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Analysis of Quality Control of Drawn Textured Yarn Using Six Sigma Method at Indorama Engineering Polytechnic Production Unit

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ABSTRACT

Drawn textured yarn is one of the production outputs of the Vocational Training Center at Politeknik Enjinering Indorama, a partner of PT Indorama Synthetics Tbk. In its production process at the Vocational Training Center of Politeknik Enjinering Indorama, product defects are still encountered. To reduce product defects, the Six Sigma method with DMAIC approach is employed. For companies prioritizing product quality, quality control over the products must be conducted. This can manage and control the number of rejected or damaged products that could potentially harm the company's reputation in the eyes of consumers when the products are marketed.

Keywords: *Six Sigma, DMAIC, Quality Control, Fishbone Diagram, Drawn Textured Yarn*

1. INTRODUCTION

With the increasingly competitive nature of globalization and rapid advancements in knowledge and technology, an increasing number of companies in the industrial sector are required to create high-quality products. The quality of a product is one of the key factors in determining success in a competitive environment, alongside other key aspects such as marketability, pricing, and services.

In this study, the researcher conducted research at the Vocational Training Center of Indorama Engineering Polytechnic, which operates in the textile industry and produces drawn textured yarn (DTY). Drawn textured yarn is an ideal raw material for knitting and weaving. It is highly suitable for manufacturing clothing fabrics, bedding, home decorations, apparel, industrial fabrics, and automotive textiles, as well as for weaving various simulated silk fabrics. However, the production process at the Vocational Training Center of Indorama Engineering Polytechnic continues to encounter product defects. This study focuses on the production of drawn textured yarn (DTY), where defects frequently occur due to improper machine settings. To address this issue, the Six Sigma methodology can be implemented using the DMAIC approach: define, measure, analyze, improve, and control(Aziz, 2019; Gaspersz, 2002).

Six Sigma is a quality improvement vision aimed at reducing defects to a target of 3.4 failures per million opportunities for each product and service transaction. It is a comprehensive and flexible system that represents a breakthrough in quality management, allowing businesses to achieve, maintain, and maximize success (Gaspersz, 2006; Setiawati & others, 2018; Solihudin & Kusumah, 2017).

2. METHOD

2.1 SIX SIGMA

Six Sigma is a cutting-edge innovation in quality management used to strengthen market competition in an increasingly dynamic landscape. By employing the Six Sigma approach, businesses can achieve continuous quality improvement and strive for a zero-failure level. This methodology enhances efficiency, minimizes defects, and optimizes processes, making it a powerful tool for companies aiming for sustainable excellence(Gaspersz, 2006; Hidayat, 2007; Manan et al., 2018).

2.2 DMAIC

Continuous improvement can be carried out based on the Six Sigma methodology, which includes DMAIC (Hidayat, 2007; Pande et al., 2002; Pande & Holpp, 2005; Susetyo & Winarni, 2020).

1) Define

The define stage is the first step in the Six Sigma methodology for solving a problem. This stage involves defining the problem in the drawn textured yarn product that does not meet the company's predetermined quality specifications.

- Critical to Quality (CTQ)

Critical to quality is a method used to identify and categorize key aspects of product, service, and transaction quality that have a significant impact on customer satisfaction.

2) Measure

The measure stage is the second step in the application of Six Sigma. At this stage, sigma performance is measured, starting with calculations using P-chart, DPMO, and sigma values.

- Control Chart

A control chart is used for process output analysis. The data used in this analysis comes from samples of output, which are then displayed in a plotted control chart.

- DPMO (Defects per Million Opportunities)

DPMO represents the occurrence of defects within one million opportunities. To calculate the DPMO value, first, the DPU (Defects per Unit) and DPO (Defects per Opportunity) values are determined. Once these calculations are complete, the DPMO value and sigma level can be derived.

3) Analyze

The analyze stage is the third step in the Six Sigma process. In this stage, the factors causing defects are analyzed using tools such as the Pareto diagram and fishbone diagram.

- Pareto Diagram

The Pareto diagram is used to rank and analyze defect levels, from the most frequent to the least frequent.

- Fishbone Diagram

The fishbone diagram serves as a tool to illustrate the relationship between existing problems and their root causes. These elements are grouped into five categories: human, material, machine, method, and environment.

4) Improve

The improve stage is the fourth step in Six Sigma analysis. After identifying the causes of defects in the previous stage, appropriate recommendations for improvements are made to minimize defect levels in the drawn textured yarn.

5) Control

The control stage is the final step in the Six Sigma methodology. This stage involves monitoring the performance of the drawn textured yarn (DTY) production process and ensuring that the proposed solutions or improvements are implemented sustainably.

3. RESULT AND DISCUSSION

- Data Collection

The data collected by researchers in this study consists of production data from November 2023 and defect data for drawn textured yarn (DTY). Data collection was carried out using two methods: interviews and observations. Interviews were conducted with employees of the Vocational Training Center at Indorama Engineering Polytechnic to determine the production volume of drawn textured yarn (DTY) during the November 2023 period. Observations were carried out by directly and clearly monitoring the types of defects occurring in the field and counting the defect data of the products

- Data Processing

At the data processing stage, the previously collected data is processed using the Six Sigma methodology, which consists of several steps: define, measure, analyze, improve, and control.

1) Define (Defining defect types)

The following are the types of packaging product defects, which can be seen in the table below.

Table 1. *Critical to Quality* (CTQ)

No	***Critical to Quality***
1	*Broken filament*
2	X-Stitch
3	Bulging

Based on the table, three causes of product defects have been identified:

- Broken Filament

The end of the thread comes out of the spool or does not stay together with the thread, resulting in a fragmented filament. Broken Filament can be observed from thread spools that resemble human hair. This issue occurs due to various factors, such as excessively high or improper machine temperature.

- X-Stitch

The thread crosses, with one side going up and the other side going down. This type of abnormality makes the thread prone to breaking during the waving process. It happens due to various reasons, such as an incompatible cone.

- Bulging

The thread spool is not wound tightly, causing the spool dimensions to become larger and feel soft. This issue occurs due to several factors, such as improper machine settings.

2) Measure

- P-Control Chart (P-Chart)

The control chart is used as a tool to determine whether the data used in Six Sigma calculations falls within the control limits. If any data exceeds the control limits and its cause can be identified, the data is removed and recalculated to obtain the CL, UCL, and LCL values until the revised data falls within the control limits.

1. Calculating the average product nonconformity rate.

$$P = \frac{np}{n}$$
$$= \frac{43}{3532}$$
$$= 0.012$$

2. Characteristic Examination by Calculating the mean value.

$$CL = \frac{\sum np}{\sum n}$$
$$= \frac{1112}{88089} = 0.013$$

3. Determining control limits for monitoring by setting the UCL (Upper Control Limit / upper specification limit) and LCL (Lower Control Limit / lower specification limit.

$$UCL = \frac{p + 3}{n}\sqrt{p(1-p}$$
$$= \frac{0.12 + 3}{3532}\sqrt{0.12(1 - 0.12)}$$
$$= 0.14$$
$$LCL = \frac{p - 3}{n}\sqrt{p(1-p}$$
$$= \frac{0.12 - 3}{3532}\sqrt{0.12(1 - 0.12)}$$
$$= 0.12$$

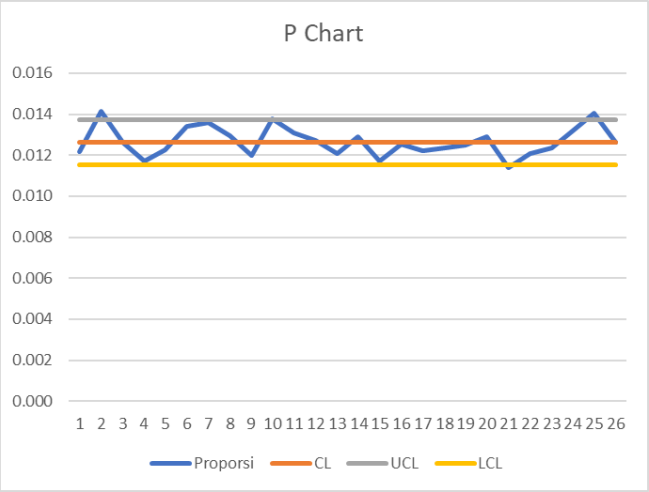

Fig. 1. P-Chart

P- Chart Control for drawn textured yarn shows that there are three periods with data points above the UCL, indicating an out-of-control state, occurring on the 2nd, 10th, and 25th. Additionally, the P- Chart Control reveals one point located at the LCL, representing a low-control state, occurring on the 21st. The high proportion of rejected products is attributed to factors such as fatigue, decreased concentration, and lack of discipline.

- Defect Per Million Opportunity (DPMO)

DPMO is an indicator used to assess product quality and process efficiency. It represents the number of defects per one million production units.

$$\text{DPMO} = \frac{D}{U\ x\ O}\ x\ 1.000.00$$
$$= \frac{43}{3532\ x\ 3}\ x\ 1.000.00$$
$$= 4058$$

- Sigma Level

The sigma level is calculated by below table.

Table 2. DPMO & Sigma Level

No	Produce	Defect	CTQ	DPMO	Sigma Level
1	3532	43	3	4058	2.9
2	3111	44	3	4714	2.8
3	3648	46	3	4203	2.9
4	3587	42	3	3903	2.9
5	3675	45	3	4082	2.8
6	3279	44	3	4473	2.8
7	3093	42	3	4526	2.8
8	3326	43	3	4309	2.8
9	3504	42	3	3995	2.9
10	3192	44	3	4595	2.8
11	3210	42	3	4361	2.9
12	3222	41	3	4242	2.8
13	3230	39	3	4025	2.9
14	3182	41	3	4295	2.8
15	3669	43	3	3907	2.9
16	3516	44	3	4171	2.8
17	3687	45	3	4068	2.8
18	3239	40	3	4116	2.9
19	3201	40	3	4165	2.8
20	3098	40	3	4304	2.8
21	3949	45	3	3798	2.9
22	3555	43	3	4032	2.8
23	3566	44	3	4113	2.9
24	3191	42	3	4387	2.8
25	3061	43	3	4683	2.9
26	3566	45	3	4206	2.9

Based on calculations, the current DPMO value is 4,058, which corresponds to a sigma level of 2.9. This means that for every one million production opportunities, approximately 4,058 processes will result in defective yarn that does not meet consumer expectations or company standards. At Vocational Training Center Indorama, this sigma level is comparable to the average industry standard in Indonesia. To reach world-class standards, Indorama must reduce the DPMO to 3.4, meaning only 3.4 defective products per million units, thus achieving a higher sigma level.

- Pareto Diagram Analysis

The Pareto diagram reveals that drawn textured yarn experiences three main defects:
- X-Stitch (50%) – the highest defect type
- Broken Filament (40%)
- Bulging (9%) – the least frequent defect

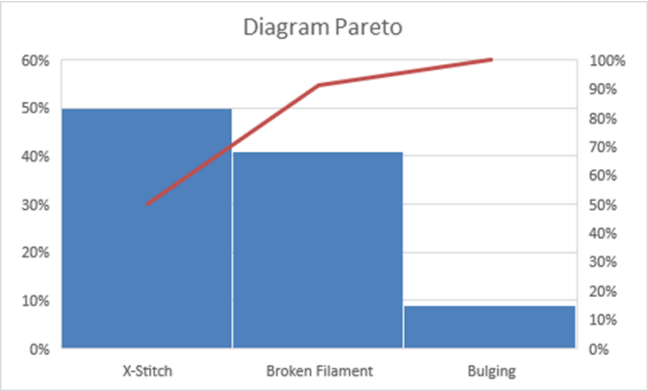

Fig. 2. Pareto Diagram

- Fishbone Diagram

The Fishbone Diagram identifies five key factors contributing to defects in drawn textured yarn that are Human (operator skills), raw materials, methods, machine& environment.

- Improve Phase

The improvement phase follows the Kaizen approach, which focuses on continuous quality improvement. Enhancements are made using the 5W + 1H framework (What, Why, Who, When, Where, How).

- Control Phase

The control phase is the final stage of Six Sigma, emphasizing documentation and dissemination of corrective actions, including:

1) Periodic maintenance and repairs of machines.
2) Raw material supervision by production staff to ensure product quality.
3) Monitoring the yarn production process to detect defects early.
4) Daily record-keeping and product weight measurement.
5) Reporting defective products based on type to supervisors.
6) Strict monitoring of raw materials, production processes, and distribution ensures that consumers receive high-quality products through a sustainable and responsible approach.

4. CONCLUSION

From the data analysis conducted at Vocational Training Center Politeknik Engineering Indorama, key findings include:

1) Root causes of defects are primarily due to lack of company oversight, which results in operators working inefficiently, improper SOP implementation, and poor working conditions (e.g., loud machinery noise, high temperatures, dirty and dusty environments), leading to decreased concentration and lower-quality output.
2) The current DPMO value is 3,865, which is equivalent to a sigma level of 2.9. To reach world-class standards, Indorama must reduce DPMO to 3.4.
3) Quality improvement recommendations for each defect type:
   - X-Stitch Defect Recommendations:
     1. Adjust machine speed settings.
     2. Perform regular machine spare part checks.
     3. Conduct periodic operator training to improve skills.
     4. Reconfigure or inspect machine spare parts before operation.
     5. Strengthen raw material supervision to maintain product quality.
   - Broken Filament Defect Recommendations:
     1. Optimize machine temperature settings.
     2. Perform regular machine spare part inspections.
     3. Periodic operator training to enhance skills.
     4. Reconfigure or inspect machine spare parts before operation.
     5. Strengthen raw material supervision to maintain product quality.

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