of all operations so as to meet the needs and expectations of customers (Ariani, 2004). Six Sigma is defined in various ways. Sig Sixma is a way of measuring the process, the goal is near perfect, presented with 3.4 DPMO. In other words, Six Sigma is a comprehensive and comprehensive system to build and sustain performance, success and business leadership. But not all companies have to reach level 6 of Six Sigma is said to be successful, in fact some of them only reach from 4 or 5 levels already able to achieve the goals that have been made (Cavanagh, 2000).

Six Sigma is a systematic method that uses data collection and statistical analysis to determine sources of variation and ways to eliminate it (Harry & Schroeder, 2000). The Six Sigma method is based on a simple problem-solving methodology DMAIC which stands for define, measure, analyze, Improve, and Control, which combines various statistical tools as well another process improvement approach. Basically, customers will be satisfied if they receive their expected value. If the product is processed at the Six Sigma quality level then the company expects 3.4 failures per million of occasions or expects that 99.9997% of what customers expect will be in the product. The calculation is better known as Defect Per Million Opportunities (DPMO).

The benefits of Six Sigma for the company (Pande, 2002), which are: To achieve sustainable success, Set performance goals for everyone, Strengthen customer value, Accelerate improvement level, Promote learning and cross-pollination.

Step The process of improvement in Six Sigma is known as DMAIC (Define, Measure, Analyze, Improve, Control). DMAIC is a process for continuous improvement towards Six Sigma targets. DMAIC is done systematically, based on science and facts (Sartin, 2008). DMAIC is the key to solving Six Sigma problems. DMAIC includes steps that need to be implemented sequentially, each of which is essential to achieving the desired outcomes (Sartin, 2008). Successful implementation of the Six Sigma quality improvement program is demonstrated through enhanced process capability in delivering products to zero failure rates (Sartin, 2008). Therefore, the concept of process capability calculation becomes very important to understand and implementation of Six Sigma program. Technique of determining process capability related to Critical Total Quality (CTQ) for variable and attribute data. Data is a record of something, both qualitative and quantitative that is used as a guide for action

2.3 Operation Process Chart (OPC)

In determining the tools used to help understand the steps of the actual process for producing product packaging, many tools can be used among others: Big picture Mapping, Flow Process Chart, Value Stream Mapping, Operation Process Chart. However, this research used Operation Process Chart (OPC) because this research only discussed the sequence of operations starting from the beginning of the process until it became the final product or component of the product while other tools such as big picture mapping and value stream mapping both describe the whole process that happened but including also determine the number of products, delivery capacity and useful for finding waste that occurs during the manufacturing process.

Operation Process Chart (OPC) is a diagram illustrating the process steps that raw materials will experience on the sequence of operations and

checks. From the beginning to the finished product as a component and also contains the information needed for further analysis, such as time spent, materials used and place or machine tool used (Wignjosoebroto, 2003). OPC are one systematic and clear tool for communicating widely and simultaneously through these work maps we can get the information necessary to improve a working method. Thus, in an Operation Process Chart (OPC), only operations and inspection activities are recorded, sometimes at the end of the process recorded on storage.

There are four things to consider or consider in order to obtain a good work process through the analysis of the operation process map, which is the analysis of materials, operations, examination and completion time of a process.

2.4 Critical To Quality (CTQ)

CTQ are elements of a process that significantly affects the output of the process itself. CTQ is a very important attribute to note because it is directly related to the needs and desires of customers, and is the elements of a product, process, or practices that directly impact on customer satisfaction.

CTQ can be used to identify processes or products to be corrected to translate customer requests. It usually takes the form of a problem derivative or breakdown of all problems until a real or identified problem is identified to satisfy the customer's wishes.

2.5 Pareto Chart

In determining the tools used to determine the frequency of occurrence, many tools can be used among others: Check sheet, Histogram or Pareto Chart. But in this study used Pareto Chart because this research not only discuss the frequency of defects occurring in a process but at the same time determine the priority of a problem based on the largest and vital amount of frequency in a process. The Pareto Diagram is a method for managing errors, problems with defects and to help focus on problem-solving efforts. The most frequent problem is shown by the highest first bar graph and placed on the leftmost side and so on until the least problem occurs is shown by the last lowest bar trunk on the far right side. This diagram is based on the work of Vilfredo Pareto, an economist in the 19th century. Joseph M. Juran popularized Pareto's work by stating that 80% of company problems are the result of a cause that is only 20% (Heizer & Render, 2011). Using the pareto diagram, it can be seen which problem is dominant so that it can know the priority of problem solving

2.6 Process Capability Index (Cp)

Process capability is the ability of the process to produce or deliver output in accordance with customer expectations and needs. Process capability is a critical performance measure that shows the process is capable of producing in accordance with product specifications established by management based on customer needs and expectations (Gaspersz, 2002). Successful implementation of the Six Sigma quality improvement program is demonstrated by enhancing process capability in delivering products to zero defect levels. Conversely, if the process has a bad capability, the process will produce many products that are outside the boundaries of the specifications that cause losses because many products will be rejected.

The Process Capability Index (Cp) is calculated using the following formula: (Park, 2013)

Cp= (Level Sigma)/3

Assessment criteria :

If Cp $\geqslant$ 2 then the process capability is very good and able to meet the specified quality targer specification.

If 1,00 $\leqslant$ Cp $\leqslant$ 1.99 then the process capability is not enough to be sufficient so that the need to improve the process towards the target of zero failure.

If Cp <1.00 then the process capability is low and is very unable to achieve the target quality at zero failure rate.

2.7 Failure Mode and Effect Analysis (FMEA)

Fuzzy, FMEA, AHP, ANP is a risk assessment tool that is widely used in various industries, but in this study used FMEA as a priority tool for risk assessment of all causes that occur even though fuzzy techniques can improve accuracy in determining the value of risk but there is doubt in the application in real life (Liu, HC et al, 2013). While the AHP technique has a weakness that only involves the perception of subjectivity of the expert and is a mathematical method without any statistical test so that there is no limit of confidence of the correctness of elections formed (Saaty, 2008). Therefore the use of FMEA is used in this study to determine the solution of the problem.

FMEA (failure mode and effect analysis) is a structured procedure for identifying and preventing as many failure modes as possible. FMEA is a tool used to help identify and eliminate or reduce the sources and root causes of a quality problem before being in a system, sub-system, product or production process (Borror, 2008).A failure condition can be seen from anything that is included in the design flaw / failure, conditions outside the specified set limits, or changes in the product causing disruption of the function of the product. The following are the steps in making FMEA (Borror, 2008):

1. Identify potential product defects
2. Register any product defects
3. Identify the cause of each product defect
4. Identify the effects of any product defects
5. Determine the probability factor, namely numerical weighting on each cause of defects of the product
6. Determine the value of RPN (Risk Priority Number)
7. Determine action recommendations to be implemented on potential failures that have high RPN values.

The RPN value is determined to determine the appropriate action to take on the defects of the existing product. The RPN value is the result of multiplication between:

1. The level of seriousness of the effects resulting from the form of failure occurs (severity)
2. The frequency level of cause of failure occurs (occurance)
3. Level of ability to control the failure that can occur (detection)

2.8 Theory of Inventive Problem Solving (TRIZ)

TRIZ is a problem solving method based on creativity, logic, and data, resulting in solutions to existing problems. TRIZ is an acronym in Russian from Teoriya Resheniya Izobretatelskikh Zadach, in English known as "The Theory of Inventive Problem Solving". Geinrich proposed and developed the first time in 1946, in his observations of hundreds of thousands of patents of products that have been issued. These observations provide a wide range of solutions summarized in 40 inventive principles. Each principle applied is a result of contradictions that occur from a variety of specific attributes when the solution is analyzed. (Rantanen & Domb, 2002).

Ideality function or final result, separation principle, 40 inventive principles, 39 engineering parameters, and contradiction matrix are the main tools used in troubleshooting in TRIZ. Ideality function is a statement that states the ideal conditions to be achieved. Contradiction in means opposite or conflicting conditions in terms of results. An improved parameter is contradictory to other parameters hence ideal conditions of the system are difficult to achieve.

In TRIZ there are two types of contradictions: technical contradictions and physical contradictions. Technical contradiction or known trade-offs, is a difficult or even unachievable condition because it is hindered by the natural conditions of the system. In other words, when a parameter increases then other parameters will decrease. While physical contradictions are situations where a parameter increases due to the presence of other opposing parameters (Rantanen & Domb, 2002). TRIZ use procedure consists of 4 stages (Rantanen & Domb, 2002) Problem identification that is:

1. Formulate the problem
2. Find the contradiction attribute and create a matrix that will be developed with TRIZ through 39 engineering parameters.
3. Find existing troubleshooting by looking at 40 inventive principles
4. Apply TRIZ solutions that are still general to more specific solutions.

3. Research Implementation

In this research, 4 (four) phase (DMAI) are used to solve problems about process improvement. The concept used is a quality control tool for mass customization production system based on customer order using Six Sigma for improvement purpose by integrating 4 stages of DMAIC methodology consisting of Critical to Quality (CTQ) and type of process and defect for identification of object problem, prioritizing problems with pareto diagrams, and calculating sigma levels for evaluation controls on current production process priorities, as well as FMEA-TRIZ integration to find the root cause of the use of the Inventive (Inovative) Principal in the TRIZ method to help provide recommendations for improvements that are appropriate to the company's situation. The depiction of the research framework that will be created can be seen in Figure 3

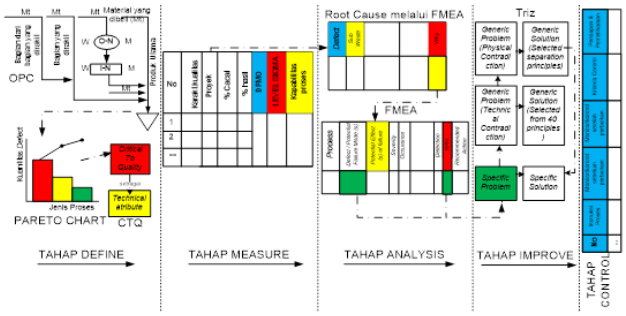

Figure 3. Research Concept

In Phase Define, described quality problems faced by the company and the determination of the goals to be achieved. This problem is obtained by brainstorming with the company management and direct observation. In addition, the depiction of the production process with the help of tools Operational Process Chart (OPC), Identification CTQ, Identify Defect Influence on Product Quality and determination of critical defect with Pareto Chart.

In Phase Measure, will be measurement stage of the research object in the critical process of printing process. The printing process is one of the processes in the manufacture of product packaging. Observation is done by obtaining the company's secondary data on the number of good product and the number of defects in the printing process. At this stage, the process level performance measurement is done by calculating the DPMO value, process sigma level and process capability.

In Analyze Phase aims to find the priority of product quality problem of defective packaging in printing process which is critical process based on pareto chart defect data with Failure Mode and Effect Analysis (FMEA) method. Information about the causes of the problem is obtained from the interviews with the operator and the employee concerned in the field and make direct observations in the relevant departments.

The improvement stage is the last stage in the DMAIC methodology in this research. Researcher gives recommendation of improvement to the priority of the problem causing the defect of the product at the company. It proposes improvements to the production process based on failure mode analysis with the highest RPN value in the FMEA Table in the previous stage (analyze stage) and integrated with the TRIZ method with the aim of eliminating the number of product defects to increase the sigma value. In this process, identification of contradictions of existing matrix related parameters involved in each defect cause and determination of innovation principle of TRIZ to each technical response.

4. Case Study

4.1 Define Phase

Defining Objects Amatan conducted in this research is a product packaging that the production in the Printing department where applying job orders based on customer requests originating from other companies. For defect cases, the number of defects occurring in the production process is 1.81%, exceeding the 1.00% target set by the company with an average

case of 63 defect cases per month. the number of defect cases in the printing process dominates as many as 176 cases where the printing process is the first process in the manufacture of product packaging. Where in the printing process using a printing machine to process printed product packaging with 8 color stations. Below table 1 is a complaint data (return) from customers (other companies) in the period January to September 2017. While in table 2 is the case data of product packaging defects for each production process.

Table 1. Data Complain (Product Return) From Customer

MONTH	2017				Target
	CASE	*Product Return* (kg)	*Finish Good* (kg)	%	(kg)
1	52	7.018,72	374.170,84	1,88%	5.311,00
2	47	4.193,11	291.004,41	1,44%	5.311,00
3	73	6.860,05	306.719,84	2,24%	5.311,00
4	70	4.777,60	410.062,22	1,17%	5.311,00
5	79	10.809,31	404.506,84	2,67%	5.311,00
6	40	2640,58	314.178,04	0,84%	5.311,00
7	71	5376,83	351.804,12	1,53%	3.125,00
8	56	7782,45	369.117,96	2,11%	3.125,00
9	79	9411,9	382.969,00	2,46%	3.125,00
total	567	58.870,55	3.204.533,27	16,33%	
Average/ Month	63,00	6.541,17	356.059,25	1,81%	
Target/Month	60	5.311,00		1,00%	

Table 2. Data Case From Production Process

Month	**Total Case in Process**			
	Printing	Laminasi	Slitting	Bag Making
1	24	16	8	0
2	14	10	12	0
3	26	15	17	6
4	23	20	20	5
5	14	44	15	2
6	13	14	9	2
7	22	17	10	0
8	21	9	14	0
9	19	23	15	0
Total	176	168	120	15

Operational Process Chart of the product packaging process describes the process steps that will be experienced by raw materials, especially the operation process and the examination. The OPC contains the necessary information for further analysis, including time spent, the material used and the place or machine used for the manufacture of product packaging.

The following are OPC packaging products.

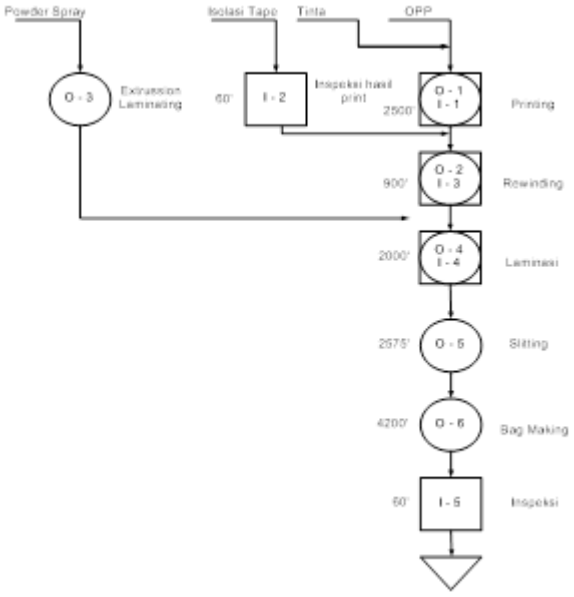

Figure 4. Operational Process Chart

From Figure 4 it can be seen that the total time for the manufacture of the product packaging takes time for 12295 seconds in the form of one roll of production where one roll of production is 3000 meters and For the whole production process there are 6 stages of production process and 5 times the inspection process until finally the product put into place storage of finished products.

Furthermore, identification Critical To quality to obtain the main attribute of consumer needs as well as elements of the process / activities that directly affect the achievement of the desired quality. In Case, the critical process is printing process. It is expected that defects in the printing process to make the product packaging can cover all the standards and specifications desired by the customer. Below is a list of the various CTQ attributes of the printing process.

Table 3. CTQ Product Package

Product	Process	CTQ	Spesification
Product Package (in roll)	*Printing*	Printing Size and type of raw material	In accordance with spec each type of product packaging based on customer wishes (OPP, PE, dan PP)
		Ink composition	In accordance with the spec & ink levels used for each type of product
		Print Position	The position of printed packaging in the form of a roll (reverse or surface)
		Direction Rolls	The direction of roll rolling rolls of packaging (feet or head)
		Ink viscosity	-Colors In accordance with the packaging output design (-1,0,1)

Product	Process	CTQ	Spesification
			- The ink attachment that sticks to the packaging results is tested through celotape test
		Package design size	- In accordance with the standard design pitch size on the packaging view - The distance between the photocell with each other in accordance with the packaging product design
		Color registers	In accordance with the standard pitch color size on the packaging view

For the type of Defect occurs due to the key quality characteristics of a product does not match the standard set by CTQ itself. Defect that occurs in the printing process are: miss print, line, ink blot, blobor mold, color is not standard, blocking, spots, dry ink, blusseing, mottling.

Below in figure 5, pareto diagram for the type of defect that will be prioritized for improvements to the printing process.

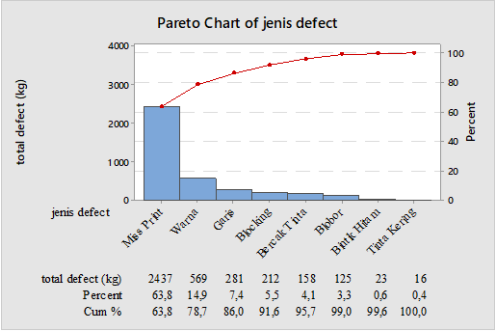

Figure 5. Pareto Chart Total defect in printing process.

Based on pareto rules that apply 80-20, it can be taken three types of critical defect that will be done improvement on the printing process. The three types of critical defects are in the form of data defect attributes ie defect miss print which has a percentage of 63.8%, color defects that have a percentage of 14.9% and defect the line with a percentage of 7.4%.

4.2 Measure Phase

The phase measure is the measurement stage of the research object in the critical process of printing process. At this stage, the process level performance measurement is calculating the DPMO value, process sigma level and process capability. Based on the total product data defect and total production obtained DPMO calculation as follows

$$\text{DPMO} = \left(\frac{number\ of\ failed\ units}{number\ of\ inspection\ units}\right) \text{x } 1.000.000$$

$$\text{DPMO} = \left(\frac{58870{,}55}{3204533{,}27}\right) \text{x } 1000000 = 18371{,}02$$

Based on the above DPMO then determine the sigma level, by way of calculation as follows

$$Level\ sigma = normsinv\left(\frac{1.000.000-\text{DPMO}}{1.000.000}\right) + 1{,}5$$

$$Level\ sigma = normsinv\left(\frac{1.000.000-18371{,}02}{1.000.000}\right) + 1{,}5 = 3{,}58$$

From the above calculation can be seen that the printing process on the production of product packaging is currently still low because the DPMO value is still high, which amounted to 18371 which can be interpreted that from one million opportunities there will be 18371 possibility that the printing process will produce defects. DPMO value is then converted into sigma level and obtained value 3.58 sigma. The value can still be categorized as good for industry in Indonesia because the average industry in Indonesia is still at the level of 3 sigma, but the sigma level has not been able to compete in world class which has quality control at 6 sigma level. then performed the calculation process capability (Cp) is used to determine the ability of the current process in producing products that meet the predefined specifications. Here is a calculation to determine the value of printing process capability.

$$\text{Cp} = \left(\frac{Level\ Sigma}{3}\right) = \left(\frac{3{,}58}{3}\right) = 1{,}19$$

Because the value of $1.00 \leqslant \text{Cp} \leqslant 1.99$, namely Cp = 1.19 then the process capability is in a position not enough able to produce a product in accordance with product specifications set by the management company. Based on the needs and expectations of customers so need to improve the process towards the target of zero failure. From the above calculation results can be seen that printing capability on the printing machine overall product packaging is currently still low because the value of Cp of 1.19 and the value of Cp is less than 2 then the process capability is identified not reach the target specification and still need to be improved the process of use achieve zero failure.

4.3 Analyse Phase

In Analyze Phase aims to find the priority of product quality problem of defective packaging in printing process which is critical process based on pareto chart defect data with Failure Mode and Effect Analysis (FMEA) method. The FMEA method aims to analyze potential process failures and evaluate those failures. By using FMEA researchers can find out the failures that give the largest contribution to each critical defect so that a priority for recommendation improvement. Calculations and SOD scale assessments are made according to the type of defect that is the focus for improvement. In the use of this FMEA, valuation and weighting are based on mutual agreement with the company. Here below is the highest RPN value in each critical defect in the printing process

Table 4. Results FMEA table for highest RPN value on each defect

Defect	**Failure Mode**	**Potential Failure Effect**	**Potential Causes**	**Current Controls**	**RPN**
Miss Print	Cylinder Component (*gear*)	symptoms are not smooth on the print process	Gear on cylinder wear	Check the gear	324
	Hazing	Chrome results in rough	Unengraved rough terrain is	Rub / sandpaper cyl with 600	280

		cylinder	not printed	emery (sandpaper)	
	Cylinder Component (*Bearing*)	Bearing damage in cyl, impression roll and idle roll	The bearing component is not precise	Check and change bearing components	224
Colour	Colour	Viscosity & Density ink is not suitable	Ink composition incorrect	Set the viscosity & density according to the color reference	70
Line	Outline	Ink composition does not match	Good ink mixed with dry ink	Cleaning on the bowl part of the ink filler	42
	Small lines like hair	Dirt easily catches	Doctor Blade is too hard pressed	Setting doctor blade according to SOP	24
	Double print line	pigments along the doctor blade	Semi-hard pigment (slightly solid / solid / clump) under doctor blade	Put a low pressure around the place of the line	

4. 4 Improve Phase

The improvement stage is the last stage in the DMAIC methodology used in this study. At this stage, the researcher gives recommendation of improvement to the priority of the problem causing the defect of the product at the company. It proposes improvements to the production process based on failure mode analysis with the highest RPN value in the FMEA Table in the previous stage (analyze stage) and integrated with the TRIZ method with the aim of eliminating the number of product defects to increase the sigma value. In this process, identification of contradictions of existing matrix related parameters involved in each defect cause and determination of innovation principle of TRIZ to each technical response

Table 5. Conflict Parameter Miss Print defect problem.

No	Kontradiksi
	Gear on cylinder wear
1.	Interaction in system >< gear resistance (10) *force* >< (14) *strength*
2.	Compatibility Operation >< Gear Endurance (29) *manufacturing presisi* >< (14) *Strength*
3.	Cause of cylinder (gear) wear >< Friction on the surface (31) *Object Generated harmfull factor* >< (11) *Stress or pressure object*
4.	Machine element complexity >< Detection of gear location (36) *Device Complexity* >< (37) *Difficulty of detecting and measuring*
	Unengraved rough terrain is not printed
1	System interaction >< Chrome layer resilience (10) *Force* >< (14) *Strength*
2	Position change vulnerability >< Operation Suitability (30) *External harm affects the object* >< (29) *Manufacturing Precision*
3	Simplicity of Operation >< Operation Suitability (33) *Ease of Operation* >< (29) *Manufacturing Precision*
	The bearing component is not precise
1	Contour bearing >< Press roll movement (12) *Shape* >< (5) *area moving object*
2	The vulnerability generates miss register >< Operation Suitability (30) *external harm affect the object* >< (29) *Manufacturing Precision*
3	Ease of fabrication >< Vulnerability generates miss register (32) *ease of manufacturing* >< (30) *external harm affect the object*

Table 6. Parameter Conflict Problem defect color

No	Kontradiksi
	Colour are unspeck
1.	Stability of viscosity & density of ink >< wasted time (13) *stability of the object's composition* >< (25) *loss of time*
2.	Stability of viscosity & density ink >< wasted material (13) *stability of the object's composition* >< (26) *quantity of substance*
3.	Dosage viscosity & density ink >< wasted time (28) *measurement accuracy* >< (25) *loss of time*
4	Dosage of viscosity & density of ink >< susceptible to dirt particles (28) *measurement accuracy* >< (30) *harmful factor acting on subsystem*

Table 7. Parameter Conflict Problem defect Line

No	Kontradiksi
	Arise outline, small, double and dashed line
1	Ink composition does not match >< good ink susceptibility mixed with dry ink (13) *stability of the object's composition* >< (26) *quantity of substance*
2	Ink composition is not suitable >< susceptible to dirt particles (13) *stability of the object's composition* >< (30) *harmful factor acting on subsystem*
3	Setting doctor blade >< susceptible to dirt particles (28) *measurement accuracy* >< (30) *harmful factor acting on subsystem*
4	Vulnerability produces semi-hard pigment >< detection of location pigment (30) *External harm effects the objects* >< (37) *Difficult of detecting and measuring*

Then the parameters are changed and the parameters are maintained based on the contratiction matrix. Changed parameters are the most important parameters that need improvement to support process improvement activities. Refer to table 8, the black portion is meaningless because of the similarity of the engineering parameters, to the part marked with the strip (-) means that it has no contradiction relationship, and the yellow part is the suggested principle.

Table 8. Contradiction Matrix Defect Miss Print cause Gear on cylinder

	Worsening Parameter	*Stress or pressure object*	*Strength*	*Difficulty of detecting and measuring*
	Improving Parameter	11	14	37
10	*Force*	18, 21, 11	35,10,14,27	36,37,10,19
29	*Manufacturing presisi*	3,35	3,27	-
31	*Object generated harmful factor*	2,33,27,18	15,35,22,2	2,21,27,1
36	*Device Complexity*	19,1,35	2,13,28	15,10,37,28

Table 9. Contradiction Matrix Defect Miss Print Cause Unengraved Rough Terrain Is Not Printed

	Worsening Parameter	*Strength*	*Manufacturing Precision*
	Improving Parameter	14	29
10	*Force*	35,10,14,27	28,29,37,36
30	*External harm affects the Object*	18,35,37,1	26,28,10,18
33	*Ease of Operation*	32,40,3,28	1,32,35,23

Table 10. Contradiction Matrix Defect Miss Print Cause The bearing component is not precise

	Worsening Parameter	*Area moving object*	*Manufacturing Precision*	*External harm affect the object*
	Improving Parameter	5	29	30
12	*Shape*	5,34,4,10	32,30,40	22,1,2,35
30	*External harm affect the object*	22,1,33,28	26,28,10,18	
32	*Ease of manufacturing*	13,1,26,12	-	24,2

After mapping the contradiction on the contradiction matrix, then the idea of improvement proposed as follows: Principle 10 (Preliminary Action) is Perform before the required, to clean the components by using a vacuum cleaner. The purpose of the preliminary action principle is to prepare before processing begins. Principle 28 (Mechanical Interaction Substitution) is Replace mechanical methods with sensory methods (optical, acoustic, taste or odor). required a special tool that with Vibration Tester to measure vibration. Principle 3 (Local Quality) is Make each part of the function object in the most appropriate conditions for operation, namely the addition of lock nut on Gear.

Then, for colour defect contradiction matrix below table (refer table 11)

Table 11. Contradiction Matrix Defect Colour

	Worsening Parameter	*Loss of time*	*Quantity of substance*	*Harmful factor acting on subsystem*
	Improving Parameter	25	26	30
13	*Stability of the object's composition*	35,27	15,32,35	35,24,30,18
28	*Measurement accuracy*	24,34,28,32	2,6,32	28,24,22,26

After mapping contradictions on the contradiction matrix, then the idea of improvement suggestions as: Principle 24 (Intermediary) is Combining one temporary object with another that can be easily moved again, the company through KA Group Operator and KA Group RM (maintenance) Printing conducts training and sharing on how SOP measurements measure the viscosity size according to standard against the operator responsible for measuring the viscosity and unloading-pairs against printing machine components. Then, Principle 15 (Dynamicity) is Allows design of system characteristics to be optimal or find optimal operating conditions refer supplier development strategy.

Then, for line defect contradiction matrix below table (refer table 12)

Table 12. Contradiction Matrix Defect Line

	Worsening Parameter	*Quantity of substance*	*Harmful factor acting on subsystem*	*Difficulty of detecting and measuring*
	Improving Parameter	26	30	37
13	*Stability of the object's composition*	15,32,35	35,24,30,18	35,22,39,23
28	*Measurement accuracy*	2,6,32	28,24,22,26	26,24,32,28
30	*External harm effects the objects*	22,19,29,40		22,19,29,40

After mapping the contradiction on the contradiction matrix, the following ideas for improvement are proposed: Principle 24 (Intermediary) is Using an intermediate or intermediary process ie the company adds a tool in the form of installation of CCTV in each print machine amounting to 8 to monitor the state of print when printed ink. Then, Principle 19 (Periodic Action). It does not take continuous action, but uses periodic acts of cleaning the bowl (ink tube) and around the inked-ink pump channel (pigments that have been too long attached) once a day at the beginning of shift 1 when the production process has not run exactly in the early.

Performed a control system mechanism that aims to ensure that the improvement and improvement of quality is done and run on target, so that the implementation of each sub-process can be controlled so that the defect does not happen repeatedly.

5. Result

For the measurement of process level performance, the printing process which is the first process and a critical process in the manufacture of product packaging is still high, amounting to 18371.02 which is interpreted that from there will be 18371,02 opportunities that the printing process will result in product defects. DPMO value is then converted into sigma level and obtained value 3.58 sigma. The value can still be categorized as good for industry in Indonesia because the average industry in Indonesia is still at the level of 3 sigma, but the sigma level has not been able to compete in world class which has quality control at 6 sigma level. From the calculation of process capability (Cp) print machine on the printing process have a potential index value of 1.19 process.

From the results of Failure Mode and Effect Analysis (FMEA), the impact of adverse effects in case of defect miss print is bearing damage, impression roll in the cylinder component, in unengraved coarse area not printed as a result of chrome on rough cylinder and gear on cylinder in wear condition. While the impact of adverse effects if there is a color defect resulting from viscosity and density ink does not match with different packaging specs, the influence of solvent also affect the viscosity of ink printed on the packaging. For damapk due to line defect is the composition of ink that is not appropriate because of the good ink mixed dry ink that has settled in the base of the bowl.

Recommendation of improvement given to the problem of miss print on the product packaging that has been printed is to check and cleaning with vacuum cleaner before the damage occurs on the component parts in the gear Box, the use of tools Vibration Tester is a machine vibration tool, the addition of lock nut on the nut . The recommended improvements to the problem are color defectsconduct training and sharing on how SOP measurement measures the correct viscosity size, conducting supplier development strategy so that the quality of ink material is in accordance with the specification. The recommended improvement for the problem of line defects is through the CCTV equipment placed at each station, performing the ink bowl cleaning and around the ink pump channel regularly.

6. Conclusion

The result of Printing process performance based on Defect per Million Opportunities (DPMO), sigma level, and process capability is obtained: Defect per Million Opportunities (DPMO) value in printing process for January-September period is 18372. Company Sigma level for printing process is at 3.58 sigma. Process Capability (Cp) for the printing process in producing the product is at 1.19

From result of Failure Mode and Effect Analysis (FMEA), the cause of defect factor based on highest Risk Priority Number for critical defect that is: The cause of defect Miss Print is most often caused by the cylinder component of the gear and bearings and the type of failure for hazing (blurred color in the printed area). The most common cause of color defects is the ink composition used in the printing process is not in accordance with the standards that become the reference in the manufacture of product packaging.. The cause of the line defect on the product packaging is a fine ink mixed with dried ink that has settled in the bottom of the bowl (ink container) after Work In Process (WIP) in which there are also dirt particles.

Recommendation of improvement for critical defect problem for printing process based on FMEA and TRIZ integration: Defect Miss Print on gear & bearing component is principle 10 (Preliminary Action) that is checking and cleaning on component part in gear box printing machine using vacuum cleaner , principle 28 (Mechanical Interaction Substitution) Replacing mechanical methods with sensory methods for detection of gear components with the help of VIBRATION TESTER tool, and Principle 3 (Local Quality) is the addition of lock nut on the gear to reduce the vibration of the gear. Defect color is not standard on the packaging is by principle 24 (Intermediary) that is doing training and sharing about how SOP measurement measure of viscosity, principle 15 (Dynamicity) that is doing supplier development strategy to improve quality of ink material supplied by supplier. Defect the line on the packaging is by: Principle 24 (Intermediary) that is the installation of CCTV in each of the 8 print machine station to monitor the print state, Principle 19 (Periodic Action) that is using periodic action for cleaning of bowl (ink tube) channel ink pumps that have jellying.

REFERENCES

[1] Amiruddin, Wahyu Agung Ramadhan. 2022. “Simulation of Leakage Current Characteristics and Hydrophobic Properties of the Surface Pollution Layer of Silicone Rubber Polymer Insulator”. Excitation Journal, Vol. 1, No.2.

[2] Ensikat, Hans J, dkk. 2011. “Superhydrophobic in Perfection The Outstanding Properties of The Lotus Lead”. Beilstein Journal of Nanotechnology. Page 152-161.

[3] Bhusan, Bharat, dkk. 2009. “Micro Nano and Hierarchical Structures for Superhydrophobicitty, Self-Cleaning and Low Adhesion”. Journal of Phil. Trans. Royal Society R.Soc. A. 367, hLM. 1631 – 1672.

[4] Lag, J., Hadas, A., Fairbridge, R., Munoz, J., Pombal, X., Cortizas, A., Almendros, G., Chesworth, W., Camps Arbestain, M., Macias, F., Chesworth, Ward , Jaynes, W. 2008. Hydrophilicity, Hydrophobicity, in : Encyclopedia of Earth Sciences Series. Pp. 329 – 330.

[5] Law, K. – Y. 2014. Definitions for Hydrophilicity, Hydrophobicity, and Superhydrophobicity : Getting the Basics Right. J. Phys. Chem. Lett. 5, 686 – 688.

[6] Katsuki, H., Furuta, S., Watari, T., Komarneni, S., 2005. ZSM-5 Zeolite/Porous Carbon Composite: Conventional- and Microwave-Hydrothermal Synthesis from Carbonized Rice Husk. Microporous Mesoporous Mater. 86, 145–151. https://doi.org/10.1016/j.micromeso.2005.07.010.

[7] Faisal, H., 2009. Synthesis and Characterization of Natural Rubber-Silica Composite Materials.

[8] Apriliana., Gita Ayu., 2015. Thermoelectric Characterization of PED 4000/Amorphous Silica Composite Using Dynamic Mechanical Analysis (DMA). Sepuluh Nopember Institute of Technology. Surabaya.

[9] R.E. Smallman R. J., 2000. Modern Physical Metallurgy and Materials Engineering. Erlangga. Jakarta

[10]Latif, C., 2014. Effect of Calcination Temperature Variations on Silica Structure 3.