Quality Control Analysis of Conveyor Production in Curing Machine with Statistical Process Control

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Abstract

A transmission belt manufacturer in Indonesia, producing v-belts and conveyor belts. Many faults remain in the conveyor belt manufacturing process, causing product quality to deteriorate. Bubbles in the canvas cover are responsible for more than half of all faults. As a result, a quality control process is required to ensure that the finished product meets consumer expectations. The percentage of defective goods in total production and the percentage of the main contributors to defects are determined using P control chart approach and Pareto diagram. Fishbone diagrams are used to investigate the sources of faults and prioritize the adjustments that need to be done. The findings revealed that faults in conveyor production are caused by human factors, machinery, and techniques. This study proposes that quality control be used to improve the quality of conveyor products by identifying the major contributors to defects and their causes.

Keywords
Quality Control, Conveyor Belt, Statistical Process Control, Defective Products, Fishbone Diagram

1. Introduction
The appropriateness of a product or service to the specifications of a customer's needs is defined as quality (Hartini 2012). Quality control is a closely associated activity to the manufacturing process, in which the product's quality features are examined and tested to ensure that they satisfy the needed specification criteria (Susetyo et al. 2011). According to (Kotler 2004), customer satisfaction is a person's experience of joy or disappointment because of comparing his perceptions or impressions of a product's performance or results to his expectations.

A largest transmission belt company in Indonesia, one of its products is conveyor belts (Halepoto et al 2016). There are still inconsistencies between the items produced and consumer specifications in the manufacturing process (Sanchez et al. 2020). As consumer demands grow, the conveyor belt division will be required to manufacture excellent products (Weihe et al. 2021). A method, which is a process used to monitor standards, measure, and take corrective action while a product or service is being produced, is one way that can be used to carry out quality control (Heizer and Render 2006). Statistical Process Control (SPC) is an effective technique for improving the quality of products and services over time (Jiju Antony 2000). This strategy has a number of advantages, including decreasing wasted energy and expenses, improving procedures for the best output, and enhancing product quality to reduce customer complaints (Antony 2000). As a result, a quality control procedure will be carried out in this study utilizing SPC approach to control the conveyor production process and provide customer satisfaction.

2. Methods
Research and data collection are in a transmission belt company. The time of the research was carried out from August 1-August 31, 2019. Primary data collection was carried out by direct observation and interviews, then for secondary data using data obtained from the company in the form of the number of production and conveyor defects that occurred for seven months last (Rucitra and Amelia 2021). The data obtained is then processed using Minitab Software (Masir et al. 2021). The techniques used in analyzing the data are check sheets, Pareto diagrams, and SPC (Statistical Quality Control) analysis with P control charts, Fishbone Diagrams, and proposed improvements using the 5W+1H technique (Manojkumar and Kumar 2021).

2.1 Quality Control

This graphic is excellent for highlighting the key elements that influence the situation at hand and have an impact on the quality. The arrows that create fish bones in the fishbone graphic also allow us to see additional, more specific aspects that affect and influence these primary factors (Nurkholiq et al. 2019).

2.2 Statistical Quality Control

SQC basically refers to the use of statistical methods to gather and analyze data to assess and track the production quality. The application of statistical methods to monitor, regulate, analyze, manage, and improve products and processes is known as statistical quality control. A statistical technique known as statistical quality control uses probability theory to analyze or examine samples as part of a product's quality control procedures. Two common applications of the SQC technique of quality control include selecting whether to accept or reject several produced items as well as monitoring the execution of work as individual operations while the work is in process (Hendrawan et al. 2020).

2.3 Fishbone Diagram

This diagram is excellent for highlighting the key elements that influence both the quality and the current issue. The arrows in the fishbone diagram that form fish bones also allow us to see additional, more specific aspects that affect and influence these primary factors (Haryanto 2019).

2.4 5W+1H

The 5W+1H method is one of various techniques that may be used to find suggested improvements. The 5W+1H approach, also known as what, why, who, when, where, and how method, is a way to find problems when both the problem's specifics and its solution are known (Trenggonowati dan Arafiany 2018).

Data collection is done by recapitulating the data obtained from the internal company into a check sheet (Dinaryo et al. 2020). The data used is production data and defects that occurred from January 2019 to July 2019. The types of defects that occur in the conveyor production process are Bare (A), Canvas-Canvas Bubbles (B), Cover-Cover Bubbles (C). Bubble Cover – Canvas (G), Marking Defect (M), Porosity (S), Ply Embossed on Cover Surface (R), and Foreign Body Defect (X). The recapitulation of the results of data collection can be seen in Table 1 below:

Table 1. Data on Recapitulation of Total Disability for January – July 2019

Month	Amount Production (m)	Type of Defect								Total
		A	G	X	M	S	R	B	C	
January	23959	51	340	4	0	9	0	8	0	412
February	19506	99	64	3	0	10	0	1	0	177
March	22026	105	270	4	0	8	0	4	0	391
April	2380	100	305	6	1	5	6	15	7	445
May	25139	356	306	0	0	3	0	27	0	692
June	11568	22	26	3	0	0	0	5	0	56
July	23190	295	373	13	0	7	6	18	0	712
Total	127768	1028	1684	33	1	42	12	78	7	2885

According to the data above, overall production is 127768 m2, with the kind of Bare (A) flaws totaling 1028, period. Cover bubbles – Canvas (G) totaled 1684 points, Foreign Body Defects (X) totaled 33 points, Defects in Marking (M) totaled 1 point, Porosity (S) totaled 42 points, Ply arising on Cover Surface (R) totaled 12 points, and Ply arising on Cover Surface (S) totaled 42 points. The Cover–Cover (C) bubbles are 7 points, while the Canvas-Canvas (B) bubbles are 78 points. The total disability was 2885 points—the procedure of rectifying conveyor product faults is now carried out by patching problems that develop.

3. Results and Discussion

3.1 SPC (Statistical Process Control) analysis using the P control chart attribute

In this research, the P control chart (damage proportion control chart) is utilized as a tool to examine process control statistically using Minitab Software. The first step to producing a control chart is to compute the average product damage.

$$p = \frac{np}{n}$$

Description:

np = number of defective products in subgroup

n = number checked in subgroup

The second step is to calculate the central line (CL). The centerline is the average product breakdown (p).

$$CL = \bar{p} = \frac{\sum np}{\sum n}$$

Description:

$\sum$np = Total number of damaged

$\sum$n = Total number checked

The third step is to calculate the upper control limit (UCL) and the lower control limit (LCL).

$$UCL = \bar{p} + 3\sqrt{\frac{p(1-p)}{n}}$$

$$LCL = \bar{p} - 3\sqrt{\frac{p(1-p)}{n}}$$

Description:

$\bar{p}$ = average product damage

n = total group/sample

Data processing on SPC analysis using the map attribute control P produces a graph that can be seen in Figure 1.
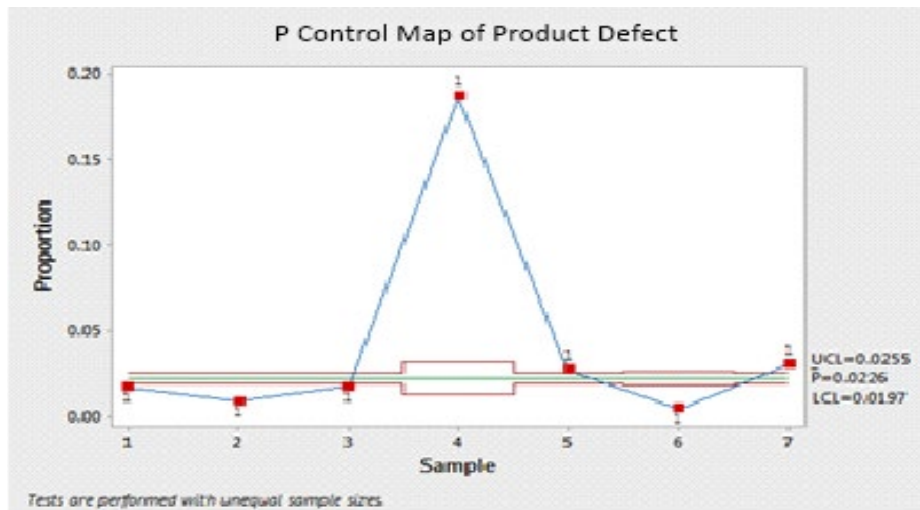

Figure 1. Conveyor belt Defect P Control Map

The UCL is 0.0255 and the LCL is 0.0197, with a p or CL value of 0.0226, according to the results of the p control chart on conveyor belt production above. Chart p shows that all points are outside the control limits based on the control results. As a result, quality control must be carried out through continuous improvement.

3.2 Pareto Chart

Pareto charts or Pareto diagrams are used to compare various categories of events arranged according to size, from the largest on the left and the smallest on the right, which is shown through a graph (Riyanto 2015). The Pareto graph shows the factors that occur most often and helps utilize limited resources to be maximized as best as possible by pointing to the most important problems to be overcome (Ahmed and Ahmad 2011). This tool is used in SPC and quality improvement to prioritize projects for improvement, prioritize setting up a team in corrective action to resolve problems, identify products that have the most complaints, identify the most frequent complaints, identify the causes of the most frequent rejections or for other similar purposes (Magar and Shinde 2014). Figure 2 is a Pareto diagram of conveyor belt production.
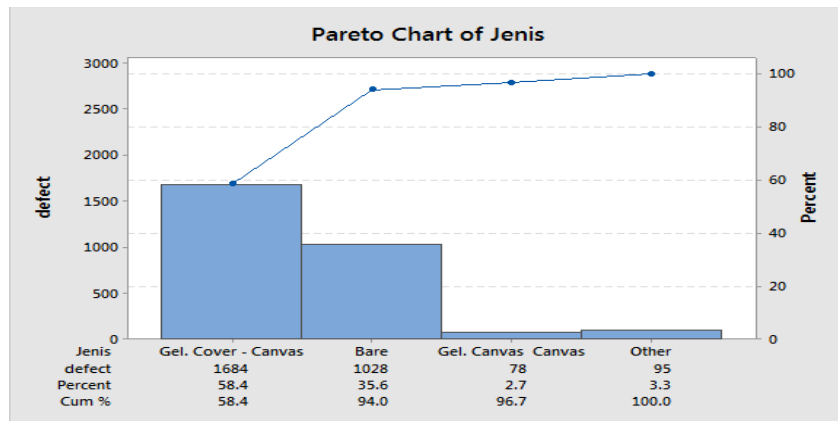
Figure 2. Pareto Diagram of Conveyor Belt Defects

Based on the Pareto diagram above, it can be seen that the conveyor belt product defect that often occurs is the bubble cover canvas, where the number of defects that occur is 1684 points per meter with a percentage of 58.4% of the total production volume of 127768 m2.

3.3 Analyze Existing Conditions

Based on the results of field observations related to the factors that cause defects in the canvas cover bubbles are Humans, Machines, and Methods. For more details, see the Table 2 below.

Table 2. Observation Results of Working Conditions

No	Factor	Actual Condition	Ideal Condition	Date	Description
1	Man	Operators work according to SOP.	Operators work according to SOP.	23 August 2019	OK
		Don't stab the green belt on the rubber mat that has been provided	Piercing the green belt on the rubber tool that has been provided.	23 August 2019	NG
2	Machine	The awl is not able to pierce a thick green belt.	The awl is capable of piercing a thick green belt.	23 August 2019	NG
3	Method	The stabbing of the green belt is uneven and tight.	Even and tight green belt stabbing.	23 August 2019	NG
		The stabbing of the green belt does not penetrate.	Stabbing the green belt until it penetrates.	23 August 2019	NG
4	Material	A green belt that is processed in good condition	Green belt that is processed in good condition.	23 August 2019	OK
5	Environment	Conditioned Work Area.	Conditioned Work Area.	23 August 2019	OK

Description:
OK: Conditioned
NG: Unconditioned

3.4 Cause and effect analysis

Fishbone diagram or fishbone diagram is a visual tool to identify, explore, and graphically describe in detail all the causes associated with a problem (Asmoko 2013). This diagram will show an impact or consequence of the problem, with various causes (Omar and Mustafa 2014). Some of the benefits of building a Fishbone diagram are that it will help determine root causes of problems or quality characteristics using a structured approach, encourage group participation, leverage group knowledge of the process, and identify areas where data is stored (C.N. 2010). Fishbone diagram shown in Figure 3.
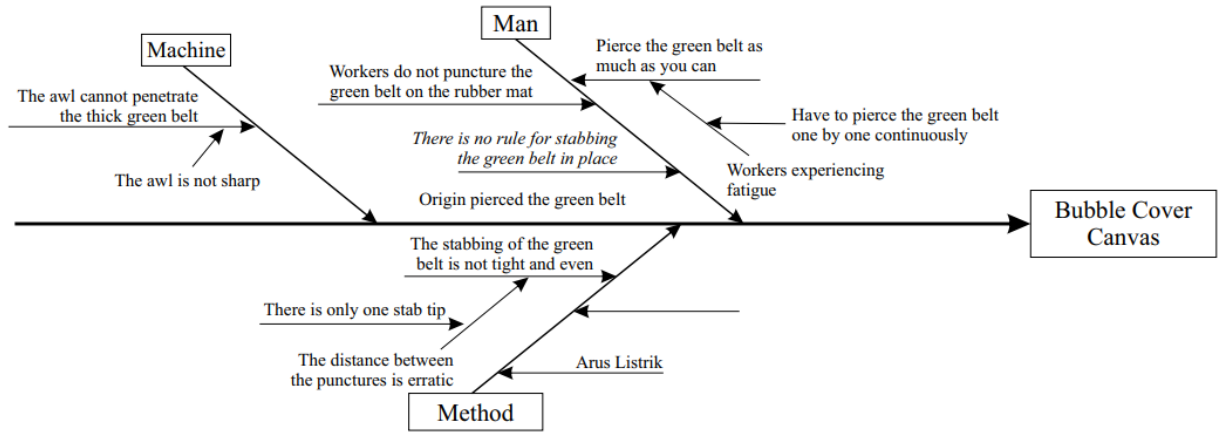
Figure 3. Fishbone Diagram of the Causes of Bubble Cover Canvas

From the results of the analysis that has been carried out, it can be recommended a problem-solving plan as follows shown in Table 3.

Table 3. Problem Management Plan

No	Factor	What		Why	Who	Where	When	How
		Problem	Solution					
1	Man	There is no SOP for stabbing the green belt in place.	Make a SOP to stab the green belt in place.	The operator does not stab the green belt on the mat that has been provided.	All operators in the curing machine.	On the curing machine.	1 September 2019	Apply the SOP to pierce the green belt in place.
		Have to pierce the green belt one by one continuously.	Increase the number of stitches.	Operators are not able to consistently continuously puncture evenly and tightly.	All operators in the curing machine	On a stealing machine.ng.	1 September 2019	Tool redesign.
2	Machine	The operator does not perform routine maintenance of the puncture tip.	Operators routinely perform maintenance of sharpening awl.	Operators do not routinely sharpen tools.	All operators in the curing machine.	On the curing machine	1 September 2019	Operators do tool sharpening once a week.
3	Method	Only use one end of the stab.	Increase the number of stitches with a distance between stitches of 2 cm.	Operators are uneven and tight in stabbing.	All operators in the curing machine.	On the curing machine	1 September 2019	Re-Design tool.

3.5 Repair Solution Analysis

1. Man

The first factor is that when conducting field observations on the curing machine, the operator does not pierce the green belt at the available puncture site. This can happen because the operator stabs the green belt when the position is hanging so that the stabbing process cannot be maximized and allows the results of the puncture to only reach the surface of the green belt. Therefore, to overcome this, the recommendation that can be made is to make an SOP to stab the green belt in place. In addition, the supervisor's role is also needed as a party which reminds if the operator does not stab at the provided place. For the second human factor, the operator must pierce the green belt one by one continuously. Of course, this will cause the operator to tire easily. To overcome this, the recommendation that can be done is to redesign the tool by increasing the number of puncture ends.

2. Machine

One of the causes of bubbles in the canvas cover is the operator being unable to puncture the thick conveyor belt until it penetrates to the bottom. The thing that causes this to happen is that the tool used is unable to penetrate the conveyor belt because it is not sharp enough. Therefore, maintenance of the stabbing device is one solution that can reduce the bubbles of the canvas cover on the conveyor belt. Tool maintenance that can be done is to sharpen the awl regularly. Based on the results of interviews with operators, the maintenance of the awl is carried out only when the tool looks bent or blunt, without carrying out routine maintenance of the tool. Therefore, it is necessary to sharpen the tool regularly once a week because when the awl is maintained sharp, it will help the operator to be able to penetrate the thick conveyor belt.

3. Method

Based on field observations, the operator performs stabbing with erratic distances between holes. The operator does not puncture tightly and evenly so that there is still air space between the cover and the canvas. If the air space between the cover and the canvas is not punctured, it will cause bubbles for the canvas cover when the cooking process is complete in the curing machine. Therefore, to overcome this, the way is to increase the number of stabs ends with a distance between the stab ends of approximately 2 cm to minimize the air trapped in the space between the canvas covers and also tighten the green belt stabbing which is not only at the beginning and at the end.

6. Conclusion

Chart p shows that the conveyor production process in the curing machine is out of control for the proportion between the number of defects and the amount of production, based on the results of data processing using a control. There were eight types of flaws in the conveyor belt production process in the curing machine from January to July 2019, namely: bare (A), bubble Canvas-Canvas (B), Bubble Cover – Cover, and Bubble Cover – Cover (C). Canvas (G), Marking Defect (M), Porosity (S), Ply Embossed on Cover Surface (R), and Foreign Body Defect are all examples of bubble covers (X). The bubble cover canvas is the most prevalent sort of product defect. The Fishbone Diagram and the 5 M methodology are used in product defect analysis to examine the factors that cause the most problems by examining five elements: person, machine, method, material, and environment. However, only human, machine, and method elements are important to this challenge. Improvement suggestions can be made, for example, in terms of human factors, such as giving instructions to maintain stabbing the green belt on the provided base so that the green belt can be punctured optimally. It is standard procedure to do maintenance on the machine or tool factor, such as sharpening the awl once a week in order to pierce the green belt. The procedure entails increasing the number of punctures while maintaining a 2 cm spacing between them and flattening the punctures to reduce the amount of air trapped in the conveyor belt.

References

A. B. and T. T. Jiju Antony, "Key ingredients for the effective implantation of statistical process control.," *Work study*, vol. 49, no. 6, pp. 242–247, 2000.

Ahmed, N., M., & Ahmad, "An application of Pareto analysis and cause-and-effect diagram (CED) for minimizing rejection of raw materials in lamp production process.," *Manag. Sci. Eng.*, vol. 5, no. 3, pp. 87-95., 2011.

Antony, B. M. "Statistical Process Control: An Essential Ingredient For Improving Service And Manufacturing Quality," *Manag. Serv. Qual. An Int. J.*, vol. 10, no. 4, pp. 233–238, 2000.

Asmoko, H. *Teknik Ilustrasi Masalah – Fishbone Diagrams.* Balai Diklat Kepemimpinan, Pusdiklat SDM, BPPK, Magelang., 2013.

Dinaryo, N. I. M., Pujawan, I. N., & Arvitrida, "Simulation Modelling of Warehouse Capacity Re-allocation to Improve Inbound Logistics Performance: A Study Case.," 2020.

Halepoto, S. I. A., & Khaskheli, "Modeling of an integrated energy efficient conveyor system model using belt loading dynamics.," *Indian J. Sci. Technol,* vol. 9, no. 47, pp. 1–6, 2016.

Hartini, S. "Peran Inovasi : Pengembangan Kualitas Produk dan Kinerja Binis.".," *J. Manaj. Dan Kewirausahaan Univ. Airlangga, Surabaya.*, vol. 14, no. 1, 2012.

Haryanto, E. "Analisis Pengendalian Kualitas Produk Bos Rotor Pada Proses Mesin Cnc Lathe Dengan Metode Seven Tools.," *J. Tek.*, vol. 8, no. 1, 2019.

Heizer, B. J. dan Render, *Operation Management*. Jakarta: Salemba Empat, 2006.

Hendrawan, D. S. M. Wirawati, and H. Wijaya, "Analisis Pengendalian Kualitas Pada Proses Boning Sapi Wagyu Menggunakan Statistical Quality Control (SQC) Di PT. Santosa Agrindo.," *J. Ind. Eng. Manag. Res.*, vol. 1, no. 2, pp. 195–206, 2020.

I. G. and C. N., "Application Of Fishbone Diagram To Determine The Risk Of An Event With Multiple Causes," *Manag. Res. Pract.*, vol. 2, no. 1, pp. 1–20, 2010.

Magar, V. B. V. M., & Shinde, "Application of 7 quality control (7 QC) tools for continuous improvement of manufacturing processes.," *Int. J. Eng. Res. Gen. Sci.*, vol. 2, no. 4, pp. 364–371, 2014.

Manojkumar, M. S., & Kumar, "Elimination of visor defects using 7 QC tools.," *Mater. Today Proceedings,* vol. 45, pp. 8203-8206., 2021.

Masir, A. N. R. N., Ataei, M., Sereshki, F., & Qarahasanlou, "Availability simulation and analysis of armored face conveyor machine in longwall mining.," *Rud. Zb. (The Mining-Geological-Petroleum Bull.*, vol. 36, no. 2, pp. 69–82, 2021.

Nurkholiq, A. O. Saryono, and I. Setiawan, "Analisis pengendalian kualitas (quality control) dalam meningkatkan kualitas produk.," *J. Ekonologi Ilmu Manaj.*, vol. 6, no. 2, pp. 393–399, 2019.

Omar, Z. A., & Mustafa, "Implementation of six sigma in service industry.," *J. Qual. Meas. Anal.*, vol. 10, no. 2, pp. 77–86, 2014.

J. Rucitra, A. L., & Amelia, "Quality control of bottled tea packaging using the Statistical Quality Control (SQC) and the Failure Mode and Effect Analysis (FMEA).," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 733, no. 1, p. 012057, 2021.

Rucitra, DJ. A. L., & Amelia, "Quality control of bottled tea packaging using the Statistical Quality Control (SQC) and the Failure Mode and Effect Analysis (FMEA).," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 733, no. 1, p. 012057, 2021.

Riyanto, O. A. W. "Implementasi metode quality control circle untuk menurunkan tingkat cacat pada produk alloy wheel.," *J. Eng. Manag. Ind. Syst.*, vol. 3, no. 2, 2015.

Sanchez, J. M., Exposito, E., & Aguilar, "Autonomic computing in manufacturing process coordination in industry 4.0 context.," *J. Ind. Inf. Integr. 19, 100159.*, vol. 19, p. 100159., 2020.

Susetyo, H. C. Joko., Winarni., "Aplikasi Six Sigma DMAIC Dan Kaizen Sebagai Metode Pengendalian dan Perbaikan Kualitas Produk," *J. Teknol. Inst. sains Teknol. AKRIND*, vol. 4, no. 1, 2011.

Trenggonowati L. and N. M. Arafiany, "PENGENDALIAN KUALITAS PRODUK BAJA TULANGAN SIRIP 25 DENGAN MENGGUNAKAN METODE SPC DI PT. KRAKATAU WAJATAMA Tbk.," *J. Ind. Serv.*, vol. 3, no. 2, 2018.

Weihe, J. T., Schnabel, U., Winter, H., Möller, T., Stachowiak, J., Neumann, S., ... & Ehlbeck, "Reduce and refine: Plasma treated water vs conventional disinfectants for conveyor-belt cleaning in sustainable food-production lines.," *J. Appl. Physics,* vol. 129, no. 22, p. 223304., 2021.

Biography

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