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Integration of SQC and TRIZ to Reduce Batik Fabric Defects in Dyeing and Scouring Process at PT. Batik Danar Hadi

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Abstract. *Product quality is a crucial factor in maintaining the competitiveness of the batik industry, including at PT. Batik Danar Hadi. This company faces issues with defects in batik fabric, particularly during the dyeing and scouring processes. This research aims to identify the types and main causes of defects, and to formulate technical solutions through the integration of Statistical Quality Control (SQC) and TRIZ methods. SQC was performed using check sheets, histograms, u-control charts, pareto diagrams, and fishbone diagrams. The results show that the dominant defects are ciri (holey) and mottle, with a contribution of 92%. Production deviations occurred in March and April, where the u-chart value exceeded the upper control limit. The five main causes of defects include machines, methods, raw materials, labor, and environment. TRIZ is used to formulate solutions based on contradiction parameters and inventive principles, resulting in technical solutions such as segmentation, rapid action, and the use of composite materials. The integration of SQC and TRIZ has proven effective in systematic quality improvement.*

Keywords: *product defects; batik fabric; statistical quality control; Theoriya Resheniya Izobreatatelskikh Zadatch*

I. INTRODUCTION

Batik is an Indonesian cultural heritage that is recognized by UNESCO as an Intangible Cultural Heritage (Susanti et al., 2023). The uniqueness of its techniques and motifs reflects the richness of local culture. In the face of market competition and high demand, quality and production efficiency are crucial to maintaining the competitiveness of the batik industry (Gaol et al., 2024). The complexity of the production process, from material selection to finishing, as well as the involvement of human factors, tools, materials, and the environment, often lead to variations in product quality. Without effective quality control, product defects can increase, which affects customer satisfaction and the company's reputation (Islachiyana et al., 2023).

PT. Batik Danar Hadi, a renowned batik producer established in 1967, is known for its commitment to maintaining the quality and preserving traditional batik. Despite its extensive experience, the company still faces problems with product defects, such as pattern differences, torn fabric, and uneven wax thickness. These problems have an impact not only on product quality but also on production timeliness, operation costs, and customer perception of the brand. This demonstrates that quality improvement efforts depend not only on worker skills or material quality, but also on the company's quality control systems and approaches.

According to Montgomery in (Sahara et al., 2023), quality control is a series of technical and managerial activities to evaluate the quality of a product or service by measuring quality attributes and comparing them with established specifications. Muslimah & Keriswanto (2015) added that quality control not only includes identifying the differences between actual performance and standards, but also involves taking appropriate corrective actions. In general, quality control aims to ensure that products or services meet quality standards without neglecting cost efficiency to remain competitive (Yolanda Amarta & Hazimah, 2020). Each company sets specific tolerance limits as a reference for regulating and monitoring product quality (Djunaidi et al., 2024). One method that

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can be used for quality control is Statistical Quality Control (SQC), which is a problem-solving approach using statistical techniques to monitor, evaluate, and improve processes and product quality (Ishak et al., 2020). This method is effective in minimizing variability to meet consumer expectations (Kurniawan & Azizah, 2022) and is applied from the beginning to the end of the production process to ensure compliance with the company's quality standards (Dimas Ihza Mahendra et al., 2023). Mislan & Purba (2020) also emphasize that the implementation of SQC helps detect process deviations objectively and systematically. According to Andrew Setiawan Rusdianto, Noer Novijanto, and Rosy Alihsany in (Farida & Mardiana, 2023), the advantage of SQC lies in its ability to monitor processes based on objective data rather than subjective options. In addition, SQC can detect deviations through patterns of increase or decrease, thereby enabling early preventive actions to avoid repeating mistakes. However, although it can identify and control variations, SQC does not fully offer a solution-oriented and creative improvement approach. Therefore, integration with other methods such as TRIZ is needed.

As explained by Imaduddin, Jamal Rizal, and Anita in (Apriandani & Rochman, 2024), Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ) is a philosophy, process, and a set of tools designed to comprehensively solve problems or contradictions, with the main goal of generating new ideas for problem-solving. This problem-solving method was developed by Genrich Altshuller, using an approach that relies on inventive principles and contradiction analysis (Neyland et al., 2022). TRIZ provides 40 solution principles organized according to 39 engineering parameters, which can be applied to systematically address various technical problems (Nugraha & Haryono, 2022). The effectiveness and efficiency of TRIZ in addressing technical issues have also been demonstrated by Harris in (Nurrokhman et al., 2024). Meanwhile, according to Diana Puspita Sari and Andry Harmawan in (Triz et al., 2023), the strength of TRIZ lies in its ability to solve complex problems even without the need for initial identification of root causes or predetermined solution direction. By combining the strengths of SQC in statistical analysis with the capabilities of TRIZ in designing creative solutions, this integrated approach can enhance the overall effectiveness of the quality control system.

Several previous studies have shown the effectiveness of each method individually as well as in limited integration. (Dimas Ihza Mahendra et al., 2023) applied SQC to identify defects in

Figure 1. Holey (*Ciri*) Defect

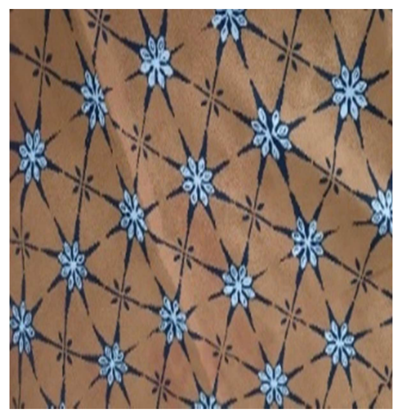

Figure 2. Mottled Defect

Figure 3. Crushing/ Uneven Defect

production but did not proceed to formulate solutions Mahardhika & Al-Faritsy (2023) conducted research at the same location but with a different focus and combination of methods, namely Six Sigma and Kaizen, while Jakti & Al Faritsy (2024) integrated methods such as Six Sigma and TRIZ in the context of the manufacturing industry, yet did not apply them specifically to the batik industry, particularly in the dyeing and scouring processes. Farida & Mardiana (2023) also highlighted the importance of quality control in the batik industry but did not incorporate an innovative approach based on inventive principles. Based on this literature review, a research gap can be identified, namely the absence of direct integration between SQC and TRIZ methods in the context of quality improvement in the batik industry, particularly at PT. Batik Danar Hadi.

Based on this, the objective of this research study is to analyze the types and main causes of batik fabric product defects in the dyeing and scouring processes at PT. Batik Danar Hadi using the SQC approach, and to formulate innovation and applicable technical solutions through the application of inventive principles in the TRIZ method.

II. Research Method

This research was conducted at PT. Batik Danar Hadi, with the research object being batik fabric produced through the dyeing and scouring processes during the production period from January to December 2024. Data were collected through observation and interviews to obtain primary data, as well as documentation of production and product defect data as secondary data.

The research approach used is quantitative by applying the Statistical Quality Control (SQC) and Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ) methods. SQC analysis was conducted using quality control tools which are part of the seven tools, including check sheets, histograms, u-control charts, pareto diagrams, and cause-and-effect diagrams, aiming to identify the types of defects and the dominant causal factors that affect product quality. Furthermore, the TRIZ method was used to formulate technical solutions through the stages of identifying contradiction parameters, creating the contradiction matrix based on the 39 technical parameters, and determining solutions using 40 inventive principles.

III. Result and Discussion

Check Sheet

Check sheet is a data recording tool used to monitor activities over a certain period of time, calculate the frequency of events, and collect data related to patterns, locations, and causes of defects in a process (Wardah et al., 2022). The following is production data for January – December 2024 presented in Table 1. Check Sheet for the January – December 2024 Production Period.

Based on Table 1, total production was 17,385 pieces with 97 defective products. The batik fabric production data analyzed were from the dyeing and scouring process, which had passed the selection in the previous stage, namely batik painting with wax. The highest production was in January with 1,845 pieces, while the lowest was in April with 550 pieces. The highest number of defects was recorded in March at 28 pieces (1,87%). The three types of defects identified were holey defects (52 pieces), mottles (37 pieces), and crushed (8 pieces).

Histogram

After creating the check sheet, the next step is to create a histogram as a visualization of the data distribution. This graph is presented in bar form, with data classified into several categories or specific value ranges, allowing the distribution pattern to be seen more clearly (Damayant et al., 2022). Below are histograms that serve as data visualizations, shown in Figure 4. Histogram of Monthly Batik Fabric Production and Figure 5. Histogram of Monthly Batik Fabric Product Defects.

Based on the analysis with EasyFit software, the monthly batik fabric production data follow a Wakeby distribution. This is reflected in the

Table 1. Check Sheet for the January – December 2024 Production Period

Month	Total Production (pieces)	Type of Defect			Total Defective Products	Percentage of Defective Products compared to Production Quantity
		Ciri (Holey)	Mottle	Crushed/ Uneven		
January	1845	8	4	0	12	0,65%
February	1692	5	3	0	8	0,47%
March	1498	15	11	2	28	1,87%
April	557	7	3	0	10	1,80%
May	1497	2	1	1	4	0,27%
June	1555	6	7	0	13	0,84%
July	1670	0	4	2	6	0,36%
August	1335	0	2	1	3	0,22%
September	1797	6	1	0	7	0,39%
October	1267	3	1	0	4	0,32%
November	1550	0	0	2	2	0,13%
December	1122	0	0	0	0	0,00%
Total	17385	52	37	8	97	7,31%

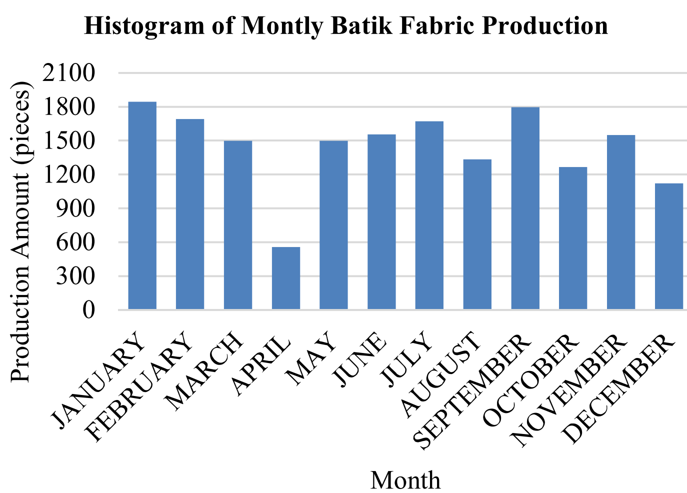

Figure 4. Histogram of Monthly Batik Fabric Production

asymmetrical histogram, with a peak at the beginning of the year and a fluctuating decline thereafter. This pattern is consistent with the characteristics of the Wakeby distribution, which can capture high skewness, extreme kurtosis, and long distribution tails. The Wakeby distribution is also suitable for data with extreme values, such as the low production in April, which are difficult to model with a symmetrical distribution.

The analysis using EasyFit software shows that the histogram data in Figure 5 follows a General Logistic distribution pattern. This is evident from the sharp peak at the beginning of the year followed by an uneven decline towards the end of the year, which is consistent with the characteristics of the General Logistic distribution, which can flexibly capture skewness and long tails.

Control Chart u (u-Chart)

A control chart is a visual tool for monitoring and assessing whether a process is in quality

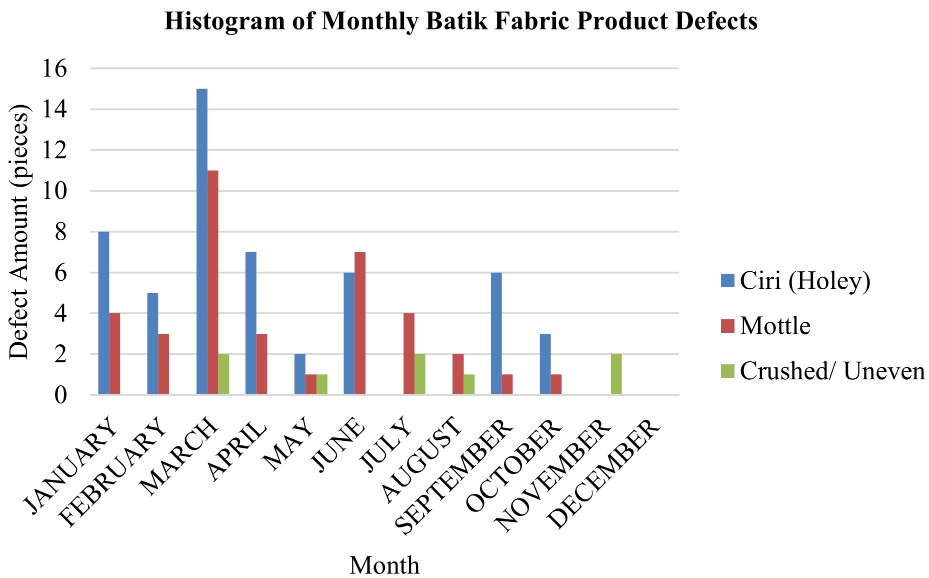

Figure 5. Histogram of Monthly Batik Fabric Product Defects

control according to statistical standards (Fadilah et al., 2019). Yolanda Amarta & Hazimah (2020) also explain that control charts show changes in data over time, but do not directly explain the cause of deviations even if the deviations are visible. One type, the u-control chart, is used to observe the number of nonconformities per unit, especially when sample sizes vary and a unit can have more than one defect.

The u-control chart has several elements that require prior calculations, namely the monthly u value, center line (CL), upper control limit (UCL), and lower control limit (LCL). The u value can be calculated using the formula:

$$u_i = \frac{c_i}{n_i} \quad \text{.... (1)}$$

$$u_{January} = \frac{12}{1845} = 0{,}0065 \quad \text{.... (2)}$$

Calculating the average value of u or center line (CL) from the u-control chart:

$$CL = \bar{u} = \frac{\sum_{i=1}^{g} c_i}{\sum_{i=1}^{g} n_i}$$

$$CL = \frac{97}{17385} = 0{,}0056$$

$$UCL_{January} = 0{,}0056 + 3\sqrt{\frac{0{,}0056}{1845}}$$

$$UCL_{January} = 0{,}0108$$

Calculating the upper control limit (UCL) and lower control limit (LCL) on the u-control chart:

$$UCL = CL + 3\sqrt{\frac{CL}{n_i}}$$

$$UCL_{January} = 0{,}0056 + 3\sqrt{\frac{0{,}0056}{1845}}$$

$$UCL_{January} = 0{,}0108$$

$$LCL = CL - 3\sqrt{\frac{CL}{n_i}}$$

$$LCL_{January} = 0{,}0056 - 3\sqrt{\frac{0{,}0056}{1845}}$$

$$LCL_{January} = 0{,}00$$

where:

$\bar{u}$ = average observed nonconformities from a number of items inspected
u_i = number of sample discrepancies per-*i* unit
c_i = number of defects per unit in the-*i* observation
n_i = size of items/ samples examined per unit in the-*i* observation (2)
g = number of samples

Based on the calculation in Table 2 above, the calculation results will be used to illustrate the

Table 2. Control Chart Calculation for January – December 2024

No	Bulan	n	C	u	CL	UCL	LCL
1	January 2024	1845	12	0,0065	0,0056	0,0108	0,00
2	February 2024	1692	8	0,0047	0,0056	0,0110	0,00
3	March 2024	1498	28	0,0187	0,0056	0,0114	0,00
4	April 2024	557	10	0,0180	0,0056	0,0151	0,00
5	May 2024	1497	4	0,0027	0,0056	0,0114	0,00
6	June 2024	1555	13	0,0084	0,0056	0,0113	0,00
7	July 2024	1670	6	0,0036	0,0056	0,0111	0,00
8	August 2024	1335	3	0,0022	0,0056	0,0117	0,00
9	September 2024	1797	7	0,0039	0,0056	0,0109	0,00
10	October 2024	1267	4	0,0032	0,0056	0,0119	0,00
11	November 2024	1550	2	0,0013	0,0056	0,0113	0,00
12	December 2024	1122	0	0,0000	0,0056	0,0123	0,00
	Total	17385	97				

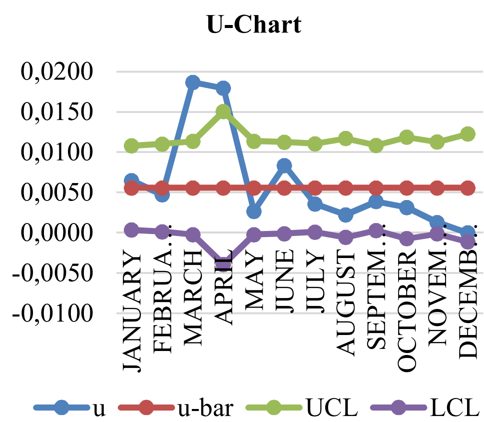

Figure 6. Control Chart Graph for January 2024 - December 2024

u-control chart, which can be seen in Figure 6. Control Chart Graph for January 2024 – December 2024.

Based on Figure 6, several defect percentages exceeded the upper control limit, indicating potential quality deviations that require root cause analysis and process improvement. The highest defect rates per unit occurred in March 2024 at 1,87% and April 2024 at 1,80%, caused by factors during the production process. Meanwhile, the defect percentages within the control limits indicate that the process is still statistically under control, but needs to maintain consistency.

Pareto Diagram

Pareto charts are used to identify the root causes of problems and prioritize solutions. According to Pareto's Law, approximately 20% of the factors often account for 80% of the impact, therefore, focusing on the dominant factors enables more effective and comprehensive improvements (Ramadhani, 2019). Figure 7 presents the data visualization in the form of a pareto diagram.

Based on Figure 7, holey defects have the highest frequency at 52 pieces (54%), followed by mottle defects at 37 pieces (38%), so that these two types of defects together contribute to 92% of the total defects. Crush defects were recorded at 8 pieces (8%). This visualization aligns with the Pareto Principle, which states that most effects come from a few causes. Therefore, improvement efforts should be prioritized on holey and mottle defects for optimal results.

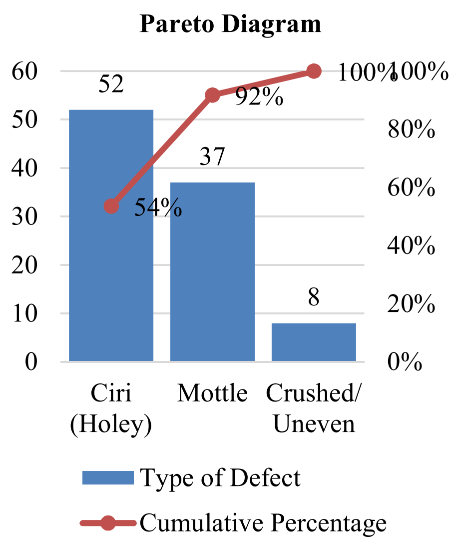

Figure 7. Pareto Diagram

Cause Effect Diagram

According to Heizer and Render in (Hamdani, 2022), a cause-and-effect diagram, also known as an Ishikawa or fishbone diagram, is shaped like a fishbone, with the main problem at the head and the causes along the fins and spines (Putri et al., 2023). Below are the results of further analysis regarding the causes of defects, using fishbone diagrams for the two dominant defects, as shown in Figure 8 and Figure 9.

Based on Figure 8, characteristic defects in fabric are caused by five main factors: machines, methods, materials, labor, and the environment. Low-quality machines and inadequate scouring technology may damage the fabric. Improper methods and excessive use of chemicals also pose a risk of damaging the fabric structure. Materials that do not meet specifications, such as fabric that is too thick or too thin, increase defect potential. Labor-related causes include a lack of skill and accuracy due to failure to follow standard operating procedures. An excessively hot work environment can also cause the fabric to become damp or overly dry, ultimately affecting final product quality.

Figure 9 shows a fishbone diagram for mottled defects, which are caused by five main factors: methods, labor, raw materials, environment, and machinery. The method factor is dominant, stemming from inconsistent dyeing duration, the absence of standard operating procedures (SOPs), variations in techniques among workers, and color contamination. Labor-related causes include insufficient skills in performing tasks. Raw materials that are too thick or too thin affect color absorption, while excessively hot environmental conditions reduce work comfort and disrupt the stability of the production process. In addition, poorly maintained and unclean equipment can also lead to mottled fabrics due to residual dye adhering to the walls of the dyeing equipment.

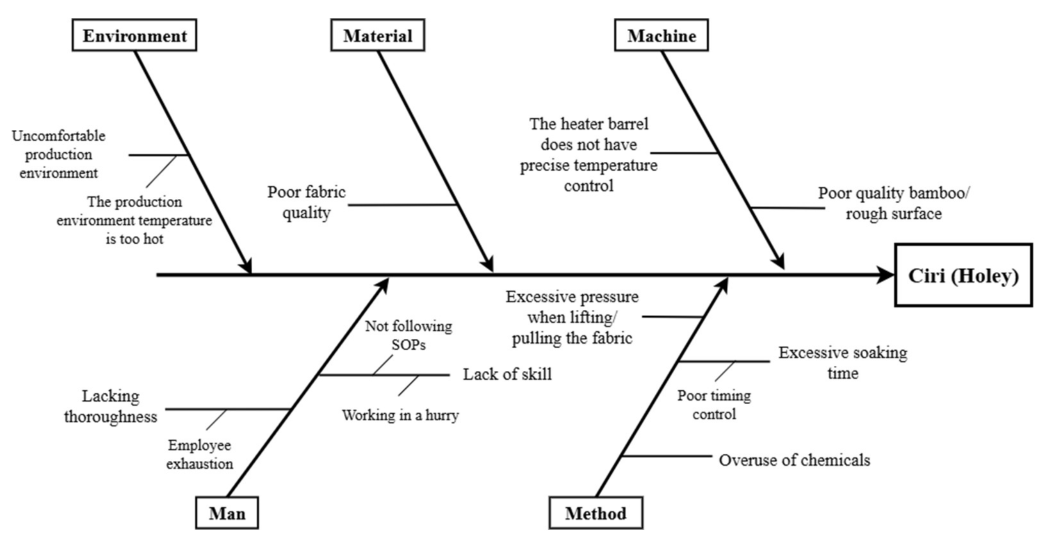

Figure 8. Fishbone Diagram Ciri (Holey)

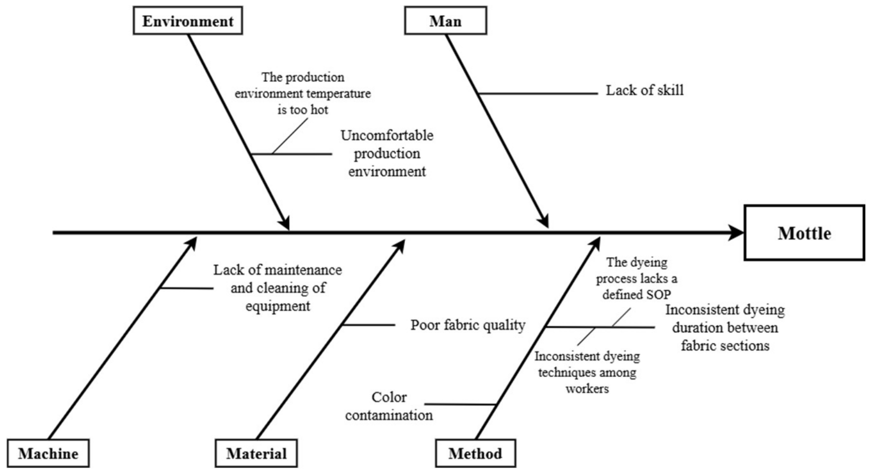

Figure 9. Fishbone diagram of mottle defect

Table 3. Parameter Contradiction of Ciri Defects (Holey)

No	Factor	Causes	*Improving Feature*	><	*Worsening Feature*
1	Machine	Poor quality bamboo/ rough surface	Manufacturing precision (29)	><	Ease of operation (33)
2	Method	Excessive pressure when lifting/ pulling the fabric	Force/ Intensity (10)	><	Loss of Time (25)
3	Material	Poor fabric quality	Strength (14)	><	Ease of operation (33)

Table 4. Parameter Contradiction of Mottle Defects

No	Factor	Causes	Improving Feature	><	Worsening Feature
1	Method	Inconsistent dyeing duration between fabric sections	Manufacturing precision (29)	><	Loss of Time (25)
2	Man	Lack of skill	Reliability (27)	><	Productivity (39)
3	Environment	Uncomfortable production environment	Temperature (17)	><	Loss of Energy (22)

Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ)

TRIZ is a method developed by Genrich S. Altshuller in 1960 to generate innovative solutions for problem-solving (Neyland et al., 2022). his method offers 40 solution principles based on 39 system parameters (Nugraha & Haryono, 2022).

Based on the fishbone diagram analysis, the dominant causal factors were identified and further examined to determine the improving parameters and the worsening parameters. According to the TRIZ approach, the comparison between these parameters produces a TRIZ contradiction matrix, which serves as a guide for selecting the parameters that need to be modified as required (Prabowo & Wijaya, 2020), as shown in Table 3 dan Table 4.

Based on the contradiction parameter table in Table 3, the causes analyzed were derived from the fishbone diagram. Three main factors were selected for further analysis using the TRIZ method. The selection of these factors was based on observations and interviews with the Head of Quality Control and was considered to represent the most dominant causes of defects.

Table 5. Ciri Defects (Holey) Contradiction Matrix

Improved Feature \ Worsened Feature		Lost of Time	Ease of operation
		25	33
Force (Intensity)	10	10, 37, 36	1, 28, 3, 25
Strength	14	29, 3, 28, 10	32, 40, 25, 2
Manufacturing precision	29	32, 26, 28, 18	1, 32, 35, 23

Table 6. Mottles Contradiction Matrix

Improved Feature \ Worsened Feature		Loss of Energy	Loss of Time	Productivity
		22	25	39
Temperature	17	21, 17, 35, 38	35, 28, 21, 18	15, 28, 35
Reliability	27	10, 11, 35	10, 30, 4	1, 35, 29, 38
Manufacturing precision	29	13, 32, 2	32, 26, 28, 18	10, 18, 32, 39

In addressing the root causes of a problem, an approach is needed that focuses on repairing or improving certain aspects, referred to as improving features. However, these improvement efforts often have side effects, namely the deterioration of other aspects when one aspect is improved, which is known as a worsening feature.

Based on Table 4, improvements in production systems often lead to technical contradictions, where enhancing one aspect may inadvertently reduce the performance of another. The TRIZ method addresses this by identifying two key parameters: improving features (aspects to be enhanced) and worsening features (aspects that may deteriorate as a result). Identifying these parameters is essential for determining the appropriate inventive principles, ensuring that the proposed solutions are optimal without introducing new problems.

The next step is to compile a contradiction matrix to obtain numerical references corresponding to the 40 TRIZ inventive principles. These principles then serve as a basis for formulating the most appropriate solutions to the identified issues. The contradiction matrices for ciri defects (holey) and mottles are presented in Tables 5 and 6.

Tables 5 and 6 present the intersection results between improving parameters and worsening parameters based on the 39 TRIZ technical parameters. This intersection generates solution principles derived from the contradiction matrix, which serve as the basis for formulating alternative solutions to the root causes of defects. The resulting inventive principles then act as a reference for selecting the most appropriate and feasible solution in accordance with the company's conditions, as summarized in Table 7.

After obtaining the TRIZ solution matrix, several alternatives were evaluated to determine the most ideal solution and the one that best suited the conditions at PT. Batik Danar Hadi.

Table 7. Determination of Inventive Principles

No	Reason	Conflict Parameters	TRIZ Inventive Principles
1	Poor quality bamboo/ rough surface	Manufacturing precision (29) x Ease of operation (33)	Segmentation (1) Color changes (32) Parameter changes (35) Feedback (23)
2	Excessive pressure when lifting/ pulling the fabric	Force (10) x Loss of Time (25)	Preliminary action (10) Thermal expansion (37) Phase transitions (36)
3	Poor fabric quality	Strength (14) x Ease of operation (33)	Color changes (32) Composite materials (40) Self-service (25) Taking out (2)
4	Inconsistent dyeing duration between fabric sections	Manufacturing precision (29) x Loss of Time (25)	Color changes (32) Copying (26) Mechanics substitution (28) Mechanical vibration (18)
5	Lack of skill	Reliability (27) x Productivity (39)	Segmentation (1) Parameter changes (35) Pneumatics and hydraulics (29) Strong oxidants (38)
6	Uncomfortable production environment	Temperature (17) x Loss of Energy (22)	Skipping (21) Another dimension (17) Parameter changes (35) Strong oxidants (38)

Table 8. Recommended Solutions

No	Selected Inventive Principles	Recommended Solutions
1	Parameter changes (35)	The bamboo surface is further processed (e.g., sanded and coated with a protective finish) to make it smoother without replacing the primary material. This approach maintains cost efficiency while enhancing tool quality.
2	Preliminary action (10)	Implement training programs or SOPs to ensure that pressure is properly set before the fabric is lifted.
3	Composite materials (40)	Select a blended fabric that is both strong and easy to process, increasing durability without sacrificing processing flexibility
4	Mechanics substitution (28)	Directly address the root cause by ensuring uniform and consistent dyeing duration through the use of automated tools, without interrupting the fabric process.
5	Segmentation (1)	Assign each worker to a specific task according to their expertise, so that skill limitations do not disrupt the overall process.
6	Skipping (21)	Apply a simple, quick-to-implement solution that requires no large system changes and immediately reduces the impact of high temperatures on work comfort—such as turning on fans before the temperature rises significantly or scheduling heavy tasks during cooler periods (morning/evening).

Improvement recommendations were then developed based on the 40 previously identified inventive principles. The selected solution was considered the most relevant and applicable to the company's problems, as presented in Table 8.

The resulting solution recommendations are selected based on subjective considerations, observation results, and interviews with the Head of Quality Control, while still taking into account efficiency aspects without compromising the flexibility of the production process. If the recommended solution cannot be implemented, the proposal must be reviewed and adjusted to field conditions, based on alternative solutions derived from the conflict parameters in the TRIZ method.

IV. CONCLUSION

Based on the research findings, the most dominant types of defects in batik fabric during the dyeing and rolling process at PT. Batik Danar Hadi are ciri defects (holey) and mottles, with a cumulative percentage of 92% of the total defects. Statistical Quality Control (SQC) analysis indicated deviations in the production process in March and April, as shown by u-chart values exceeding the upper control limit.

Cause-and-effect diagram analysis identified five main factors contributing to these defects: machines, methods, raw materials, labor, and the environment. To develop technical solutions for these causes, the TRIZ method was applied, referring to contradiction parameters and inventive principles. The resulting principles include segmentation, the use of composite materials, changes in physical parameters, prior actions, and feedback. The integration of SQC and TRIZ has proven effective in systematically, innovatively, and practically analyzing problems and formulating improvement solutions.Design optimization using the TRIZ method resulted in the following solutions: a frame made of anodized aluminum alloy, blades and clamps made of food-grade stainless steel 304, a standing work position, tool dimensions adjusted for standing comfort, a full protective cover, separation of wheel and anti-slip functions, and proper tool placement before use.

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