Moisture Reduction to Enhance Shock Absorber Performance Using a Combination of Eight Steps and VDI 2222 in the Motorcycle Industry

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ABSTRACT

Purpose: This study addresses the issue by developing a machine to reduce moisture levels and improve shock absorber performance within a two-wheeled vehicle manufacturing company to ensure product quality and safety.

Methodology/Approach: This study uses an 8-step improvement approach combined with Verein Deutscher Ingenieure (VDI) 2222, then enriched with 5W+1H and Specific Measurable Achievable Relevant Timebase (SMART), and finally evaluated with the Cost-Benefit Ratio (CBR) method.

Findings: The study revealed that the product's moisture level exceeded the inspection manual's standard, causing compression instability and potential safety risks. The intervention reduced the moisture level from 538 ppm to 336 ppm, achieving a 38% reduction. The improvement project demonstrated a CBR of 4.2, indicating its potential and profitability.

Research Limitation/Implication: This research has implications for management in replicating this result across other production lines to reduce lead time and lower fixed costs on cleaning machines.

Originality/Value of paper: This research demonstrates the value of using an external air blow machine to reduce moisture levels to standard quality, thereby decreasing lead time and fixed costs in shock absorber production.

Category: Research paper

Keywords: compression stability; moisture level; motorcycle; shock absorber

Research Areas: Quality by Innovation; Quality Engineering

1 INTRODUCTION

In the past, consumer perceptions represented aspects of quality known as quality, cost, and delivery (QCD) (Ocakci et al., 2021). In today's perception, convenience is an additional perception that has become as important as quality (de Souza, Tortorella and Gimenes, 2020; Zhu et al., 2020). In fact, in some cases, convenience increases the cost and creates a selling point far above the standard price in the QCD concept (Kaufman, 2019; Smith, 2020; Xing et al., 2021). However, consumers want to appreciate it by buying the product, besides considering the technological development (Courtright, 2019; Lin, Chen and Li, 2019; Wang, Wang and Lee, 2022).

Product specifications must meet the standard when making a shock absorber. Some of these specifications are necessary now, and some are anticipatory. Anticipatory specifications are qualities expected to impact after a specific time if these conditions are unmet (Poli, 2017; Geden et al., 2019). Specifications required at this time or during the manufacturing process are dimensional specifications, while anticipatory specifications are moisture levels in shock absorber components (Yuselin, 2023).

Moisture content is the level of wet air in an environment caused by water vapour. The moisture level of an environment is affected by temperature. In an environment with high moisture, the air will feel hotter because water vapour reduces the air's capacity to absorb heat. The water vapour that remains on the shock absorber components has the potential to increase the corrosion rate (Rahman, Haque and Islam, 2020; Zhang, Liu and Wang, 2020; Alzam et al., 2021) as well as compression instability (the condition of the shock absorber when it receives pressure from the wheel so that the shock absorber shortens) and extension (the condition of the shock absorber releasing pressure from the wheel, so that the shock absorber extends) (Kemzūraitė, Žuraulis and Więckowski, 2014; Hryciów, 2022; Kluczyk et al., 2022). The compression instability occurs due to the difference in the density of cleaning water and oil in the shock absorber (Long et al., 2018; Zhang, Liu and Wang, 2020; Yang et al., 2023). Compression instability initiates shock absorber rejection in the dumping force tester process. In addition to the impact of rejects, compression and extension instability also reduce the comfort of vehicle users because the shock absorber does not function to minimise shock and vibration to the maximum. In the inspection manual handbook, there is a standard value that becomes a reference for moisture and allowable tolerances.

Based on the Gemba carried out, findings were observed in the form of water spots on the shock absorber component, specifically the outer shell. This condition is shown in Figure 1.

The finding of water spots initiated data collection through a series of tests on several outer shell components for 8 weeks. After cleaning, this test determines the moisture content in the shock absorber outer shell component. Based on the assembly manual of the shock absorber manufacturing handbook, the moisture content of a shock absorber component must be 500 ppm (Rahman, Haque and Islam, 2020; Zhang, Liu and Wang, 2020). Statistically, by adding a little mathematical calculation, it can also be seen that there is a tendency to increase the moisture content linearly. Figure 2 shows a graph of the moisture content test results conducted in the quality control laboratory and their increasing trend.

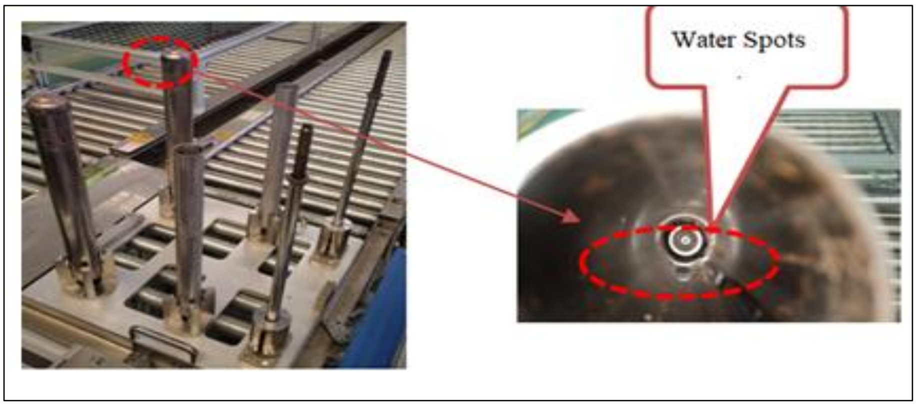

Figure 1 – Water spots on outershell components

Figure 2 shows the moisture content test results for the 8-week period starting in December 2023 and ending in January 2024. The moisture content graph shows that the moisture content of the outer shell component has not met the standards according to the inspection manual, which is <500 ppm. The average moisture for 8 weeks was 538 ppm.

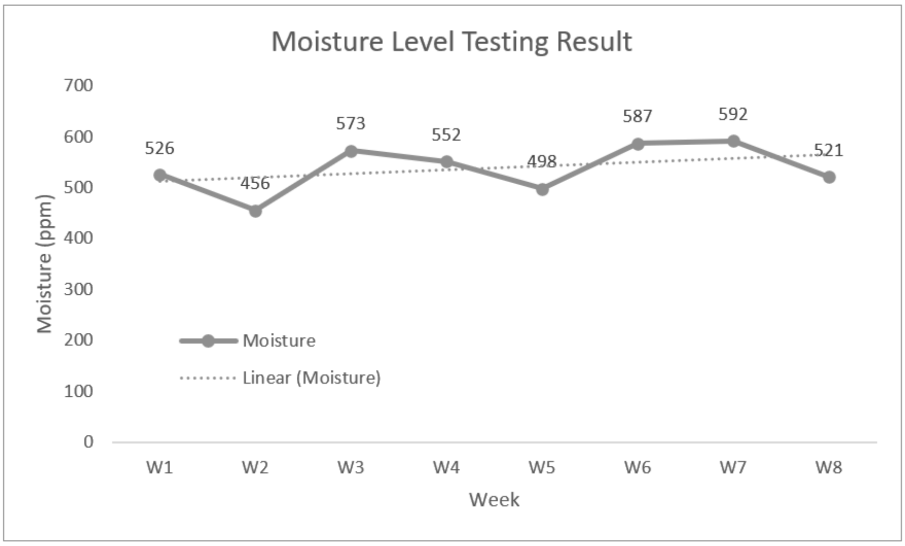

Figure 2 – Moisture levels and trends

In previous research, the effect of air moisture on strength is an interesting topic. In earlier research, increased air moisture has been found to reduce material strength, increase corrosion rates (Rahman, Haque, and Islam, 2020; Zhang, Liu, and Wang, 2020; Alzam et al., 2021), and increase compression instability. In a broader concept, it will affect component performance, company performance in the QCD aspect, and the safety aspect of driving (du Plesis, 2020; di Sarno, Majidian and Karagiannakis, 2021). The previous study indicates the importance of this research. This research aims to answer this problem by making a machine that can reduce moisture levels. The proposed machine's moisture levels can be maintained according to the inspection manual handbook to ensure aspects of shock breaker product quality, cost, delivery, company performance, and passenger and driver safety (Yin et al., 2019; Malekan et al., 2021).

2 METHODOLOGY

The research method section describes the flow of the research process and the research data used as materials and tools. The method combines the 8-step method (Gupta and Jain, 2019; Harry and Schroeder, 2020; Setiawan, Perdana, and Aisa, 2024) and the Verein Deutscher Ingenieure (VDI) 2222 design method (Manek, Mangesa,.

2.1 Research Flow

The research flow to reduce moisture levels was carried out following the process flow described in Figure 3.

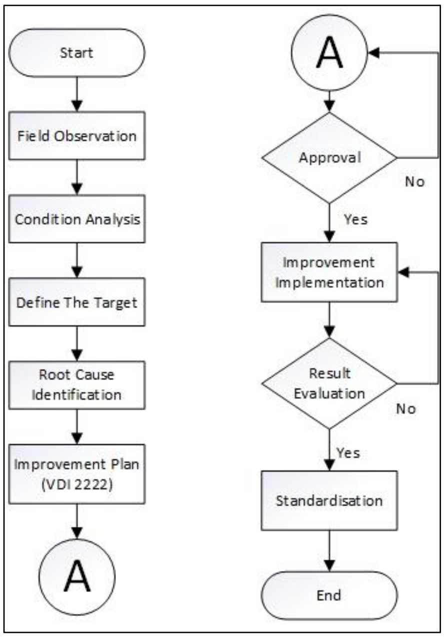

Figure 3 – Research flow

2.2 Moisture Level Testing

Moisture content testing consists of several stages, from sampling to making a test result report. Details of the moisture level testing flow are explained in Figure 4.

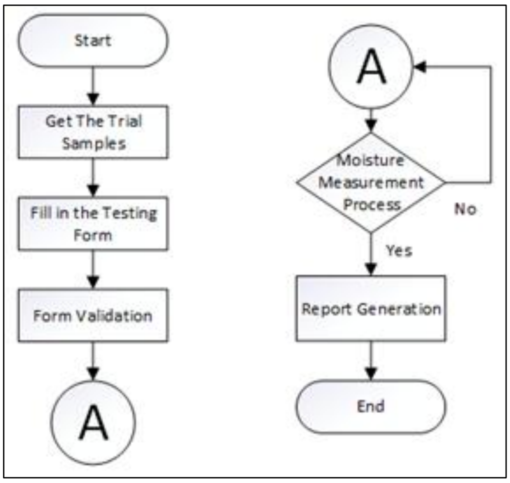

Figure 4 – Moisture testing flow

The moisture content testing flow follows internal standards, namely the Internal Engineering Standard (IES). The measuring instrument used also follows IES: a moisture tester measuring instrument with a distillation method approach. The following is a detailed image of the moisture content testing equipment. Based on Figure 5, there are three main processes, namely weighing, distillation, and testing (tester).

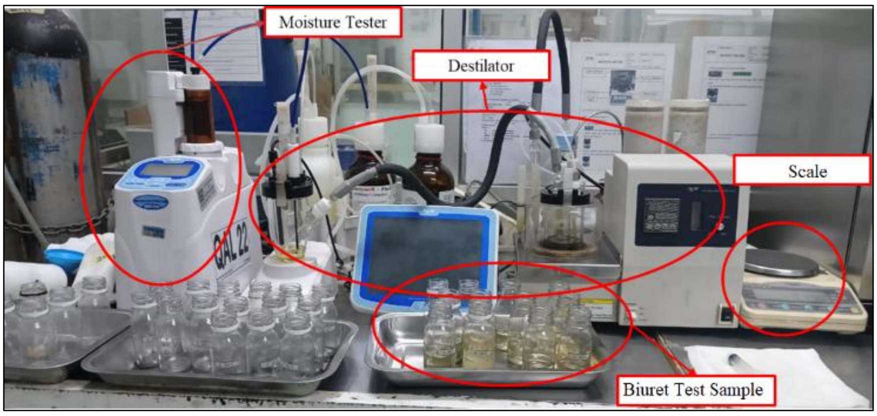

Figure 5 – Moisture testing tools

2.3 Moisture Level Testing

The moisture content test data was obtained from several samples taken. Sampling was adjusted to IES, specifically requiring a minimum of 10% of the processed components or five outer shell components. Several factors influence the moisture content of the outer shell components:

- The blowing process that the outer shell component goes through.
- The use and concentration of chemicals in air cleaning during cleaning.
- Moisture of the test room and component temperature.

Figure 6 shows the moisture test data for the outer shell components for 8 weeks from December 2023 to January 2024.

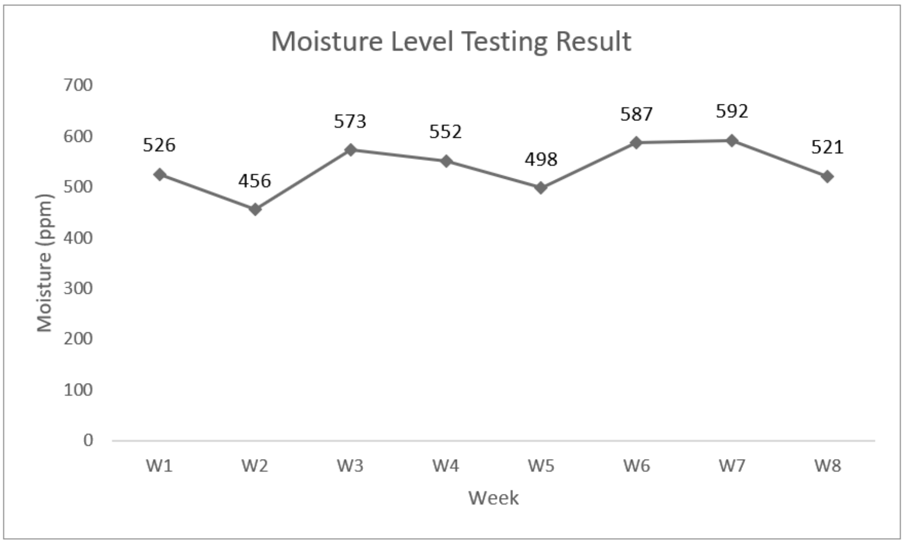

Figure 6 – Moisture levels graph

2.4 Idemitsu Moisture Level

Type 12 oil from PT Idemitsu Lube Techno Indonesia is used in shock absorber manufacturing. The oil distribution process goes through several stages, from delivery to the oil storage tank, sub-storage tank, gas oil filling machine, and shock absorber stage. Several stages of the distribution process have the potential for changes in the moisture content of oil 12. Table 1 explains the moisture content of oil 12 at each distribution stage.

Table 1 – Oil 12 moisture level

No.	Distribution Stage	Moisture Level (ppm)
1	Delivery	5
2	Storage Tank	5
3	Sub Storage Tank	7 – 9
4	Gas Oil Filling Machine	9 – 15

3 RESULTS AND DISCUSSION

3.1 Condition Analysis

In the production process, a cleaning section is tasked with cleaning the shock absorber components from all forms of dirt or other small objects that stick using the machine. However, in the production process, there were findings in the form of water spots on the outer shell components after passing through the machine's cleaning section. Figure 1 explains the findings of water spots on the outer shell components.

This condition is caused by the blow process in the cleaning section being less than optimal. The target of the blowing process is for the component to dry, but in reality, there are still air spots on the inside. Based on these findings, a sample test was conducted on the outermost skin component to determine its moisture content. The moisture standard, according to the Inspection Manual Handbook, is in the range of 0 - 500 ppm. Details of the test results are shown in Figure 6. Non-standard moisture impacts the quality of the shock absorber product in the form of compression instability, the potential for increased corrosion rates, and the endangering of drivers and passengers of vehicles using shock absorbers.

3.2 Define the Target

The next stage is target setting (Table 2). To ensure the target set is structured and focused, the SMART method is used, which has specific, measurable, achievable, relevant, and timely elements. Thus, the potential for success is higher.

Table 2 – Improvement target

Elements	**Description**
Specific	Reduces moisture content in the shock absorber outer shell component
Measurable	Moisture level reaches < 500 ppm.
Achievable	In the improvement process, a combination of the 8 steps and VDI 2222 methods is used to ensure that the improvement results are continuous improvement.
Relevant	Follow the company's core values, providing quality products to customers.
Timely	Due date by June 2024

3.3 Root Cause Identification

A fishbone diagram is used for the root cause identification process. A detailed explanation of the root cause is provided in Figure 7.

Based on the analysis conducted on the fishbone diagram, two main root problems are identified: low air pressure at 4.5 bar (Oehlschlagel et al., 2024) and limited cleaning media temperature at 75°. Low air pressure affects the less-than-optimal blow machine, causing it to blow dirt and small particles. At the same time, the limited cleaning media temperature is a result of the machine's capabilities.

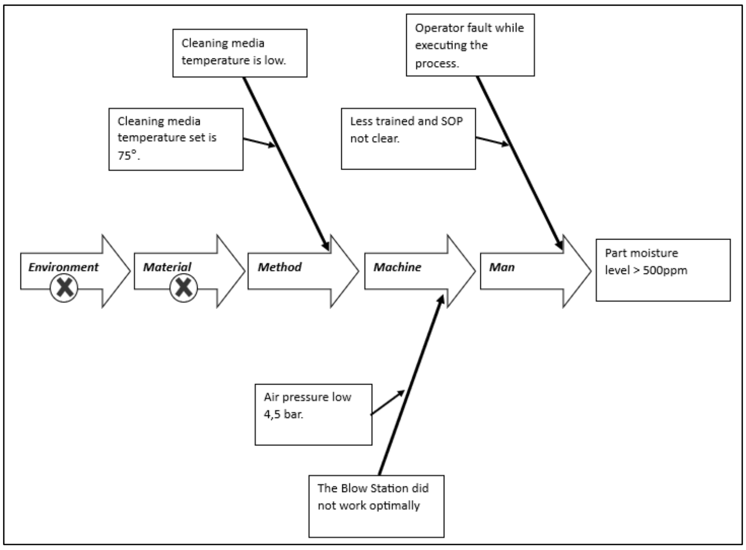

Figure 7 – Fishbone diagram for root cause identification

3.4 Improvement Plan

The 5W + 1H analysis tool was selected to improve the moisture level problem systematically. The analysis details are explained in Table 3.

Table 3 – 5W + 1H analysis

Elements	**Description**
What	The moisture level in the shock absorber outer shell component is below the standard of 500 ppm.
Why	The air pressure and temperature of the ejected air are less than the standards.
Where	Shock absorber production line
Who	PIC Project A
What	The moisture level in the shock absorber outer shell component is below the standard of 500 ppm.
When	Due date by June 2024
How	Making an external air blow machine

3.5 Improvement Concept

This improvement concept stage is carried out using the VDI 2222 method.

3.5.1 Analysis Stage

Based on the observations and analysis, several data obtained shall used as a reference for making an external air blow machine. The following are the data from the results of the observations and analysis.

- The empty area for placing the machine is 400 x 400 mm. The size was adjusted to the existing layout plan.
- The installation process is carried out in a closed room.

- The available air pressure is 4.0 - 4.5 bar.

3.5.2 Conceptual Stage

The stage described the external air blow machine concept to reduce the moisture level in the outer shell component. The sequence at this stage is:

A. Design Idea

The design idea for an external air blow machine is a machine that sprays pressurised air, which aims to remove dirt or other particles and dry the outer shell component. Thus, the moisture level in the outer shell component will decrease. This tool consists of three parts, namely the frame, the blow nozzle, and the gripper. This tool has several features, namely:

- The nozzle system is a command, so it does not cause difficulties in the Dandori process because the outer shell component consists of several models with different lengths.
- Knock down the system on the gripper to make it easier to perform maintenance or replace parts because the gripper is the part that has much direct contact with the outer component, so the potential for wear or damage is high. The

B. Explanation of Part Functions

The explanation of the part functions has been conveyed simultaneously in the design idea section in the previous sub-chapter. The external air blow machine design is divided into three parts, namely the frame, the blow nozzle, and the gripper.

C. Design Stage

After the design idea is obtained, the list of demands or specifications requested is collected, and the functions in the design are explained. The next step is to create two design variations. The design variations of the external air blow machine image are presented in Figure 8.

The first design variation consists of 1 main assembly and three sub-assemblies. Air becomes the medium for the blowing process with a knockdown gripper. Thus, component replacement will be easy, and the remaining liquid from the blow process will go down into the box and be disposed of using a tap.

The second design variation consists of 1 main assembly and three sub-assemblies. Air becomes the medium for the blowing process, but the gripper is fixed. With this condition, the gripper material must be strong. The remaining liquid from the blow process will go down into the tray, and there is no need to drain.

- Design comparison of external air blow machine: The two design variations are compared by considering the design aspects and criteria in the previous sub-chapter. The comparison of design variations is shown in Table 4.

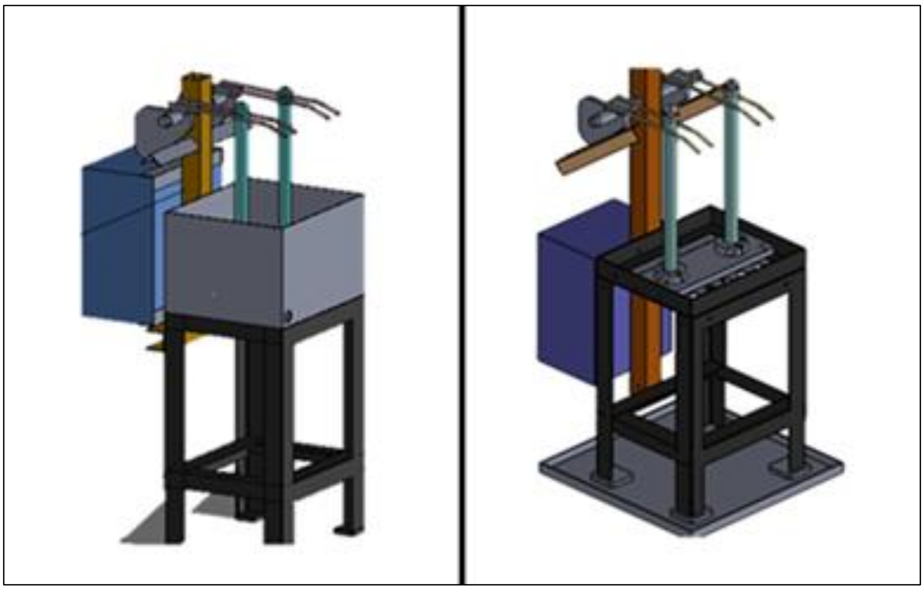

Figure 8 – Design variations of the external air blow machine

Table 4 – Design variation comparison

Aspect	**Description**	**Design 1**	**Design 2**
Function	The nozzle system is command-based	v	v
	Able to perform optimal blow process	v	v
Geometric	Maximum dimension 400 x 400 mm	v	v
	The nozzle shape does not interfere with the loading/unloading process	v	v
Safety	Safe for the operator	v	x
Maintenance	Easy to maintain	v	v
	Spare parts and materials are easy to get	v	v
	Easy to clean	v	x
Manufacturing	The manufacturing process can be processed internally	v	v
Cost	Affordable manufacturing costs	v	v
	Affordable maintenance costs	v	x

- Based on the design comparison of 2 external air blow machines presented in the previous sub-chapter, design variation one meets the criteria.
- Selected design details: The next stage is to complete a detailed design, referring to the list of parts and bills of material from the selected design.
- Calculation of the selected design critical point: The detailed location of the critical point is shown in Figure 9.

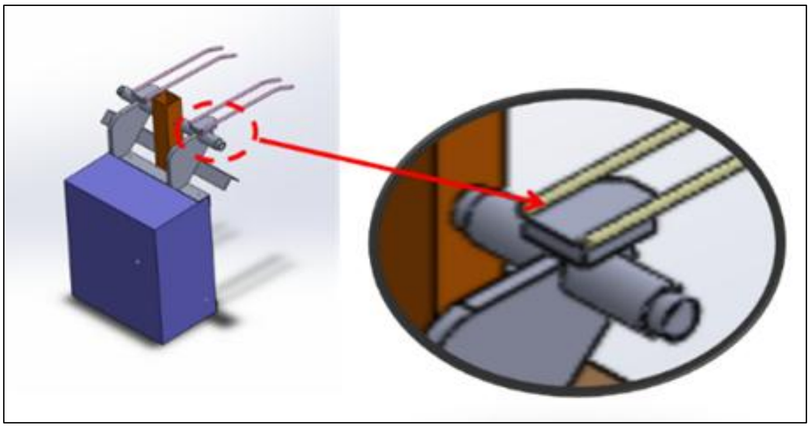

Figure 9 – Location of the critical point

3.6 Improvement Implementation

3.6.1 Machining and Assembling Process

Machining and assembly are the initial steps after the improvement plan. Table 5 describes the machining and assembly processes for each part of the selected design.

Table 5 – Machining and parts assembling

Sub Assembly	Parts	Machining Process	Assembling Proces
Assy Frame	Base Frame	Cutting	Welding
	Base Plate	Milling	
	Stopper Frame	Milling	
	Horizontal Plate	Cutting	
	Box Cleaning	Cutting	
Assy Blow Nozzle	Base Plate	Milling	Bolt and Nut
	Clamp Shaft	Turning	
	Shaft	Cutting	
	Nozzle	Turning	
Assy Flange Gripper	Flange Gripper	Cutting	Welding, Bolt, and Nut
	Box Panel Plate	Cutting	
	Swing Stopper	Milling	
	Shaft Gripper	Turning	
	Slider	Cutting	
	Gripper Plate	Milling	
	Gripper	Turning	
	Swing Sensor	Milling	

3.6.2 Trial

The trial process, better known as the trial, is taken after all parts are finished, including the machining, assembly, and electrical installation processes. This process shall determine whether the designed machine is running according to plan and the parameters set.

3.6.3 Layouting and Installation

The layout and installation process is a continuation process after the trial process. The layout and installation serve to place the external air blow machine in its actual position. Thus, the external air blow machine is ready to be used in the mass production process.

3.7 Result Evaluation

Machining and Assembling Process

Moisture level is the main improvement target—a significant decrease in repair by installing an external air blow machine, as described in Figure 10. The average moisture level after the improvement was 336 ppm. Based on simple mathematical calculations, the average moisture decrease is 38%. This finding supports previous research on the effect of air pressure on the disappearance of water droplets and small particles through improvement steps using a combined method of 8 steps (Gupta and Jain, 2019; Harry and Schroeder, 2020) and VDI (Manek, Mangesa and Bale, 2022; Nofirza et al., 2023).

3.8 Cost-Benefit Ratio

Cost Benefit Ratio (CBR) is an evaluation tool that compares a project's total benefits with the costs incurred. By understanding the ratio, the CBR value will assist in the decision-making process regarding the feasibility or effectiveness of a project (Paulden, 2020; Ekins and Zenghelis, 2021). With the help of CBR, decision-making on a project will be more objective, efficient, and transparent. With CBR, the risk of failure anticipated (Hashemi, Ebadati and Kaur, 2020; Morelli, Casagrande and Forte, 2022), and project prioritisation (Stimel and Sekerka, 2023) can also be carried out (Sururi and Agustapraja, 2020). CBR with a value of more than 1 shows a profit because the benefits that arise exceed the costs incurred.

By performing mathematical calculations, the CBR value is 4.2. The CBR value indicates that the proposed improvement has good potential because the value of the benefits is much greater than the costs incurred.

3.9 Standardisation

Each product has specifications that refer to specific industry standards or international standards. Thus, the specifications must be stated clearly from the beginning, be clear, and not have multiple interpretations. Therefore, the set achievement measurement evaluation shall use the product standards. After installing the external air blow machine, the standardisation drives operation runs optimally. The standardisation in question is the Operation Manual (OM) and personal protective equipment (PPE) standards.

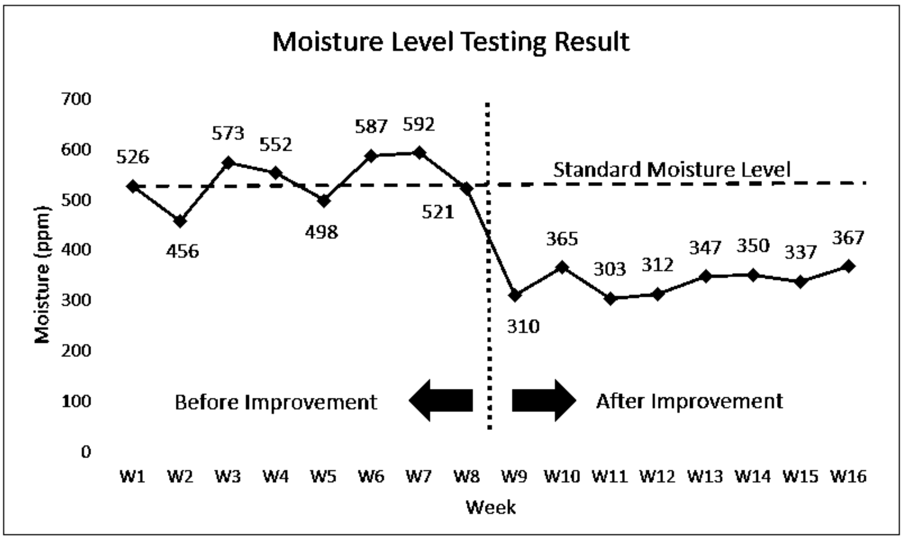

Figure 10 – Moisture level comparison graph

3.10 Next Improvement

Several conditions found in use can be used as a basis for the following improvement proposal: adding an air compressor booster tool, which helps maintain stable air pressure. In several series (types), the air compressor booster has a filter and air dryer, which removes water from pressurised air.

4 CONCLUSION

Based on the analysis and evaluation results, this study concludes that with an external air blow machine, the moisture content in the outer shell component, which initially had an average of 538 ppm, decreased to 336 ppm. This decrease is equivalent to a percentage decrease of 38%. The improvement project has a CBR of 4.2, which means that the project has potential and is profitable. The implication for management is that improving moisture content by using an external air blow machine can also be duplicated on other production lines. With this duplication, lead time will reduced, and the fixed cost of cleaning the machine will decrease.

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CONFLICTS OF INTEREST

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