Analysis of Factors Causing Production Defects using the Six Sigma Method and Statistical Process Control in PT Daiho Indonesia

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Abstract. The problem that often occurs in manufacturing companies in Indonesia is product defects. To achieve high-quality standards and meet standards, it is necessary to identify problems that cause defects in a product so that appropriate solutions or actions can be found to overcome these problems. This research is used to analyze production defect factors and how to resolve them using Six Sigma, which consists of the Define, Measure, Analyze, Improve, Control process, which can make it easier to solve problems and determine the sigma level before and after taking corrective action. In this research, researchers also used Statistical Process Control Tools (SPC), which were used to control, analyze, manage, and make improvements. Based on the results of the analysis, production defects are caused by human factors, materials, methods, machines, and molds. The results of research using the Six Sigma method and Statistical Process Control Tools (SPC) can increase the sigma value to 4.68 (5-sigma) and reduce the percentage of defects by 0.47%.

Keywords: Six Sigma, Statistical Process Control (SPC).

1 Introduction

Indonesian manufacturing companies always strive to provide high-quality products that will benefit their companies and bring satisfaction to customers. The problem that often occurs in manufacturing companies in Indonesia is product defects. To achieve high-quality standards and meet standards, it is necessary to identify problems that cause defects in a product so that appropriate solutions or actions can be found to overcome these problems.

Quality control is important for business actors and needs to be considered carefully so that business actors can understand the impact of errors made during the production process and minimize potential problems, and this can help businesses make good decisions in terms of quality and quantity (Tenny, et al., 2018).

To be able to compete in the industrial world today, companies are required to continue to optimize effectiveness and efficiency by minimizing the occurrence of defects in production. Product quality or product quality is the main thing that needs to be considered in every business behavior (Pamungkas, 2023).

The main focus that a company must pay attention to is quality management. One of the crucial factors that must be improved in order to increase product competitiveness is quality, because in every purchase of a product to be consumed, consumers often consider the quality of a product. A product can be interpreted as high quality if it can meet customer needs and is also used effectively and produced in the right way (Putri, 2019).

PT Daiho Indonesia is a manufacturing company from Japan that operates in the injection molding or plastic sector and is located in the Batu Ampar industrial area of Batam. PT Daiho Indonesia produces various kinds of plastic products according to customer requests. Defects in products that occur during the production process can cause an increase in labor costs and raw material costs from previously agreed costs or budgets. This can hamper delivery due to insufficient stock, and it is feared that defective products will also be sent to customers. The research uses data in the form of the number of production defects in the Chest Plate product, types of production defects, and images using Six Sigma and Statistical Process Control (SPC), which are expected to be able to resolve production defect problems due to high consumer demand so that It is very important to minimize the number of defective products and be able to meet production targets.

Production Defect

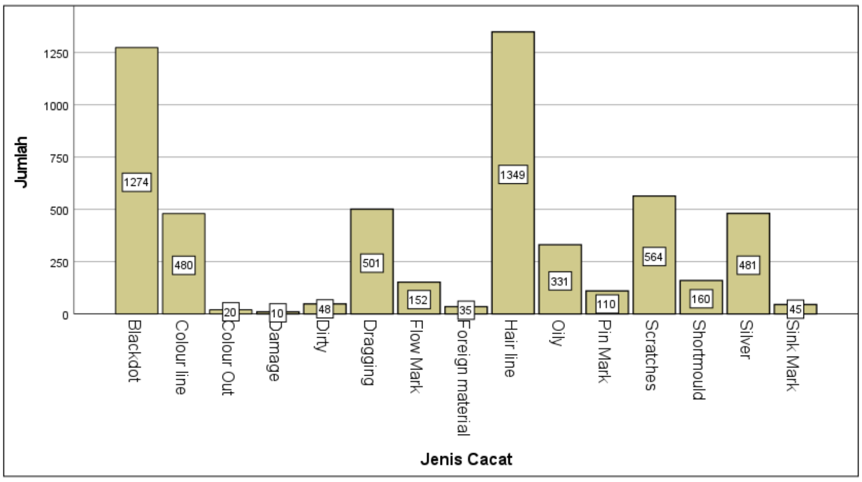

Fig. 1. Diagram of the number of production defects
(Source: PT Daiho Indonesia Daily Production Report 2024

2. Literature Review

2.1 Quality

Gasperz (2001) divides the meaning of quality into conventional and strategic. The conventional definition is to show the characteristics or features of the product. The characteristics are work ethics, morality, ease of use, aesthetics, and so on. Meanwhile, the definition of strategic quality is any product or service that can achieve customer satisfaction. Another definition of quality is the unity of form and characteristics of a product or service, namely adhering to the ability of the product or service to meet customer satisfaction. A product is designed and manufactured to be used according to its function. A product that meets standards can be considered quality.

2.2 Defective Product

Defective products are products that are produced in a damaged condition or do not comply with predetermined quality standards. In a manufacturing company, defects in the product may occur. Defects in products can result in increased raw material or material costs and also labor costs. A defective product can be interpreted as a product that does not function properly according to the purpose for which it was made and has no use value (Muhammad, 2021).

2.3 Six Sigma

Six sigma is defined as a means of improving business processes that aim to identify and determine the factors that cause product failure, minimize processing time, and operating costs, increase productivity, be able to achieve customer desires, be able to reach a higher threshold for asset utilization, and be able to obtain more profitable investment results from production to service (Evans & Lindsay, 2007). The method that can be used to improve quality, to find out the causes and how to overcome problems is to apply the Define, Measure, Analyze, Improve, Control (DMAIC) concept in six sigma. The Define, Measure, Analyze, Improve, Control (DMAIC) concept is related to the process of making continuous corrections or improvements to achieve the six sigma target. The six sigma method is intended to improve a company's procedural competence in carrying out its production process while continuously controlling product quality to achieve zero defects (Al-faritsy, et al., 2022). The goal of Six Sigma is continuous improvement or continuous improvement of the quality of the products produced (Damayanti & Ngatilah, 2020).

2.4 Statistical Process Control (SPC)

Statistical Process Control (SPC) is a problem-solving method that is used to control, control, analyze, manage, and improve a process by applying statistical methods and procedures that are widely used to confirm that a process complies with standards. The most famous Statistical Process Control (SPC) tool is the control chart (P-Chart) which was originally developed by Walter Shewart in the early 1920s. Control charts (P-Charts) support someone in recording data and make it possible to know when events are unusual. They are also used to understand whether the product being produced is within predetermined limits. Statistical Process Control (SPC) has seven quality control tools collected by Dr. Kaoru Ishikawa is fishbone chart, flow chart, checksheets, pareto diagram, histogram, control chart, and scatter diagram (Heizer & Render, 2009).

3 Research Methods

3.1 Observation

According to (Sugiyono, 2022) observation is a type of data collection technique that has a certain level of accuracy. Not only about the person, but also about other objects. Through observation, researchers can find out the process and results of the object. In the production process, researchers can assess how well the manufacturing process behaves in terms of processing raw materials, how well or poorly the manufacturing company's components are maintained, the quality of the products produced, and how well the workforce or machine operators perform. Sources of information that are very important in research can be recorded by researchers, whether they are heard, seen or observed directly using field notes. Field notes can be useful for recording things that are not included in the interview sheet.

3.2 Interview Sheet

Contains structured interview questions as a guide for researchers in conducting interviews with internal company parties.

3.3 Documentation

The source of information used comes from the company PT Daiho Indonesia Batam, data in the form of reports, product photos, and other documents related to the research. In this research, researchers applied the Six Sigma methodology which includes the DMAIC concept, namely:

a) **Define** in this phase or stage the researcher carries out the process of identifying defective products using critical to quality (CTQ), Pareto diagrams and SIPOC diagrams.
b) **Measure** at this stage or phase, measurements can be carried out by calculating control charts or P-charts and sigma level measurements
c) **Analyze** is the stage of identifying what factors cause quality problems by using a cause-and-effect diagram or fishbone chart which can be used to find possible causes of defects in the product.
d) **Improve** is a stage or phase of improvement. Researchers used the 5W + 1H method as a corrective step to overcome this problem.

e) **Control** is a phase or stage in quality improvement by ensuring a new level of performance in standard conditions and the improvement values are maintained which can then be documented and informed which can be used as an improvement step for the next process performance.

4 Results and Discussion

4.1 Define Stage

Several production defects were found based on the product defects studied. This condition made researchers create defect or critical to quality (CTQ) criteria for the Chest Plate product

a) Critical to quality (CTQ)

Table 4.1 Critical to Quality (CTQ)

No.	Type of defect	Characteristics
1.	Hair line	This is the result of remaining material in the form of fine hair that sticks to the surface of the product.
2.	Black dot	In the form of black dots that stick to the surface of the product.
3.	Scratches	Scratches on the product surface.
4.	Dragging	Drag lines that cause the product surface to be uneven/smooth.
5.	Silver	Spots of silver streaks that appear on the surface of the product.
6.	Colour Line	In the form of other color lines that appear on the product.
7.	Oily	Oil spots stuck to the product.
8.	Short mould	The material does not fill the entire mold or mold space, so the product produced is not perfect
9.	Flow Mark	In the form of a wavy or striped pattern on the product
10.	Pin Mark	In the form of ejector pin marks appearing on the surface of the product
11.	Dirty	The appearance of dirt or foreign objects on the surface of the product

12.	Sink Mark	In the form of signs of dimples or indentations (sinks) on the surface of the product
13.	ForeignMaterial	Foreign materials mixed into raw materials
14	Colour Out	The resulting color does not match the product color that the customer wants
15.	Damage	Incompatibility with the product, damage to the product affects the appearance of the product

b) Supplier, Input, Process, Output, Customer (SIPOC)

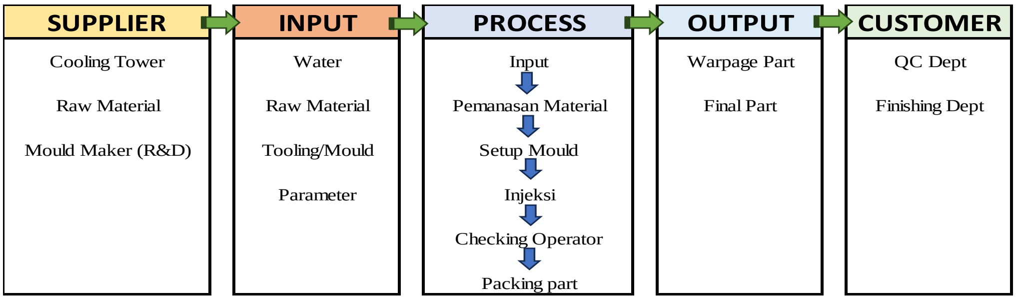

Fig. 4.1. SIPOC Diagram

4.2 Measure Stage

In the Measure Stage, Control Map (P-Chart) calculations and sigma and DPMO level measurements are carried out.

a) P-Chart

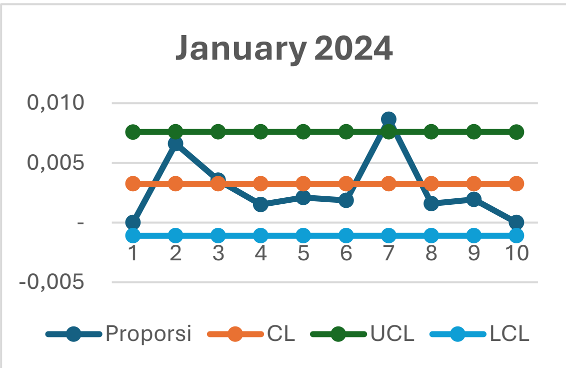

Fig. 4.2. P-chart for the period January 2024

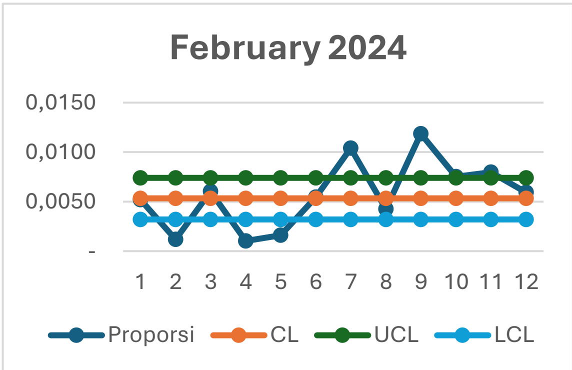

Fig. 4.3. P-chart for the period February 2024

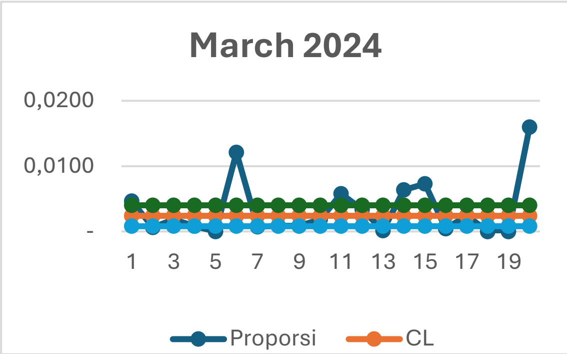

Fig. 4.4. P-chart for the period March 2024

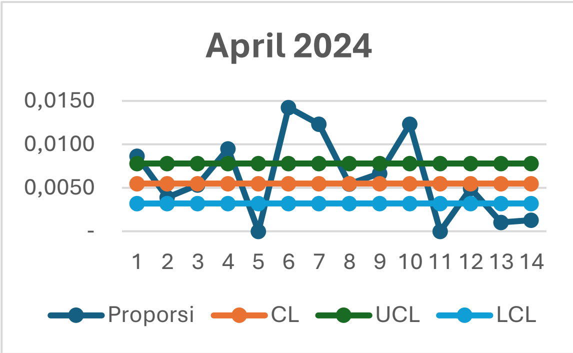

Fig. 4.5. P-chart for the period March 2024

b) Measurement of sigma level and DPMO

Table 4.2 Measurement of sigma level and DPMO

Period	Total Production	Production defects	Defect Rate	DPU	DPMO	Sigma level
January	252.560	819	0,324279	0,003243	3242,794	4,22
February	256.480	1.368	0,533375	0,005334	5333,749	4,05
March	540.396	1.312	0,242785	0,002428	2427,849	4,32
April	375.430	2.061	0,548971	0,00549	5489,705	4,04

1) **Defect Rate** $= \frac{\text{Production Defect}}{\text{Total Production}}$ x 100 % = $\frac{819}{252.560}$ x 100% = 0,324279%
2) **DPU** = $\frac{\text{Production Defect}}{\text{Total Production}} = \frac{819}{252.560}$ = 0,003243
3) **DPMO** = DPU x 1.000.000 = 0,003243 x 1.000.000 = 3242,794
4) **Sigma** = NORMSINV((1000000-DPMO)/1000000)+1,5 = 4,22

c) Pareto Diagram 80 : 20 Rules

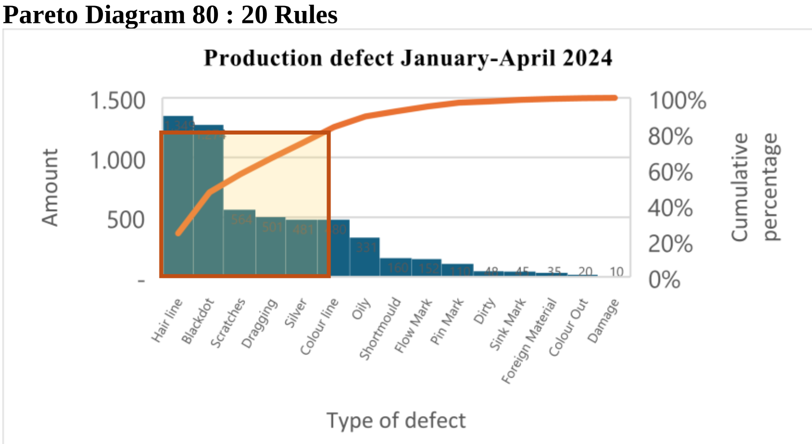

Fig. 4.6. Pareto diagram

From the Pareto Diagram 80: 20 rules shows that there are five main types of defects that will be observed, namely Hair line (24%), Black dot (23%), Scratches (10%), Dragging (9%), and Silver (9%) to achieve 20% effort and 80% optimal results.

4.3 Analysis Stage

Analysis is a stage or phase of solving the origins of the causes of problems. The analysis was carried out step by step using a cause-and-effect diagram (Cholifaturochmah, Widyaningrum, & Jufriyanto, 2022).

a) Hair line

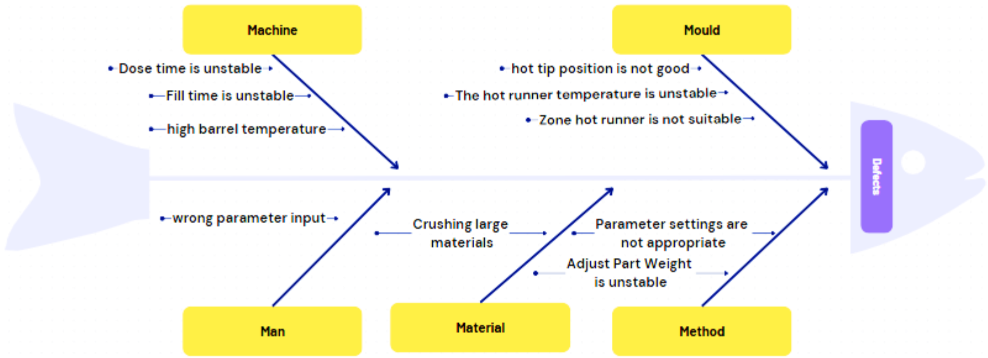

Fig. 4.7. fishbone chart hair line

b) Black dot

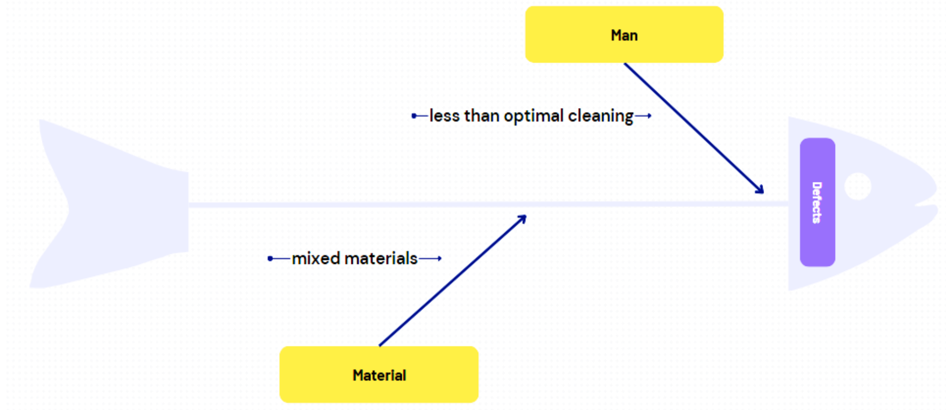

Fig. 4.8. fishbone chart black dot

c) Scratches

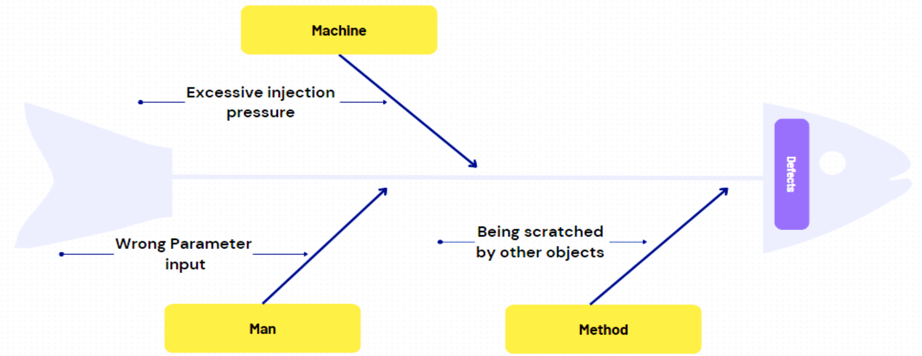

Fig. 4.9. fishbone chart scratches

d) Dragging

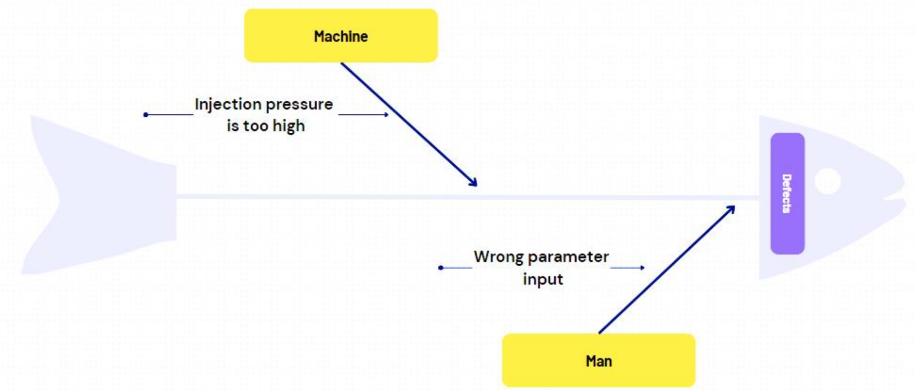

Fig. 4.10. fishbone chart dragging

e) Silver

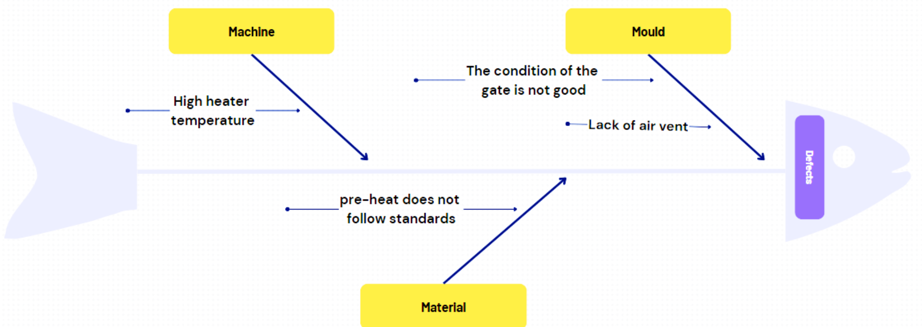

Fig. 4.11. fishbone chart silver

4.4 Improve Stage

a) 5W +1H

Table 4.3 5W + 1H

What	Who	When	Why	Where	How
Poor hot tip/gate position	Tooling Technician	During the mold maintenance process	Check the connection between the hot tip and the product defect that occurs	Injection	Replace the position of the hot tip on the mold base
The hot runner temperature is unstable	Injection Technician	During the production process	Unstable hot runner temperature, there is a possibility of product defects occurring during filling time.	Injection	Changing the hot runner temperature per bar
Inappropriate hot runner zone	Tooling Technician	During the mold maintenance process	Find different settings with bar position	Tool Room	Change the position following the sequence of cavity numbers on the mold
The mold cleaning process is less than optimal	Tooling PSM	During the mold maintenance process	A less than optimal cleaning process results in resin remaining in the mold area	Tool Room	Carrying out and ensuring mold maintenance after production
Using large crushing materials	IE Technician	Crushing machine maintenance	Crushing large amounts of material can make the temperature unstable	Injection	Replacing small machine material crushing on the injection machine
Mixed materials	Material Handler	Material change process	When changing the material, it is possible that the old material will still remain	Injection	Clean the hopper optimally before filling new material
Parameter settings are not appropriate	Injection Technician	Adjustment process	Non-standard parameter input causes defects	Injection	Check the parameters again

b) Corrective Actions taken

1) **Change the position of the hot tip,** Make improvements by changing the position of the hot tip. The hot tip in cavity 1 and 2 is changed to position in cavity 7 & 8 and vice versa**.**
2) **Adjust hot runner temperature,** Adjust the temperature on the hot runner which was previously 330^{o} -340^{o}. Make the standard hot runner temperature setting spec to 280^{o} – 310^{o}
3) **Changing the zone position,** Changing the zone position on the mold, previously zone 1 for cavities 7 and 8 was changed to cavities 1 and 2,

zone 2 which was previously for cavities 1 and 2 was changed to cavities 3 and 4, zone 3 which was previously for cavities 3 and 4 was changed became cavities 5 and 6, and zone 4 which was previously for cavities 5 and 6 was changed to cavities 7 and 8.

4) **Ensure and carry out mold maintenance after production,** When mold production is complete, ensure and carry out mold maintenance, checking the cavity area, core area, slider area and ejector pin.
5) **Use small size material crushing,** Before carrying out repair action, use material with a size of 12.01 mm, after repair use material with a smaller size, namely 2.65 mm.
6) **Parameter Checking,** Check the condition of the parameters and ensure that the parameters comply with standard parameters, if everything is OK, then the mold must be overhauled (maintenance).

4.5 Control Stage

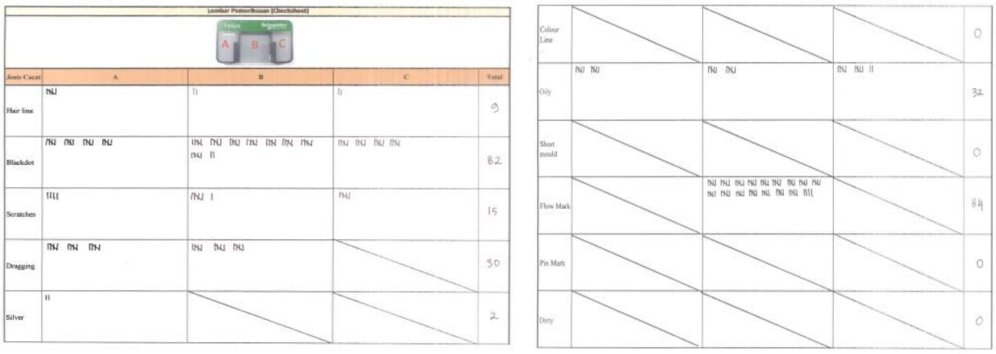

Fig 4.12 Checksheet

4.6 Repair results

a) Defect rate

Tabel 4.4 Defect rate

Period	Total Production	Production defects	Defect Rate
January	252.560	819	0,324279
February	256.480	1.368	0,533375
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May	**343.083**	**254**	**0,074035**

b) Sigma level

Tabel 4.5 Sigma level

Period	Total Production	Production defects	Defect Rate	DPU	DPMO	Sigma level
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April	375.430	2.061	0,548971	0,00549	5489,705	4,04
May	**343.083**	**254**	**0,074035**	**0,00074**	**740,3456**	**4,68**

c) **P-Chart**

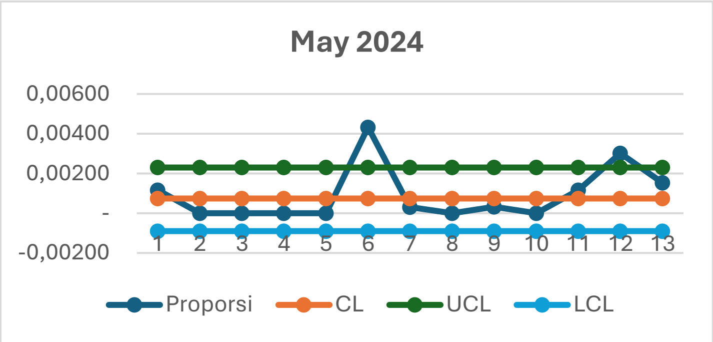

Fig 4.13 P-Chart May 2024

d) **Production defect**

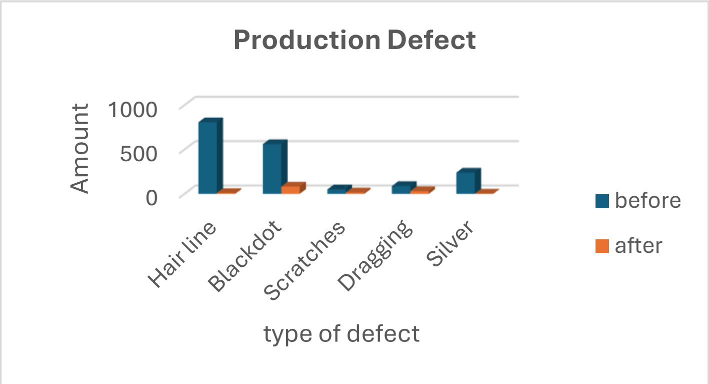

Fig 4.14 Bar chart of production defects before and after repair

5. Conclusions and recommendations

5.1 Conclusions

Based on the data that has been researched from the discussion explained in the previous chapters, the author draws the following conclusions:

1. By using statistical process control tools, namely a control chart (p-chart), points that are outside the upper control limit are still found, this is because the resulting proportion is greater than the resulting UCL value.
2. Based on the analysis that has been carried out, there are several factors that cause defects, namely human factors, mold factors, machine factors, material factors, and method factors.
3. Efforts and actions that have been taken to overcome these defective products are changing the position of the hot tip, making adjustments to the hot runner temperature by setting the standard temperature to 280-3100, changing the zone position, ensuring and carrying out maintenance on the mold after production, using crushing material minimum 2.65 mm, and check the parameters if they are appropriate but defects are still found then an overhaul (maintenance) must be carried out.
4. From the improvements that have been made, it can be seen that the sigma level before the improvements were carried out was 4.04 (4-sigma), and after the improvements were carried out,x the sigma increased to 4.68 (5-sigma).

5.2 Recommendations

Suggestions that can be taken into consideration by companies are that companies should control and supervise employees to continue to follow standards or procedures that have been created and implemented correctly and appropriately to minimize production defects.

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