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APPLICATION OF THE GREEN LEAN SIX SIGMA AND FACTORIAL EXPERIMENTS APPROACH TO IMPROVE THE QUALITY OF THE BOTTLED DRINKING WATER PROCESS

PENERAPAN PENDEKATAN GREEN LEAN SIX SIGMA DAN FACTORIAL EKSPERIMEN UNTUK MENINGKATKAN KUALITAS PROSES AIR MINUM DALAM KEMASAN

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ABSTRAK

Berdasarkan data diperoleh presentase cacat paling tinggi produk AMDK cup 220 mL PT X pada tahun 2022 mencapai 7200 produk dengan presentase kecacatan 0,1-0,9% dari jumlah produksi dimana jumlah tersebut melebihi batas yang ditetapkan perusahaan sebesar 0,5%, hal ini menunjukkan semakin besar pula dampak terhadap lingkungan. Tujuan penelitian ini yaitu mengetahui waste, waste dominan dan green waste, menentukan CTQ, menentukan nilai DPMO dan nilai sigma, menentukan faktor penyebab kecacatan produk, menentukan limbah yang dihasilkan, dan memberikan usulan perbaikan pada proses produksi dan usulan perbaikan untuk mengurangi limbah. Penyelesaian masalah pada penelitian ini menggunakan metode green lean six sigma dan factorial eksperimen. Berdasarkan hasil kuesioner seven waste diperoleh waste dominan yaitu waste defect sedangkan green waste yang terjadi yaitu water, material dan garbage. Terdapat 4 CTQ dengan memfokuskan pada jenis cacat bocor. Nilai DPMO sebesar 1139,6 dengan nilai sigma sebesar 4,551. Faktor yang menyebabkan produk defect adalah faktor man, machine, method, dan material. Limbah yang dihasilkan yaitu limbah air, cup, dan kardus. Perbaikan diprioritaskan pada setting mesin optimal menggunakan factorial eksperimen. Adapun setting mesin optimal yaitu suhu 200℃ dan kecepatan 11.520 Pcs/Jam. Usulan perbaikan untuk mengatasi limbah yaitu mengumpulkan limbah ke gudang dan menjualnya secara rutin.

Keywords: faktorial eksperimen, green, lean, six sigma, waste

ABSTRACT

Based on the data, the highest percentage of PT.X 220 ml cup AMDK products in 2022 will reach 7200 products with a defect percentage of 0.5% of the production amount where the production amount exceeds the set limit of 0.5%.The objectives of this research are to determine waste, dominant waste and green waste, determine CTQ, determine the DPMO value and sigma value, determine the factors causing product defects, determine the waste produced, and provide suggestions for improvements to the production process and suggestions for improvements for reduce waste.Problem solving in this research uses the green lean six sigma method and factorial experiments. Based on the results of the seven waste questionnaire, it was found that the dominant waste was defect waste, while the green waste that occurred was water, material and garbage. There are 4 CTQs focusing on the type of leaking defect. The DPMO value is 1139.6 with a sigma value of 4.551. Factors that cause defective products are man, machine, method and material factors. The waste produced is water, cups and cardboard waste. Improvement proposals are prioritized on optimal machine settings using factorial experiments. The optimal machine settings are temperature 200℃ and speed 11,520 pcs/hour. Improvements are to overcome waste include collecting waste in a warehouse and selling it regularly.

Keywords**:** factorial experiment, green, lean, six sigma, waste

INTRODUCTION

PT X is a company engaged in the production of bottled drinking water by producing various types of packaging, including cup 220 ml, 330 mL bottles, 600 ml bottles and 19 liter gallons. The purpose of this research is to know waste, waste dominant, and green waste that occur in the production process, determine critical to quality (CTQ) that occurs in the production process, determines the value Defect Per Million Opportunities (DPMO) and sigma value, determine the factors that cause product defects in th e production process, determine the waste generated due to defects in the production process, provide recommendations for improvements that can be made to the production process, and provide recommendations for improvements that can be made to reduce waste due to defects.

In a previous study, the proposed improvements to minimize potential failures using lean six sigma and multi-attribute failure mode analysis approaches (Ulfah *et al.*, 2019), analysis of incompatibility of bottled drinking water products at PT Amanah Insanillahia (Amrina and Fajrah, 2015).

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Plastic injection quality controlling using the lean six sigma and FMEA method (Mansur *et al*., 2016), six sigma methodology for improving manufacturing process in foundry industry (Sachin *et al*., 2017), application of Failure Mode & Effect Analysis (FMEA) for continuous quality improvement – Multiple Case Studies in Automobile SMES (Doshi *et al*., 2016), improvement of magazine production quality using six sigma method: a case study of a PT.XYZ (Hernadewita *et al*., 2019).

RESEARCH AND METHODS

In this research consists of two stages, namely the first stage of the observation and study of literature and data collection, and the second stage is the methodology of Green lean six sigma. The Six sigma approach with the step of define, measure, analyze, and improve be used after collecting data, data processing is carried out (Ulfah *et al*., 2021). In the second stage, the methodological stage of the green lean six sigma approach is arranged as shown in Figure 1.

RESULTS AND DISCUSSION

Define

Critical to Quality (CTQ) Identification

CTQ is a characteristic parameter of product quality that can be measured to satisfy consumers (Zulkarnain *et al*., 2021). In this research, it was discovered that the CTQ for the 220 mL AMDK cup production process consisted of 4 CTQs, namely leaking, tilted lid, dented cup, and water not completely filled. Leaking defects are usually caused by leaking lids and leaking cups. Slanted lid defect is a condition where the lid position does not match the position of the glass circle. A dented cup is a condition where the cup does not match its shape. The water is not completely filled is a condition where the product is filled with water.

Waste Identification

Waste is all activities that do not have added value to the input and output of the production process (Gaspersz, 2007). Waste identification is done by distributing questionnaires to get the weight of the existing waste production process (Ulfah *et al*., 2023). Waste in the production process consists of 7 wastes such as overproduction, waiting, transportation, excess processing, unnecessary inventory, unnecessary motion, and defects (Widyaningrum and Jufriyanto, 2022). This waste identification aims to find out what waste often occurs in the process of making AMDK cup 220 mL. Based on the seven waste questionnaire assessment, the highest waste score was obtained, namely defects (namely leaking, tilted lid, dented cup, and water not completely filled). Waste results occur due to failures in the production process, thereby affecting production time in achieving production targets, so it is necessary to design improvements to the production process in an effort to minimize waste defects (Yanuarsih *et al*., 2014).

Process Activity Mapping (PAM)

Identify activities in the production process using PAM mapping tools, PAM is used to map activities such as time, number of operators, and 5 activities (operation, transportation, inspection, storage, and delay) (Dewi and Sartono, 2014) in the production process and classify activities into in three types of activities, namely value added (VA), necessary non value added (NNVA), and non value added (NVA) to determine process cycle efficiency (PCE) in the production process. PCE is a parameter in measuring a company's level of productivity. PCE is one of the best parameters for knowing and measuring the amount of waste in a process or activity (Somantri and Endang, 2021).

The results of the activity classification in the 220 mL AMDK cup production process obtained a lead time of 1,318 seconds with a production process efficiency percentage of 38.69% with a VA activity of 510 seconds, necessary non value added activities of 51.44% with a process time of 678 seconds andnon value added activities amounted to 9.86% with a processing time of 130 seconds.

Current State Value Stream Mapping (CSVSM)

Value Stream Mapping (VSM) is a map that describes all the steps in the work process (including rework) related to converting customer needs into a product and shows how much value each step adds to the product (Amanda and Batubara, 2018). In VSM, you can see the VA activity and NVA activity categories (Pertiwi and Purwanggono, 2019). current state value stream mapping in the production of 220 ml AMDK Cups can describe the flow of the 220 ml AMDK Cup production process from supplier to customer. Lead time in the production process is 1,318 seconds or 21.96 minutes, while the total value added time is 510 seconds or 8.5 minutes. The following is the current state value stream mapping of the 220 mL AMDK Cup production process (Figure 2).

Environmental Impact Identification

Based on observations at the research location in the 220 mL AMDK cup production process, it was seen that there was waste that could have an impact on the environment. Based on the results of identifying the waste that occurs, it can be seen that lean waste produces green waste which has an impact on the environment. There are seven types of green waste including energy, water, materials, garbage, transportation, emissions, and biodiversity (Choudhary *et al*., 2019). Waste that occurs at PT. X is waste overproduction, inventory, transportation, defects, and over processing.

From this waste, green outcomes are produced in the form of storage, excess production time, scrap, and travel. Some of these green outcomes are then translated into green waste in the form of energy, transportation, materials and garbage.

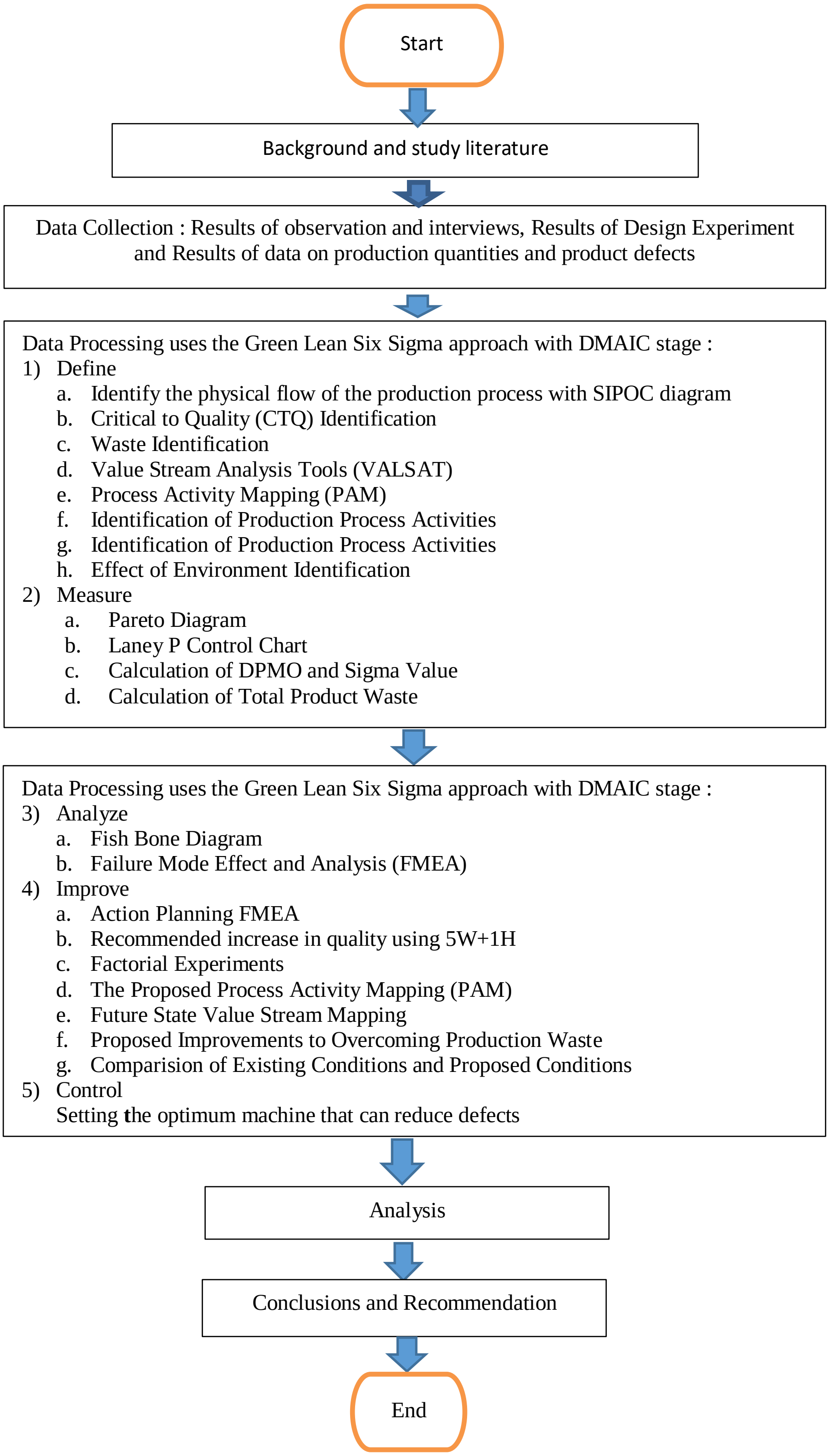

Figure 1. Research stages flowchart

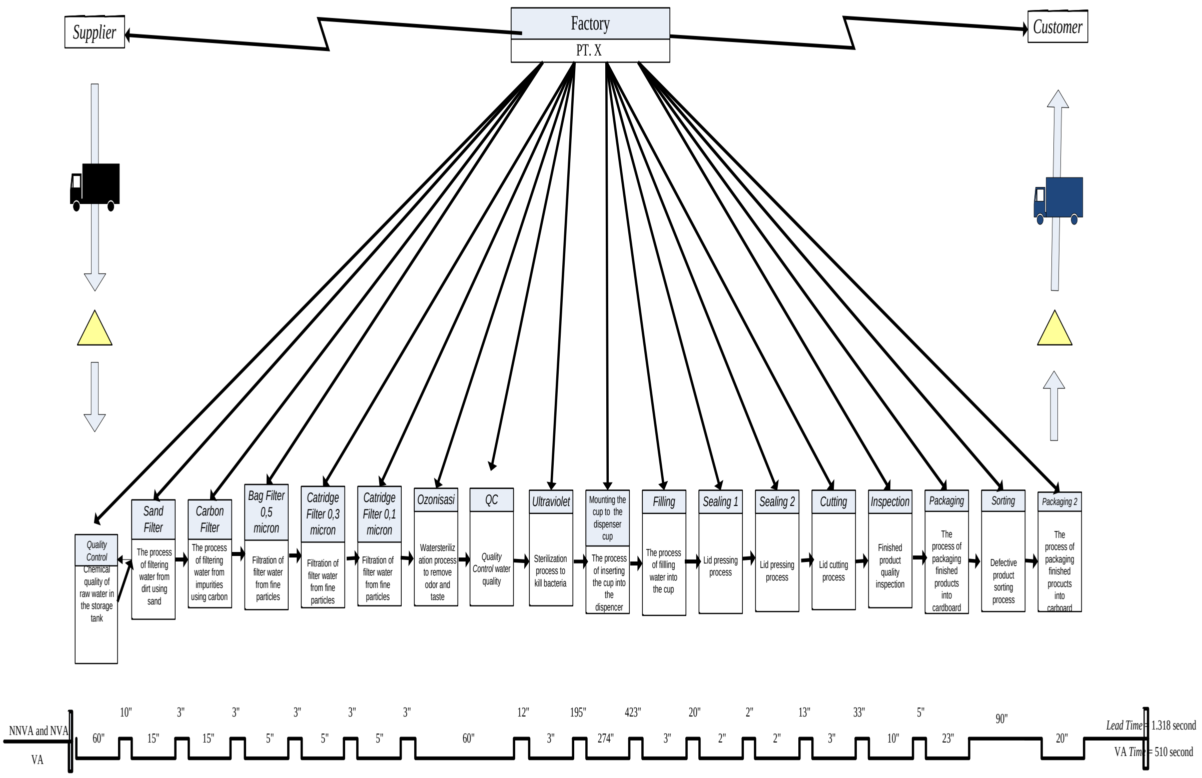

Figure 2. Current state value stream mapping

Measure

Pareto Chart

Pareto diagram is used to find the highest defect category. Based on the results of the Pareto diagram, it can be seen that the product defects that occurred were leaking defects amounting to 27,312 pcs, tilted lid defects amounting to 7,008 pcs, dented cup defects amounting to 4,796 pcs, and water defects not being fully filled amounting to 2,212 pcs. Based on the Pareto diagram, it is known that the product defect presentation with a cumulative 80% occurs in leaking defects and tilted lids. However, this research focuses on the type of defect with the highest percentage of 66.09%, namely leaking defects.

Laney P Control Chart

The P control chart is an attribute control chart for calculating the number of defects in one product unit as a sample where n (the number of samples) may be the same or vary (Jamila *et al.*, 2022). The following are the results of data processing using the P control chart in the 220 mL AMDK cup production process using Minitab 20 software.

Based on Figure 3, it can be seen that there are 10 data that are out of control and there is over dispersion (a lot of data is outside the control limits with control limits that are too narrow) so that the control chart P becomes over sensitive. Therefore, in conditions like this, a Laney P control chart can be used Laney P control charts are used to observe the proportion of defective products in the production process to adjust over dispersion (a lot of data is outside the control limits with limits that are too narrow) and under dispersion (a lot of data is within the control limits with limits that are too wide) occurs in the P control chart (Laney, 2017). Apart from that, the sample data used in this study has varying amounts with large values so that Laney P control charts can be used. Results of data processing using Laney P control charts in the 220 mL AMDK cup production process using Minitab 20 software.

Calculation of DPMO and Sigma Level

The calculation of the DPMO value and sigma value is used to measure the company's performance level. Through DPMO, a sigma level value can be obtained, which is the sigma level achieved in a process being studied (Dewi and Puspitasari, 2019). The following is the calculation of the company's DPMO value and sigma value.

Based on the sigma value calculation, the DPMO value obtained in the production process is 1139.6 and the sigma value is 4.5512, which means that in one million production opportunities there will be a defective product of 1139.6 with the sigma achievement level for the 220 mL bottle of AMDK production process including into the USA industrial average. Because this has not yet reached zero defects which can reduce waste of material and energy arising from rejects, the production process must increase its sigma value so that the number of rejects can be reduced (Dewi and Puspitasari, 2019).

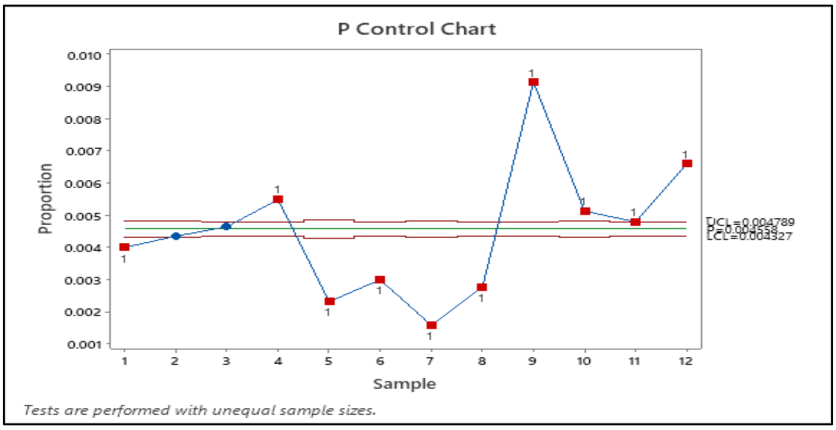

Figure 3. P control chart

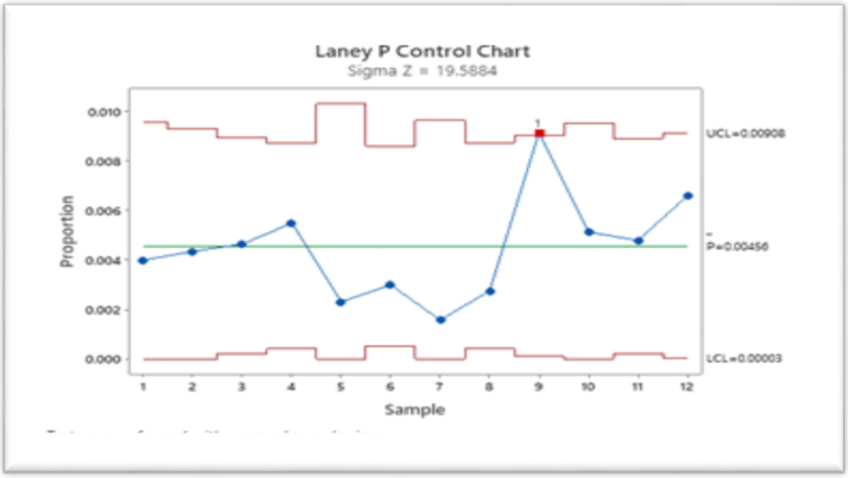

Figure 4. Laney P control chart

Table 1. Sigma level calculation

Month	Production Amount	Number of Defect	CTQ	DPU	DPO	DPMO	Sigma
January	626,064	2,496	4	0.003987	0.000997	996.7032	4.591213
February	708,192	3,072	4	0.004338	0.001084	1084.452	4.566073
March	829,392	3,840	4	0.00463	0.001157	1157.474	4.546536
April	911,904	4,992	4	0.005474	0.001369	1368.565	4.495814
May	478,944	1,104	4	0.002305	0.000576	576.2678	4.750373
June	964,848	2,880	4	0.002985	0.000746	746.2315	4.676145
July	611,712	960	4	0.001569	0.000392	392.3415	4.858142
August	908,352	2,496	4	0.002748	0.000687	686.9584	4.700075
September	789,696	7,200	4	0.009117	0.002279	2279.358	4.336667
October	638,112	3,264	4	0.005115	0.001279	1278.772	4.516449
November	833,376	3,984	4	0.004781	0.001195	1195.139	4.536896
December	765,744	5,040	4	0.006582	0.001645	1645.459	4.439171
Total	9,066,336	41,328	4	0.004558	0.00114	1139.6	4.551211

Calculation of Total Product Waste

The presence of leaking defects and water not being completely filled will cause the emergence of waste, both liquid waste and solid waste. Defective products that will produce waste are leaking defects and water not being filled completely, whereas dented cup defects and slanted lid defects do not produce waste because they can still be used by employees or sold at low prices. Cup waste is identified into 2 types of waste, namely cup waste and water waste. If it is assumed that 1 cup is filled with 220 mL, the total water waste from 29,524 cups is 6,495,280 mL. Based on the type of waste produced, it can be classified into green waste that occurs. Of the 7 classifications of green waste that occur in this company, only 3 are green waste (water, material, garbage). Based on the calculation results, it is known that the total liquid waste in 220 mL cup packaging is 6,495.28 L and the solid waste produced is 29,524 pcs in cups and 569 pcs in cardboard. The occurrence of product defects clearly causes losses to the company. Losses to the company can be calculated by multiplying the number of defective products by the selling price of 220 mL AMDK cup. It is assumed that the selling price per unit of 220 mL AMDK cup is IDR. 291.66, it can be seen that the company's total potential loss due to defects is Rp. 8,610,970.

Analyze

Fishbone Diagram

This diagram was created based on brainstorming to identify the causes of a main factor called 4M+1E (man, material, machine, method, and environment) (Hafid and Yusuf, 2018). The following is a fishbone diagram to identify the causes of defects in leaked defects based on discussions with the head of production and head of QC (Figure 5).

Failure Mode and Effect Analysis (FMEA)

FMEA is used to identify priority orders for improvements based on severity, occurrence and detection values (Romadhani, 2017). The severity value shows how badly a problem will affect the quality of a product or process. The occurrence value shows the level of frequency of failure in product or process quality. The detection value shows the opportunity for a failure to be detected before it occurs (Situngkir, 2019). From the multiplication between severity, occurrence and detection, the RPN value is produced as shown in Table 2.

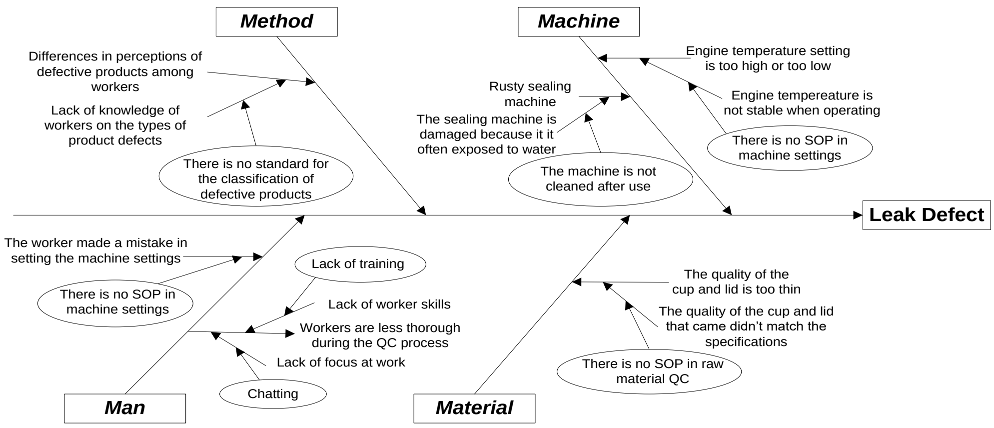

Figure 5. Fishbone diagram

Tabel 2. Failure Mode and Effect Analysis (FMEA)

No	Mode of Failure	Cause of Failure	Effect of Failure	S	O	D	RPN (1-1000)	Rank
1	Workers are less thorough during the QC process	Lack of training	Leak not detected	6	3	3	54	5
2	Workers are less thorough during the QC process	Chat	Leak not detected	6	2	3	36	7
3	The employee made a mistake in setting machine	There is no internal SOP yet setting machine	Lid torn and not glued on cup	9	4	2	72	3
4	Setting engine temperature is too high or too low	There is no internal SOP yet setting machine	Lid torn and not glued on cup	9	7	2	126	1
5	Machine sealing rusty	The machine is not cleaned after use	Lid not stick on cup	8	4	3	96	2
6	Quality cup and lid too thin	There is no SOP in QC raw materials	Lid and cup easy to tear	6	5	2	60	4
7	Differences in perceptions of defective products among workers	There is no standard for the classification of defective products	Products that are manufactured defect	5	2	4	40	6

Based on the results of discussions with the head of production and the head of QC, the results are shown in Table 2, and the highest RPN value was obtained, namely the absence of SOPs for setting the machine, causing the machine temperature setting to be too high or too low with an RPN value of 126. The results of FMEA in the form of the highest RPN value are used to determine priorities for improvements. The highest RPN results were then refined using factorial experiment (Sandi *et al.*, 2017).

Improve

Action Planning FMEA

Action planning is made to determine the most appropriate actions to be taken that have a high risk of failure (Montororing, 2022). The following is FMEA's action plan for the 220 mL AMDK cup production process based on the results. Discussion and brainstorming with the head of production and head of QC to determine an action plan strategy that can be realized (Table 3).

Factorial Experiment Design

Factorial experimental design was carried out to determine the factors and levels that influenced the 220 mL AMDK cup which did not comply with specifications. In this research, 2^2 factorial experimental designs were carried out and post-experimental tests were carried out using the Newman-Keuls range test. The factors used in the experiment are the temperature factor (Factor A) which consists of 2 levels, namely 180 C and 200 C, and the filling machine feeding speed factor (Factor B) with levels of 80% ≈ 9,216 Pcs/Hour and 100% ≈ 11,520 Pcs/hour. In determining the number of replications in this study, 3 replications were used. Determination of replication is carried out to produce more accurate estimates. The minimum number of replications used is 2 replications. After knowing the number of replications, we can know the number of experiments that will be used 12 experiments.

Tabel 3. Action planning FMEA

Rank	Mode of Failure	Potential Effect of Failure	Potential Cause	Action Planning
1	Setting engine temperature is too high or too low	The temperature is not suitable and the product leaks	There is no internal SOP yet setting machine	1. Check the machine regularly 2. Make SOP for machine usage 3. Holding training to employees
2	Machine sealing rusty	Lid does not stick perfectly on the lipscup	The machine is not cleaned after use	1. Check the machine regularly 2. Clean the machine after finishing production 3. Perform component replacement if the component is damaged
3	Wrong worker setting machine	The temperature is not suitable and the product leaks	There is no internal SOP yet setting machine	1. Create SOP for machine usage 2. Doing training on carriers 3. Holding briefing before the production process takes place
4	Quality cup and lid too thin	Product leaks easily	There is no SOP in QC raw materials	1. Make SOP quality control after the raw materials come from supplier 2. Communicate with supplier related to the specifications of the desired raw material
5	Workers are less thorough during the QC process	Products that are manufactured defect	Employees chatting	1. Improve supervision of employees 2. Make rules during working hours 3. Doing training on employees
6	Differences in perceptions of defective products among workers	Products that are manufactured defect	There is no standard for identifying defective products	1. Doing training operators and other employees 2. Make a list of categories of defects in the product
7	Workers are less thorough during the QC process	Products that are manufactured defect	Lack of training on employees	1. Improve supervision of employees 2. Make rules during working hours 3. Doing training on employees

Design of Experiment Solutions

The following is the completion of the experimental design by making an experimental design and Anova to determine the treatment effect of the factors used on the amount of drinking water cup 220 mL.

1. $SS_{total} = \sum_i^a \sum_j^b yij^2 - \frac{T^2}{NAB} = 31024 - \frac{588^2}{3.2.2} = 2212$
2. $SS_A = \frac{\sum T^2 i}{NB} - \frac{T^2}{NAB} = \frac{(363)^2+(225)^2}{3.2} - \frac{588^2}{3.2.2} = 1587$
3. $SS_{error} = SS_{total} - SS_A - SS_B = 2212-1587-280,333 = 344,667$
4. dk (A*i*) = (a-1) = (2-1) = 1
5. dk (*Error*) = (a-1)(b-1)+ab(n-1) = abn-a-b+1 = 12-2-2+1= 9
6. $MS(Ai) = \frac{SSA}{dk} = \frac{1587}{1} = 1587$
7. $F\ count = \frac{MSA}{MS_{error}} = \frac{1587}{38,296} = 41,44$

The next stage is processing analysis of variance (Anova). The processing of Anova processing results can be seen in the following Table 4. Based on the results of calculating F value and determining the hypothesis, it can be concluded that the following failed to reject H_0 if the calculated F value < F table and reject H_0 if the calculated F value > F table (Novitasari *et al*., 2014). F value calculated Factor A > F table $\alpha_{0,05(1,9)}$ namely 41.44 > 5.12 so that H_0 rejected and it can be concluded that there is an effect of temperature (Factor A) on the amount of defective 220 mL bottled drinking water. F value calculated Factor B > F table $\alpha_{0,05(1,9)}$ namely 7.32 > 5.12 so that H_0 rejected and it can be concluded that there is an effect of speed feeding filling machine (Factor B) on the number of defective 220 mL bottled drinking water. Because factor A and factor B have an influence on the response variable, it will proceed to the test after the Anova using the Newman-Keuls range test.

Newman-Keuls Range Test

The Newman Keuls test was carried out to determine whether there was an effect similarity between one treatment and another (Sudarjat, 2015). The selection of this test is based on the similarity of the number of levels used for each factor. Based on the results of the Newman Keuls test, it can be seen from which level the factors affect the results of product defects and can determine the best level of these factors on the results of product defects (Ladou, 2015). The Newman Keuls test will obtain the results of the proposed optimal conditions for each factor to reduce the amount of bottled drinking water cup 220 ml which is out of specification.

Based on the results of the calculation of the Newman Keuls range test, it is known that the optimal conditions for temperature and feeding speed of the filling machine so that the 220 mL bottled water produced are in accordance with predetermined standards, namely the temperature factor of 200 ℃ and the speed factor feeding machine filling at speed feeding machine filling 11.520 Pcs/hour.

Proposed Process Activity Mapping

In the proposed PAM there are several activity reductions, namely eliminating NVA activities and reducing NNVA activities. Activities that are included in NVA or do not provide added value such as waiting must be reduced to support smooth production processes (Amanda and Batubara, 2018). Based on the proposed plan, it is known that there is a total time reduction of 285 seconds. After reducing NVA activities to NVA and NNVA activities, the classification and total proposed production time can be seen in the following Table 5.

Based on Table 5, it is known that the lead time for the 220 mL AMDK cup production process has decreased to 1,033 seconds with an increase in process cycle efficiency of 49.37% from the previous 38.69% (an increase of 10.68%). This happens because the NVA and NNVA times are reduced (Somantri and Endang, 2021). Judging from the activity time, delay (waiting) is included in NVA activities so improvements must be made to make the production process more efficient. Apart from that, transportation is also one of the NNVA activities that should be reduced in time. (Pertiwi and Purwanggono, 2017).

Table 4. Analysis of Variance (Anova)

Source	Degrees of Freedom (dk)	Sum Square (SS)	Mean Square (MS)	F value	F table (0.05,1,9)
Temperature (Ai)	1	1587	1587	41,44	5,12
Speed Feeding Filling Machine (Bj)	1	280.333	280.333	7,32	
Error	9	344.667	38.296		
Total	11	2212	201.0909		

Table 5. Percentage of proposed production activities

No	Activity Group	Prosessing time (seconds)	% Time usage
1	Value Added	510	49.37%
2	Necessary Non Value Added	523	50.63%
	Total	1033	100.00%

Proposed Future State Value Stream Mapping

This FSVSM step was carried out to create a proposed process flow plan to eliminate and reduce waste activities so that the 220 mL AMDK Cup production process becomes efficient. Based on the proposed flow image of the 220 mL AMDK Cup production process from supplier to consumer, the proposed lead time for the production process is 1,033 seconds or 17.21 minutes, while the total value added time is 510 seconds or 8.5 minutes there was a decrease in total lead time of 285 seconds. This improvement strategy effort can be carried out continuously to determine the types and factors that cause waste in the production process so that production time is more effective and the value stream can run smoothly (Amanda and Batubara, 2018). The following is the future state value stream mapping of the 220 Ll AMDK Cup production process.

Proposed Improvements for Overcoming Production Waste

The 220 mL AMDK cup production process at PT X produces several green wastes such as water waste, cup waste and cardboard waste. Reduce is defined as activities to reduce waste accumulation. Recycling means reprocessing into other useful materials (Arisona, 2018). The following are proposed improvements to deal with waste from the production of 220 m: AMDK cups at PT X based on the 3R concept (Reuse, Reduce, Recycle).

<u>Reuse</u>

a) Collect clean water into one container so that it can be used to wash gallons because this company produces three types of AMDK packaging. This can reduce the waste of produced water so that it can be reused.
b) Collecting waste such as unused cups and cardboard in a special room such as a warehouse so as not to disrupt transportation during the production process. remaining production waste can be sold back to waste managers on a regular basis so that waste does not accumulate in the company and waste does not pollute the surrounding environment.

<u>Reduce</u>

Replace the sorting container with a closed container so that the water that comes out of the leaking product does not spill onto the floor and keeps the floor dry.

<u>Recycle</u>

Reprocess cup waste by melting it into plastic pellets so that they can be reshaped into usable products.

Comparison of Existing Conditions with Proposed Conditions

After conducting research conducted using green lean six sigma, then there is a comparison between the existing conditions and the proposed conditions. The following is a comparison of the existing conditions with the proposed conditions.

Control

The control stage is the final stage in the DMAIC cycle of quality improvement with six sigma. At this stage, the implementation of the recommendations for proposed improvements made in the previous stage is carried out. This control stage was carried out to see the quality improvement of the 220 mL AMDK Cup production process based on the results of recommendations using experimental design. Based on the results of recommendations for optimum machine settings using experimental design, the optimum machine settings that can reduce defective 220 mL AMDK cup products are when the temperature is set to 200 °C and the filling machine feeding speed is 11,520 Pcs/hour. Based on this proposal, implementation was carried out in the 220 mL AMDK cup production process for 3 observations. Based on the observations, the following results were obtained.

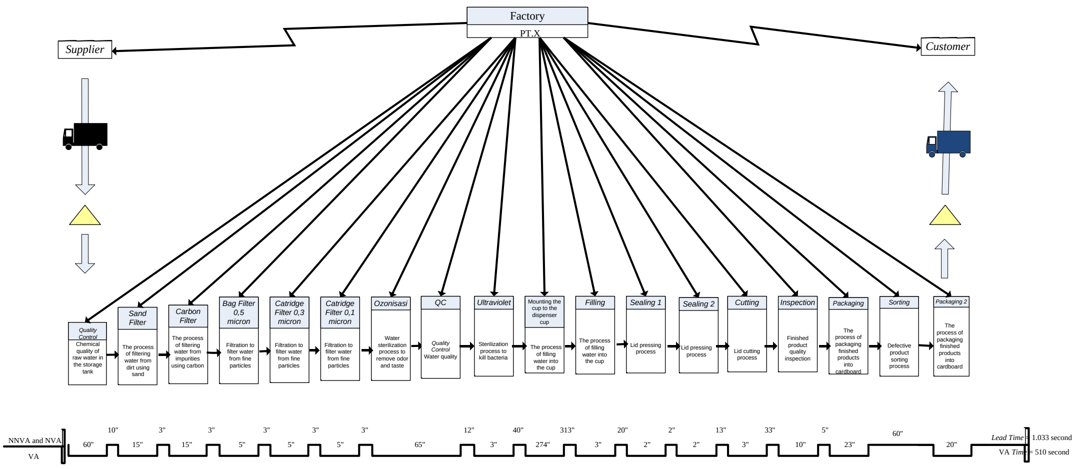

Figure 6. Future State Value Stream Mapping

Table 6. Comparison of existing conditions with proposed conditions

No	Existing Conditions	Proposed Conditions
1	In the existing PAM there are 17 activities for the operation process, 20 for the transportation process, 4 for the inspection process, 2 for the waiting process, and 2 for the storage process.	In the proposed PAM there are 17 activities for the operation process, 20 for the transportation process, 4 for the inspection process, and 2 for the storage process
2	Occurrent VSM has lead time of 1,318 seconds	On future VSM has lead time of 1,033 seconds
3	In the existing conditions produce process cycle efficiency by 38.69%	On the condition of the proposal produces process cycle efficiency by 49.37%
4	In the existing conditions, the total time for NNVA activity is 678 seconds	In the proposed conditions the total time for NNVA activity is 523 seconds
5	In the existing condition the total time on the activity The NVA is 130 seconds	In the condition of the proposed total time on the activity The NVA is 0 seconds

Table 7. Comparison before and after comparison

Parameter	Before Repair	After Repair
Defect Percentage	0,45%	0,12%
DPMO Value	1139,6	294,576
Sigma Value	4,551	4,936

Based on Table 7, it can be seen that there has been a decrease in the percentage of defects by 0.33% and an increase in the sigma value from 4.551 to 4.946. This control stage is carried out so that the quality of the company's products becomes better after implementing it in stages, but there is still the possibility of improvement in the future to reach level 6 sigma as the goal of six sigma (Rahayu and Bernik, 2020).

A product from cellulose that has recently been widely researched is Nanocrystalline Cellulose (NCC). NCC itself, its mechanical and chemical properties are widely.

CONCLUSIONS AND RECOMMENDATION

Conclusions

The waste that occurs in the 220 mL AMDK cup production process is overproduction, defects, unnecessary inventory, transportation, and excess processing with the dominant waste being defect waste. while the green waste that occurs is water, materials and garbage. CTQ that occurs are leaking defects, tilted lid, dented cup, and water not filled completely. The DPMO value is 1139.6 with a sigma value of 4.551. The factors that cause defective products are caused by several factors such as man, machine, method and material. Proposed improvements that can be made to improve the 220 ml AMDK cup production process using experimental design, namely by adjusting the machine settings using a temperature of 200°C and a filling machine feeding speed of 11,520 Pcs/hour. Apart from that, the proposal given based on VSM is to eliminate NVA activities such as lids waiting to be installed and products waiting to be sorted and reduce lid transportation time to the production site by moving the lid storage area to the front production location so that PCE has increased from 38.69% to 49.37%. Proposed improvements that can be made to deal with production waste based on the 3R concept, namely collecting residual water from defective products in one container, collecting residual production waste in a warehouse and selling it to waste managers regularly, replacing sorting containers into containers closed so that water does not spill on to the production floor, and reprocess the cup waste to be reshaped into a usable product.

Recommendation

Based on research results, it is recommended that the company implement the proposal improvements are provided and further research can be carried out with other product research objects from PT X.

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