Analysis and Improvement of Product Defects Using the Fishbone Diagram Method (Case Study: 100 Gram Skincare Packaging)

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ABSTRAK

Penelitian ini bertujuan untuk menurunkan tingkat cacat *flash* pada proses injection molding produk kemasan skincare 100 gram. Analisis awal menunjukkan bahwa cacat *flash* merupakan salah satu masalah utama yang mempengaruhi kualitas produk dengan jumlah 125.231 pcs, cacat *flash* mencapai 480 pcs sebesar 0.38% dan menjadi cacat yang dominan. Penyebab utama cacat ini diidentifikasi sebagai kerusakan pada *part bushing sleeve* dan *sleeve mold*.

Hasil analisis menunjukkan bahwa penyebab utama cacat flash berasal dari ketidaksesuaian air venting yang melebihi 0,02 mm, gate yang tidak seimbang, kesalahan perhitungan kebutuhan clamping force, serta keausan komponen bushing sleeve dan sleeve akibat pemilihan material yang kurang sesuai. Upaya perbaikan dilakukan melalui penerapan preventive maintenance, perbaikan desain mold, serta penggantian material sleeve dari Rapidur 3343 menjadi baja perkakas jenis S705.

Hasil implementasi menunjukkan penurunan cacat flash yang signifikan dari 480 pcs menjadi 83 pcs pada bulan Juli dengan total produksi 143.813 pcs atau sebesar 0,06%. Penelitian ini membuktikan bahwa penerapan metode Fishbone Diagram yang dikombinasikan dengan perbaikan material dan perawatan mold efektif dalam meningkatkan kualitas produk dan produktivitas proses injection molding. Dengan demikian, kualitas produk dapat ditingkatkan dan perusahaan dapat lebih kompetitif di pasar.

Kata kunci: ***cacat flash, repair mold, preventive maintenance,injection molding, material mold.***

This study aims to reduce the flash defect rate in the injection molding process of 100-gram skincare packaging products. The initial analysis showed that out of a total production of 125,231 units, flash defects reached 480 units or 0.38%, making it the most dominant type of defect. The main cause of this defect was identified as damage to the bushing sleeve and sleeve mold components.

Based on the analysis using the Fishbone Diagram method, the flash defect was caused by nonconforming air venting exceeding the 0.02 mm standard, gate imbalance, miscalculation of the required clamping force, and wear of the bushing sleeve and sleeve components due to improper material selection. Improvement efforts were carried out through the implementation of preventive maintenance, mold design improvements, and the replacement of the sleeve material from Rapidur 3343 to S705 tool steel.

The implementation results show a significant reduction in flash defects, from 480 units to 83 units in July with a total production of 143,813 units, equivalent to 0.06%. This study proves that the application of the Fishbone Diagram method combined with material improvement and mold maintenance is effective in improving product quality and the productivity of the injection molding process. Consequently, product quality can be enhanced, and the company's competitiveness in the market can be strengthened

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Keywords: flash defects, mold repair, preventive maintenance, injection molding, material mold.

PENDAHULUAN

S One type of plastic molding method is injection molding, which is a production option for large-scale, high-quality, and competitively priced products. Injection molding is a plastic product molding process where plastic pellets are fed into a hopper with the help of a screw that directs and heats the plastic pellets, colorants, and other components into a heating cylinder, causing plasticization to occur.

High-temperature plastic liquid is injected from a cylinder into the mold at high pressure. After the plastic liquid fills the mold within the predetermined time (holding process), the next step is the cooling process and hardening of the plastic product inside the mold. Once the plastic product is formed, the ejection process follows, where the molded product is pushed out using ejector components.

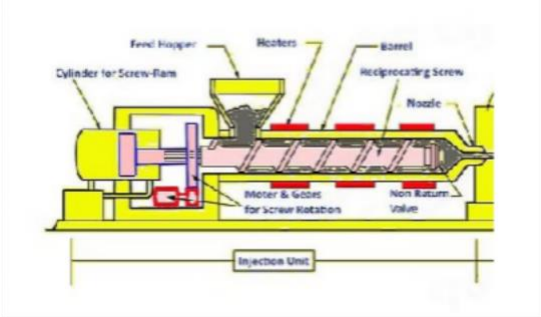


Figure 1 Injection molding Source: plasticmoulds.net

One product that uses the injection molding process is the 100-gram facial scrub packaging product. To achieve the required product performance, a trial-and-error process is necessary before mass production. This study shows that the production volume in the first month was 125,231 pieces per month. Based on the products produced, there are some product performances that do not meet expectations.

Based on previous research, it was mentioned that process parameter factors including injection pressure, holding pressure, and nozzle temperature have been proven to have a significant influence on the formation of flash defects in injection molded products. [6]

Product defects in the injection molding process are the result of the interaction of various factors, including suboptimal mold thermal conditions, especially when the mold is too cold, and issues with the raw material melting system, which can be characterized by material clogging in the nozzle area due to incomplete melting. Additionally, the inaccuracy of process parameter control, such as injection time, and the high incidence of human error are also crucial variables that directly affect the integrity and quality of the resulting product. Therefore, precision in setting operational parameters is essential to minimize defects. [2]

In the plastic injection molding process, flash is a dominant defect often caused by structural damage to the mold, particularly in the worn sub-insert area. This necessitates prioritizing mold maintenance and repair efforts to improve product quality. [3]

Mold repair and maintenance efforts have proven effective in significantly reducing the level of flashing defects in products. Therefore, the implementation of mold assessment methods is highly recommended for adoption as a standard procedure for inspecting mold condition, which is expected to serve as the basis for continuous improvement implementation to enhance product quality and production efficiency. [7]

Therefore, in an effort to reduce the number of product defects produced by the injection molding machine, a fishbone diagram (cause and effect diagram or Ishikawa Diagram) is used because the fishbone diagram is an effective graphical tool for analyzing, exploring, and illustrating problems with multiple causes (multicausality) and identifying risks. [4]

Kaoru Ishikawa introduced the fishbone diagram as one of the Seven Basic Quality Tools. The goal is to help the team identify, explore, and visualize all potential causes (often grouped into the categories of Man, Machine, Material, Method, Measurement, Environment—known as the 6Ms) that contribute to a problem (the Effect). [5]

Using the fishbone diagram method, we can trace the causes of defects in 100-gram tube facial scrub packaging and improve product quality according to established standards.

RESEARCH METHODS

The steps taken in the effort to reduce product defects are activities carried out on the production floor, resulting in the following:

Table 1. Analysis of Factors Causing Product Defects

No	Factor Cause Problem Occurring	Factor Cause Problem Occurring
1	Human Resources	1. Operators are inexperienced. 2. Operators do not follow SOPs.
2	Method	1. Abnormalities in the engine running process indicate sticking or overpacking. 2. The mold cleaning process does not meet standards.
3	Machine	1. Unstable temperature 2. Parameter settings do not match the machine data sheet (MDS). 3. The maintenance process does not meet standards.
4	Mold	1. Air venting exceeding 0.02 mm 2. Inaccurate mold design 3. Unbalanced gate
5	Material	1. Material is easily scratched. 2. Size variation and tolerance.

To reduce the number of flashing product defects using the seven tools method, please refer to Table 5, the fishbone diagram method.

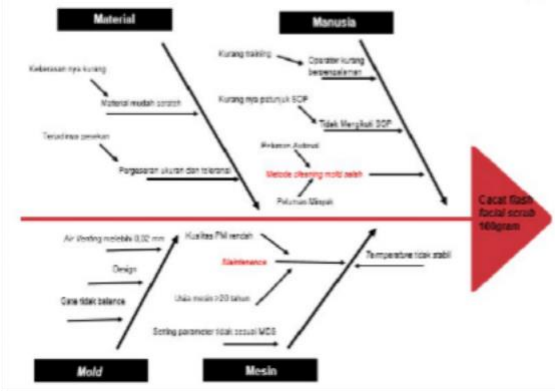


Figure 2. Fishbone Diagram

A. Data collection in the first month

Based on the data collected from Table 1, which shows defects in 100-gram facial scrub tube packaging, it was found that there are 5 types of product defects: flashing (excess plastic adhering to the plastic product), broken pins, short shots (insufficient filling of plastic liquid), contaminated material, and dirty products.

Table 2. Data Collection for the First Month

No	Type of damage	April		
		Production Quantity (pcs)	Number of Defects (pcs)	Percent (%)
1	Flashing	125.231	480	0.38
2	Material Contaminated	125.231	210	0.17
3	Short Shot	125.231	82	0.07
4	Broken Pin	125.231	72	0.06
5	Dirt	125.231	49	0.04

At this stage, data on product defects from production shows that the type of product defect is flashing, totaling 480 pieces out of 125,231 pieces, which is equivalent to 38% of the total production volume.



Figure 3. Product Defect Profile

The flashing type of defect contributes the most to the packaging of the 100-gram facial scrub, so an evaluation of the production process and product defect handling is needed, as shown in Figure 1: Flashing type product defect. Then the next step is to identify the cause of the product defect by observing and analyzing the cavity injection mold.

B. Data collection in the second month

Checking the cavity injection mold is one of the steps in tracing the cause of the flashing product defect. After observing uneven material filling processes, as seen in Figure 2, which shows cavities.



Figure 4. Cavity

After measuring the water venting located in the cavity mold using a high-precision measuring tool, it was found that the size of the water venting exceeded the design by 0.02 mm. This is indicated by the black line in Figure 3 for the water venting.



Figure 5. Air venting

Figure 4 shows that the gate holes are not balanced with the cavities, resulting in uneven

plastic flow into some of the cavities in the mold.



Figure 6. Gate Hole

The clamping force required for the injection process is determined by the projected area of the cavity.



Figure 7. Area Projection

Table 3 Second Month Research

Mei				
No	**Type of damage**	**Production Quantity (pcs)**	**Number of Defects (pcs)**	
1	Flashing	135.532	210	0.1
2	Contaminated Material	135.532	140	0.1
3	Dirt	135.532	52	0.0
4	Short Shot	135.532	30	0.0
5	Broken Pin	135.532	19	0.0

For the second month, the product damage type still shows flashing, which accounts for 210 out of 135,532 pieces, equivalent to 15% of the products produced.

C. Data collection in the third month

For image 8.a., it shows that the sleeve on the core section has insufficient hardness, resulting in scratches and ovality on the product.



Figure 8a. sleeve



Figure 8b. *Bushing sleeve* dan *sleeve*

If the bushing sleeve and sleeve materials are not hard enough, they can cause scratches and ovality, necessitating the creation of new bushing sleeves and sleeves with different materials.

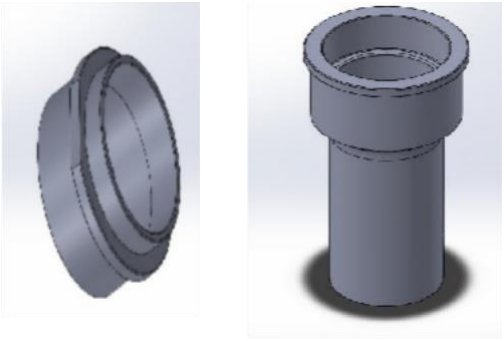


Figure 9 Sleeve Design

Table 4. Third Month Research

June				
No	**Type of damage**	**Production Quantity (pcs)**	**Number of Defects (pcs)**	**Percent (%)**
1	Flashing	125.984	120	0.10
2	Contaminated Material	125.984	70	0.06
3	Dirt	125.984	40	0.03
4	Short Shot	125.984	23	0.02
5	Broken Pin	125.984	17	0.01

In the third month, the type of defect product flashing still ranked first, accounting for 120 out of 125,984 total targeted products, or 10%. However, compared to the previous month, there was a decrease.

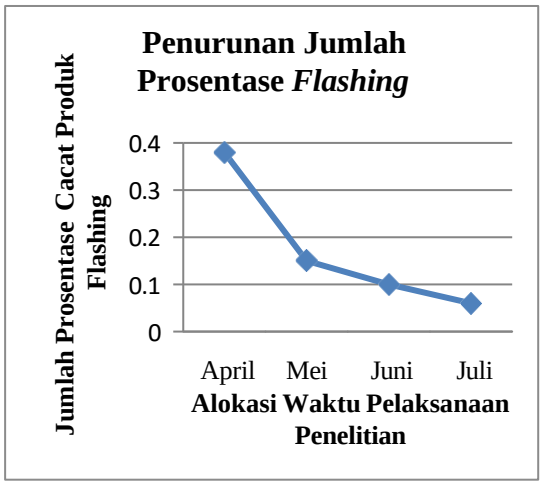
D. Data collection in the fourth month

Table 5 Fourth Month Research

No	Type of damage	Bulan Juli		
		Production Quantity (pcs)	**Number of Defects (pcs)**	**Percent (%)**
1	Flashing	143.813	83	0.06
2	Contaminated Material	143.813	70	0.05
3	Dirt	143.813	40	0.03
4	Short Shot	143.813	36	0.03
5	Broken Pin	143.813	23	0.02

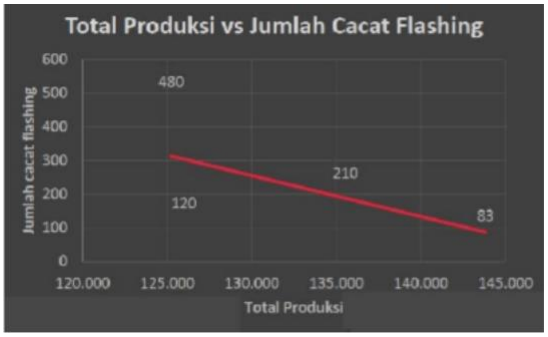
In the fourth month, the type of flashing on defective products was shown to be 83 out of 143,813, or the equivalent of 6% of the targeted products. This data achieves the target of product defects below 10%. The following table shows the decrease in the number of flashing product defects after the 7 tools method was implemented in the production line.

Table 6. Reduction in Flashing Product Defects



RESULTS AND DISCUSSION

Table 7. Scatter Diagram of Total Production vs. Total Flashing Defects



Product Defect Data

- April : *Flash* = 480 pcs (0.38%)
- Mei : *Flash* = 210 pcs (0.15%)
- June : *Flash* = 120 pcs (0.10%)
- July : *Flash* = 83 pcs (0.06%)

There was an 82.7% decrease in flash defects from April to July.

1. Human Resources

The operator plays a crucial role in the plastic molding process, so each operator change requires overlapping and close mentoring for the new operator team. In addition to the close mentoring provided to operators to ensure product quality meets customer purchase orders consistently, it is necessary to establish and continuously implement Standard Operating Procedures.



Figure 10. The operator is performing preventive maintenance.

2. Method

Scheduled preventive maintenance activities are carried out in accordance with the checklist available for the injection machine.

To extend the life of the machine, maintenance is required, paying attention

to the selection of Autosol lubricant and oil-based lubricants applied to the injection mold machine parts.

3. Machinery

The age of the injection mold is one of the causes of product defects in 100-gram facial scrub packaging that is 10-20 years old, which affects the movement mechanism of the mold. Observing and setting the parameters found in the Machine Data Sheet (MDS) of the machine, such as the heater components, pressure, clamping force, and others.



Figure 11 Machine Date Sheet

During the machine operation process, there were process abnormalities. Therefore, the indicator of the cause of flashing defects in the product is sticking (the plastic product adheres too strongly to one side of the mold, making it difficult to remove or causing damage during ejection). To overcome the sticking problem, which is

Table 8 Machinery Improve

Parameter	Action	Purpose
Mold temperature	Lower the mold temperature slightly.	Faster product cooling will help it shrink and release from the mold surface.
Cooling Time	Extend the cooling time if the product is too hot when ejected.	Overheated products tend to be softer and more likely to stick/break. However, if sticking occurs due to insufficient shrinkage, a slight increase in cooling could help.
Holding Pressure	Reduce holding pressure and holding time.	Excessive holding pressure (overpack) can force the plastic to press tightly against the mold surface, and overpack (overfilling/pressure) on the product.

4. Mold

The mold is a part of the injection mold machine consisting of two main sides that move during the clamping and opening process:

a. Fixed Half (Cavity Side) This is usually mounted on the stationary machine plate. Contains cavities that determine the outer shape of the product. There is a Sprue Bush (where the plastic first enters from the nozzle).

b. Moving Half (Core Side) Attached to the moving machine plate. Contains a core that determines the shape within the product (such as holes or wall thickness). There are ejector pins that work when the mold opens.

Because defective product data, especially for flash, is so dominant. The causes of flash defects from the mold's perspective are: (a) Non-uniform gate diameter Differences in gate size between cavities result in uneven plastic material flow. This causes some cavities to be overfilled (contributing to flash), while others may not be completely filled. (b) Quality of Mold Steel Material: The quality of the steel used to make the mold greatly affects the mold's durability and rigidity. Low-quality steel can cause deformation or wear, which ultimately leads to the appearance of flash defects. .

After checking for defects in the flashing of the 100-gram facial scrub packaging, the following issues were found: water venting exceeding 0.02 mm, unbalanced gates, incorrect calculation of area projection for clamping force requirements, and scratches and ovality on the sleeve caused by insufficient hardness.

5. Mold Component Material

The selection of materials for mold components needs to consider hardness, wear resistance, and toughness because these properties can affect the product molding process.

Incorrect material selection for mold components (such as sleeves and bushing sleeves) in injection molding machines can lead to wear

due to friction during the production process. This wear disrupts the perfect meeting at the parting line, creating a radius that allows plastic material to flow out beyond the cavity limits, resulting in overpacking. Additionally, mold materials that are prone to rust significantly reduce product quality because they can contaminate the castings and make mold movement more difficult.

The sleeve component material uses Rapidur 3343. Rapidur 3343 is a standard HSS steel used for cutting tools. Rapidur 3343 consists of 6.4% Wolfram, 5% Molybdenum, 4.1% Chromium, 1.9% Vanadium, 0.90% Cobalt, 0.3% Silicon, and 0.30% Manganese. Based on its composition, Rapidur 3343 is a standard high-speed steel with a balanced alloy that forms high toughness, making it suitable for use in sleeves. The bushing and sleeve material is specifically S705, a high-speed tool steel (High Speed Steel) often used in cutting applications requiring very high hardness, wear resistance, and hot hardness. The composition of S705 is 6.2% Wolfram (W), 5% Molybdenum (Mo), 4.8% Cobalt (Co), 4.1% Chromium (Cr), 1.9% Vanadium (V), and 0.92% Carbon (C). Based on the dominant composition of Wolfram, Molybdenum, and Cobalt in S705, this material is more wear-resistant for bushings and sleeves operating under high temperatures and loads.

When rapidur 3343 material was used for the sleeve, it produced 7,827 shots, the material rusted quickly, and wore out due to decreased performance caused by friction and repeated high temperatures. However, when the sleeve used S705 material, 25,333 shots were achieved. There was an increase in service life by more than 3 times. This is influenced by the Cobalt content, which significantly increases hot hardness and compressive strength. [1] Replacing components made of rapidur 3343 material with S705 material resulted in lower repair costs. S705 material has a hardness level exceeding that of rapidur 3343, leading to optimal durability and lifespan in operation. However, based on cost evaluation, rapidur 3343 has a higher market price compared to S705. [8] After making improvements, the flashing defect rate decreased from 480 pieces of total production to 83 pieces in July. The product defect reduction results are in line with 0.1% of the production target.

In general, the impact after replacing the bushing sleeve and product sleeve component materials is that the resulting product can be shipped according to the delivery schedule, the material's resistance allows the machine to function well, and productivity increases.

CONCLUSION

Based on the experimental results using the Ishikawa diagram method, it is very effective in reducing flash defects for flash defects on 100-gram facial scrub molds. The main problems caused by changing the sleeve material from Rapidur 3343 to S705 and the implementation of preventive maintenance successfully reduced flash defects from 0.38% to 0.06%. These results prove that improving mold material and proper maintenance systems can significantly improve product quality.

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