e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:07/Issue:04/April-2025 Impact Factor- 8.187 www.irjmets.com

ENHANCING PRODUCT QUALITY STORAGE CONDITIONS THROUGH RELIABILITY TESTING

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DOI : https://www.doi.org/10.56726/IRJMETS71496

ABSTRACT

In the electronics manufacturing industry, to meet fierce market competition, companies should improve product quality and reliability. One of the effective ways to eliminate problems and improve product quality is through reliability testing. This study would introduce how to design reliability testing to reduce product issues and improve storage conditions for raw materials used in the production process. Statistical tools would be used to analyze problems araising during the assembly process to find the root causes and thus propose reliability testing methods. The study was conducted at a company that produces mobile printers. After applying the suggested improvement alternatives, the number of mobile printer issues decreased by around 70%. In addition, the effective standards for temperature, humidity, and bearing capacity were also applied. Specifically, temperature should be ranged in 25±1(°C); Humidity should be around 55±5(%), bearing capacity of the vendor should be at least 55N (5.6Kgf). The results provide suggestions for improvement to reduce serious issues, and improve product quality.

Keywords: Reliability Test, Doe Analysis, Environment Test, Product Quality, Process Improvement.

I. INTRODUCTION

In the electronics industry, the requirements for good quality and reliable products are increasing in terms of durability, load-bearing capacity, and ability to operate in harsh conditions [1-2]. Conventional issue-checking and improvement methods tend to be too rigid, lead to time waste, extend production cycles, and increase costs. Additionally, the traditional reliability tests focus on standard performance metrics. Unfortunatly, they often fail to address the specific challenges posing by rapidly evolving hardware. Exploring these areas could provide valuable insights for improving the reliability and robustness of next-generation devices [3]. Therefore, a method to limit issues, and increase product quality is required, which could help minimize wastes and increase profits. This study would propose a method to improve product quality and the raw material storage environment by using reliability testing combined with DoE analysis, ANOVA [4], and statistical process control tools [5-6-7]. The study was carried out at a manufacturing company specializing in industrial printers, with a focus on mobile printers. Actually, company operates several plants worldwide. This study would focus on a plant responsible for producing and distributing 50% of the printers. Historical production data indicated that about 80% of issues in the current production lines come from three main types of problems. Therefore, the study aimed to address these primary causes by utilizing reliability testing along with DoE analysis, ANOVA, and SPC to reduce product defects and improve the material storage environment. The findings revealed a reduction in mobile printer issues, while also standards for temperature, humidity, and bearing capacity were implemented. Through the testing results and the application of the above measures, a new set of rules on temperature, humidity, and standard bearing capacity of gears has been applied. As results, suggested alternatives help minimize losses and production delays, ultimately improve efficiency, and reduce costs.

LITERATURE REVIEW

The effectiveness of quality improvement methods in manufacturing processes has been a subject of significant research over the years. Various techniques and approaches have been developed to enhance product quality, reduce defects, and improve overall process efficiency. Among these, the DMAIC approach, Design of

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Experiments (DOE), Analysis of Variance (ANOVA), and Statistical Process Control (SPC) are some of the most widely recognized methodologies used in modern quality management.

DMAIC Approach

The DMAIC approach, which stands for Define, Measure, Analyze, Improve, and Control, is a structured problem-solving methodology commonly used in Six Sigma projects. DMAIC provides a systematic approach to identify root causes of defects, measure the performance of processes, analyze data to understand variations, implement improvements, and establish controls to maintain long-term quality. This approach has been widely adopted in manufacturing settings due to its data-driven nature and its ability to deliver measurable improvements in product quality and process efficiency.

Design of Experiments (DOE)

Design of Experiments (DOE) is a statistical method used to plan, conduct, and analyze experiments in a controlled manner. It allows engineers and quality professionals to understand the relationship between factors affecting a process and the resulting output. DOE provides a structured approach to determine the optimal settings for process variables, enabling manufacturers to maximize performance while minimizing variability. The use of DOE is particularly beneficial when exploring complex processes with multiple variables, as it helps identify interactions between factors and their effect on the final product.

Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) is a statistical technique used to compare the means of multiple groups and determine if there are statistically significant differences between them. ANOVA is often employed in conjunction with DOE to analyze experimental data. It helps identify whether variations in process outputs are due to the factors being studied or random variation. By analyzing variance, ANOVA allows quality professionals to assess the impact of different factors on product quality and process performance, aiding in decision-making for process improvements.

Statistical Process Control (SPC)

Statistical Process Control (SPC) involves the use of statistical methods to monitor and control a process to ensure that it operates at its full potential. SPC employs control charts to track process data over time, identifying trends, shifts, or out-of-control conditions. By using SPC, manufacturers can detect variations early, preventing defects and reducing waste. SPC is especially valuable for maintaining process stability and ensuring that products consistently meet quality standards. It is commonly applied in high-volume production environments to ensure continuous improvement and reduce the occurrence of non-conformities.

II. METHODOLOGY

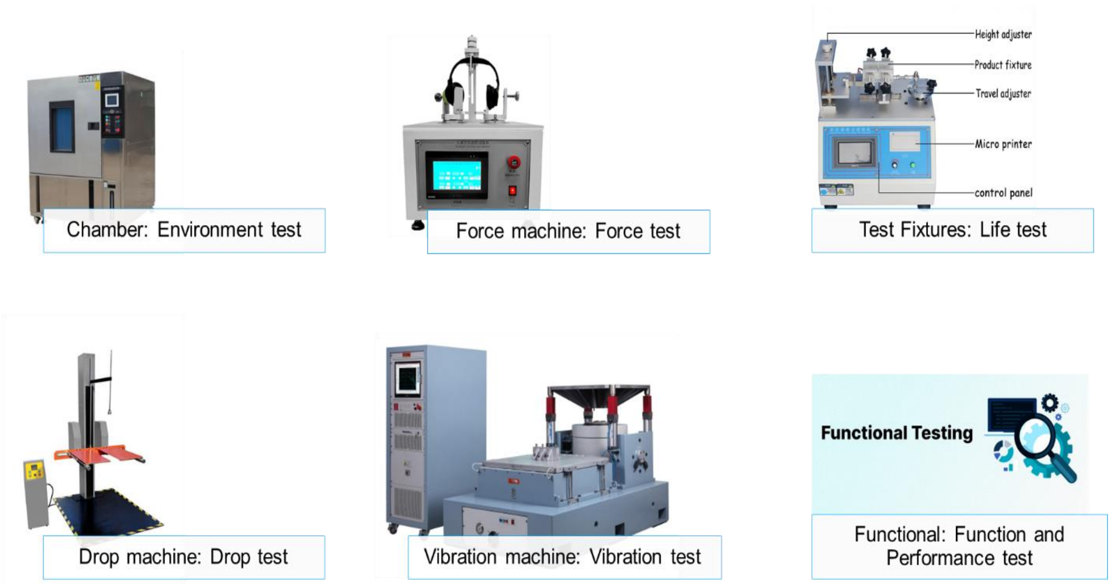

Figure 1. Reliability test machines

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Reliability testing is a crucial process used to assess the consistency and durability of a product or system over time under various conditions. The goal is to ensure that the product can perform its intended function without failure for a specified period, meeting quality and performance standards. This type of testing involves subjecting the product to stress tests, environmental conditions, and usage scenarios to simulate real-world applications. There ar some common reliability test machines are used as shown on Figure 1. By identifying potential weaknesses or points of failure early in the design or manufacturing process, reliability testing helps improve product longevity, customer satisfaction, and overall system performance.

Define – Mesure – Analyze – Improve – Control (DMAIC) approach would be used in this research. Firstly, the problem and the process that needs to be improved is identified. Information from related departments is collected. The mobile printers product and the relative processes are defined. The measures would be determined and used to measure the impact of the types of errors. The key issues would be focused on analyzing the root causes. The alternatives to eliminate them would be proposed. Final tests is to control the measures taken and then draw conclusions. DMIAC steps are shown on the diagram as following.

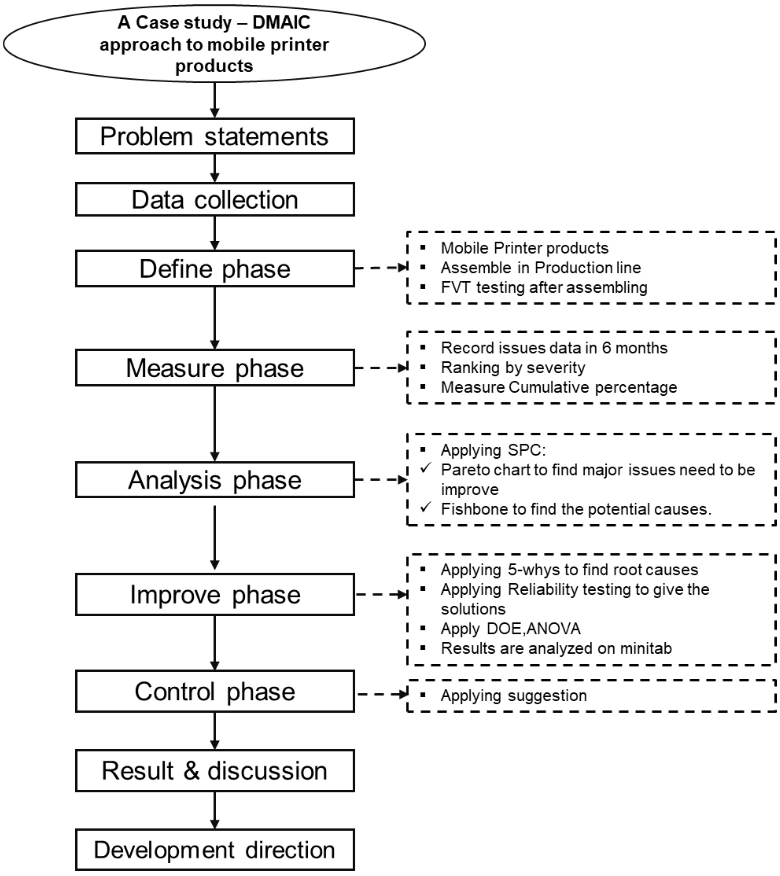

Figure 2. Methodology

III. MODELING AND ANALYSIS

1. Problem statements and data collection

This case study focuses on a manufacturing company in Vietnam that specializes in the production of industrial printers. Production data reveals that nearly 70% of the issues encountered in the current production lines are related to three main issue types as in Table 1. These recurring problems significantly impact the overall efficiency and quality of the manufacturing process. The primary objective of this research is to demonstrate the application of reliability testing in improving the sustainability of both the products and the manufacturing processes. By applying reliability testing, the company aims to identify weaknesses in product design and production processes. It could ultimately lead to enhance product durability, reduce defects, and bring more efficiency in production operations. This research approach is expected to drive improvements in long-term sustainability, product performance, and customer satisfaction.

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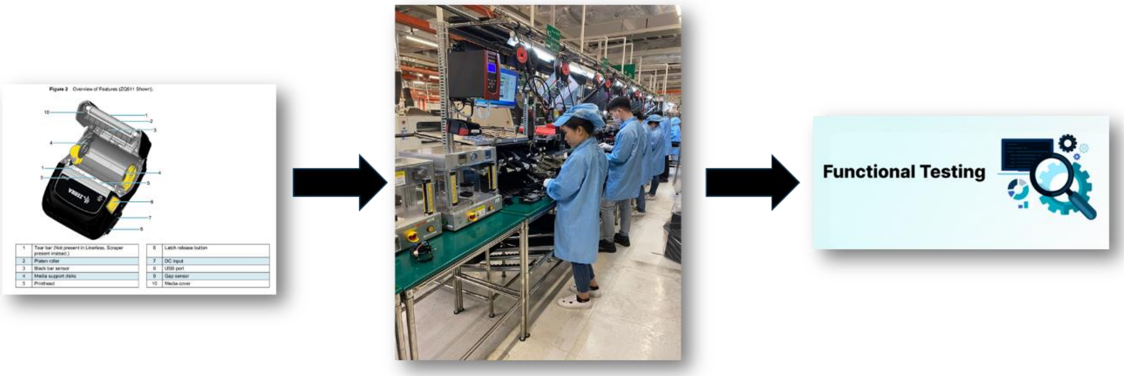
Data was collected over a period of six months from the studied manufacturing company. The data was sourced from two main channels including the production line and the Test Lab. The production line data includes information on production performance, defect rates, and common issues encountered during the manufacturing process. This data provides insight into operational challenges and quality control problems.

Additionally, data from the Test Lab includes detailed results from reliability tests, which were conducted to assess the durability and performance of the products under various conditions. The combination of these two data sources offers a comprehensive overview of the factors impacting product quality and manufacturing efficiency, allowing for a thorough analysis of potential areas for improvement.

2. Define Phase

Production line testing process is simply presented as on Figure 3, which includes three stages as followings.

- Input: It requires process assembly data in 6 months. In addition, Reliability testing methods & equipments SPC, ANOVA, DOE tools, Minitab analysis softwarewould be used.
- Process: It is known as Mobile Printers Assembly Production line.
- Output: It is necessary to have an overview of the issues situation**, which would be a**nalyzed and improved to minimize issues. Recommendations to improve the production conditions would be suggested.



➢ Mobile Printer products ➢ Assemble in Production line ➢ FVT testing after assembling

Figure 3. Production line testing process

3. Measure Phase

The data provides a list of equipment issues on a production line, detailing failures and recovery rates for various components. Problems include sensor malfunctions, abnormal noises, scratches on surfaces, connection failures (Bluetooth, WiFi, serial port), and broken parts (adaptor, media cover, gear). Each issue is associated with its failure rate and recovery percentage as in Table 1.

Table1. Issue data of production line

Issue	Symbol	Q'ty	Weigth	Severity	%	Cumulative percentage
Sensor stop working	E	99	0.12	11.88	26%	25.6%
Abnormal noise	D	115	0.09	10.35	22%	48.0%
Printed Labels are faded	N	85	0.11	9.35	20%	68.1%
Print head stop working	J	29	0.1	2.9	6%	74.4%
Scratch on printer surface	I	31	0.08	2.48	5%	79.7%
Scratch on labels surface	F	34	0.05	1.7	4%	83.4%
Adaptor failed	G	15	0.1	1.5	3%	86.6%

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Battery failed	O	27	0.05	1.35	3%	89.6%
Fail to connect Bluetooth	C	24	0.05	1.2	3%	92.1%
Fail to connect Wifi	P	28	0.04	1.12	2%	94.6%
Fail to connect serial port	A	12	0.06	0.72	2%	96.1%
Missing accessories	K	12	0.06	0.72	2%	97.7%
Media cover broken	M	12	0.03	0.36	1%	98.4%
Gear broken	B	16	0.02	0.32	1%	99.1%
Peel mode failed	H	10	0.03	0.3	1%	99.8%
Abnormal LCD display	L	10	0.01	0.1	0.2%	100.0%

4. Analyze Phase

Based on the issue data from the production line, a Pareto chart to visually analyze the frequency and impact of each problem was created, which helps prioritize issues by highlighting the most significant ones that contribute to the majority of the problems. In this case study, the key issues that mostly affect production efficiency, and failure rates were identified.

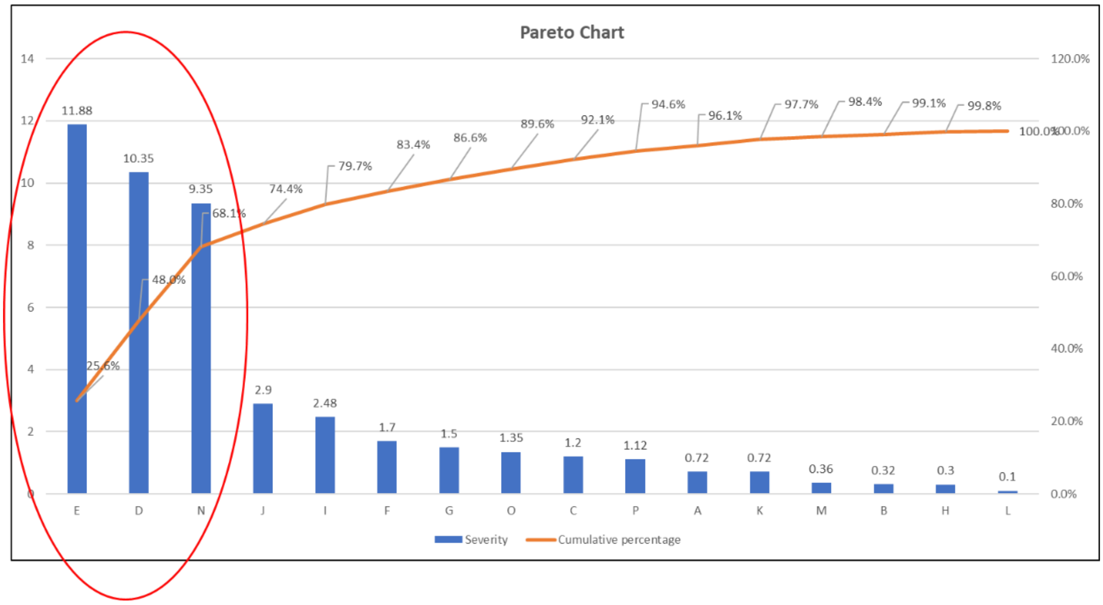

Figure 4. Pareto chart on the key issues

It shows that nearly 70% of issues are caused by 3 main reasons including Sensor stop working, Abnormal Noise, Printed Labels. It is better focusing on solving these errors to reduce the majority of issues.

The root cause analysis were figured out as on fishbone diagram (Figure 5). There are many causes leading to printer issues. However, three main causes would be focused on including Poor bearing capacity when printing and assembling, Temperature, and Humidity.

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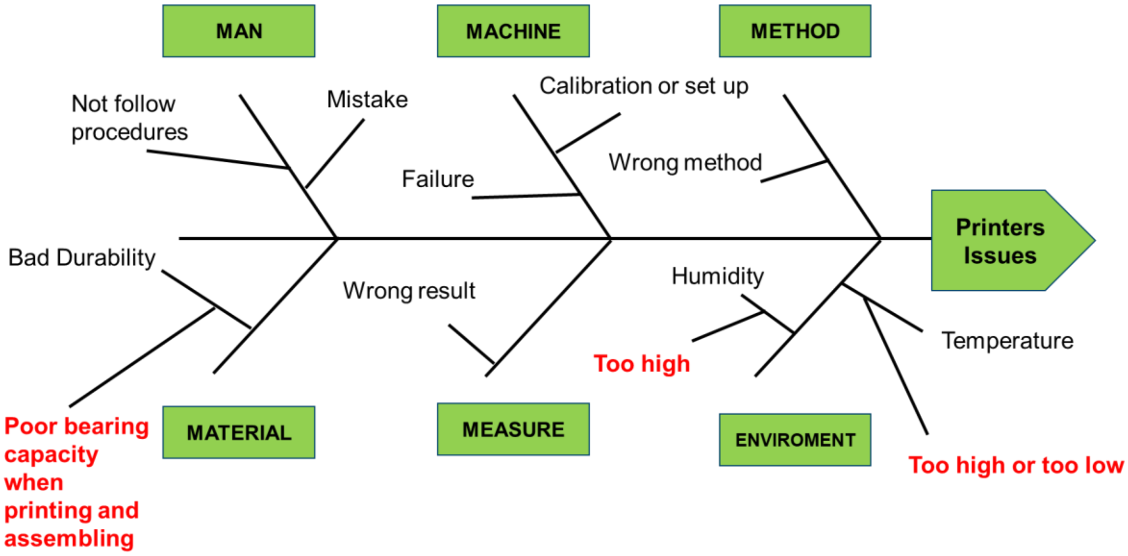

Figure 5. Root causes of the printers issue

IV. IMPROVE PHASE

- Key Inputs include 3 highest severity issues, root cause suspected, the printer samples, and reliability Test.
- Key Outputs include Reliability test results, and suggestions for improvement based on the above results

4.1 Improvement of sensor stop working issue:

Five-Whys technique is used to find out the main causes of this error. It shows that no humidity control method was applied.

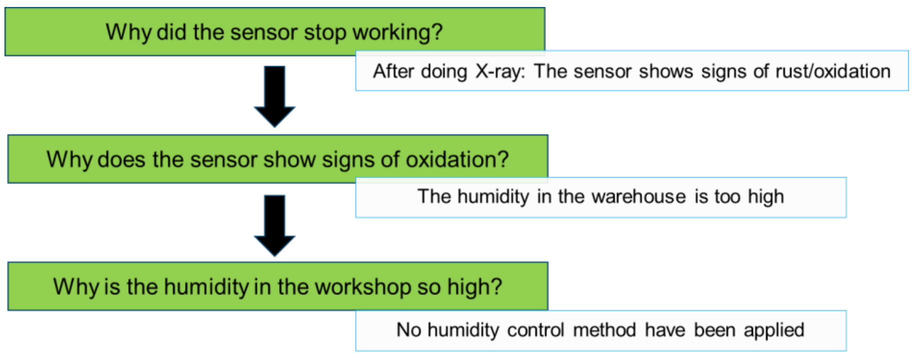

Figure 6. Sensor stop working Issue 5-Why

Therefore, the environment tests were conducted with the following conditions:

- ✓ Profile temp constant at 25 degree and humidity at 50-60-70-80 (%) was set up.
- ✓ Humidity was ranged from 50% to 80% due to limitations of the factory Environment.
- ✓ At each level of humidity, 10 samples would be tested.
- ✓ Number of replication was four times.

The test results are shown as in Table 2.

Table2. Environment tests results

	Humidity (%)			
Replicates	50	60	70	80
1	0	1	3	7
2	1	1	2	5
3	0	0	4	3
4	1	1	3	4

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Tests results shows that the higher the humidity, the greater the number of errors as on Figure 7. Therefore, the humidity should be set up at the level of "55±5 (%)", which is suitable for company facilities.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Humidity	3	48.50	16.167	15.52	0.000
Error	12	12.50	1.042		
Total	15	61.00			

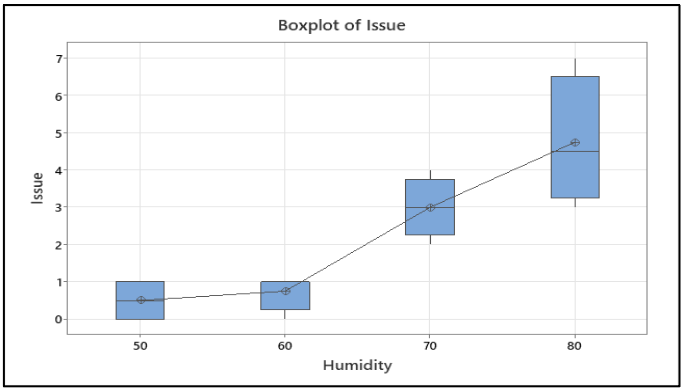

Figure 7. Affects of the environment conditions on the errors

4.2 Improvement of abnormal noise issue:

Similarly, 5-Whys technique was used to find out the main causes of this errosr. The poor bearing capacity when printing and assembling was determined as on Figure 8.

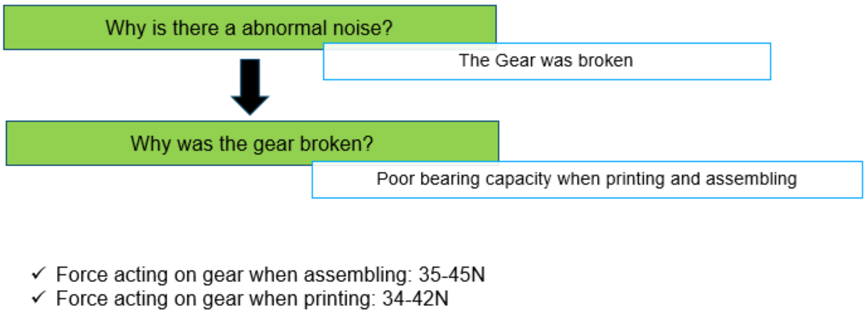

Figure 8. Abnormal Noise Issue 5-Whys

The force test was conducted with the following conditions:

- ✓ Test force was set up with gradually increasing.
- ✓ Force level was record immediately before the gear was broken.
- ✓ The experiment was performed in similarly conditions on 30 samples.

The test results are shown as following table.

Table 3. Force test results

No.	Force	No.	Force	No.	Force
1	40	11	43	21	52
2	35	12	45	22	43
3	43	13	44	23	44
4	42	14	51	24	47
5	50	15	47	25	44
6	44	16	39	26	43
7	41	17	41	27	46
8	43	18	42	28	43
9	55	19	43	29	44
10	45	20	42	30	53

The results (Figure 9) show that the tensile strength of the samples was fall in the range of 35N to 53N. Therefore, requirements for vendor is to increase Gear thickness, do a test force before delivery, and supply the bearing capacity at least 55N.

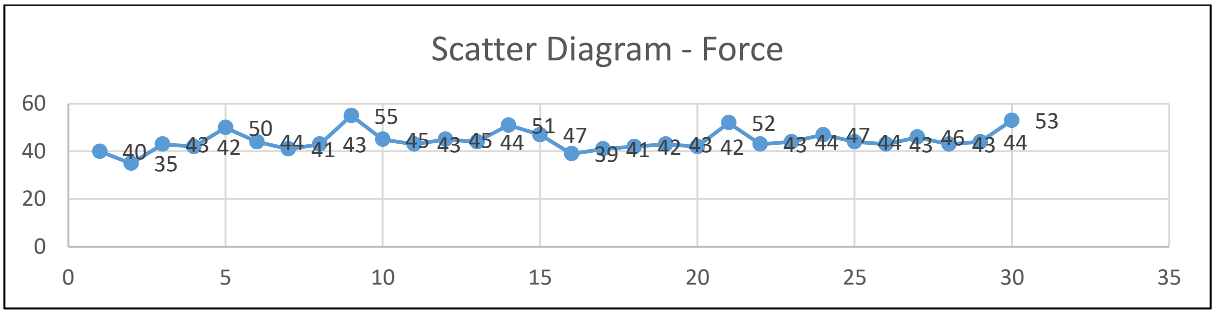

Figure 9. Force test results

4.3 Improvement on printed Labels faded issue:

The main causes of this error was identified as on Figure 10. There are no temperature and humidity control requirements on the production line.

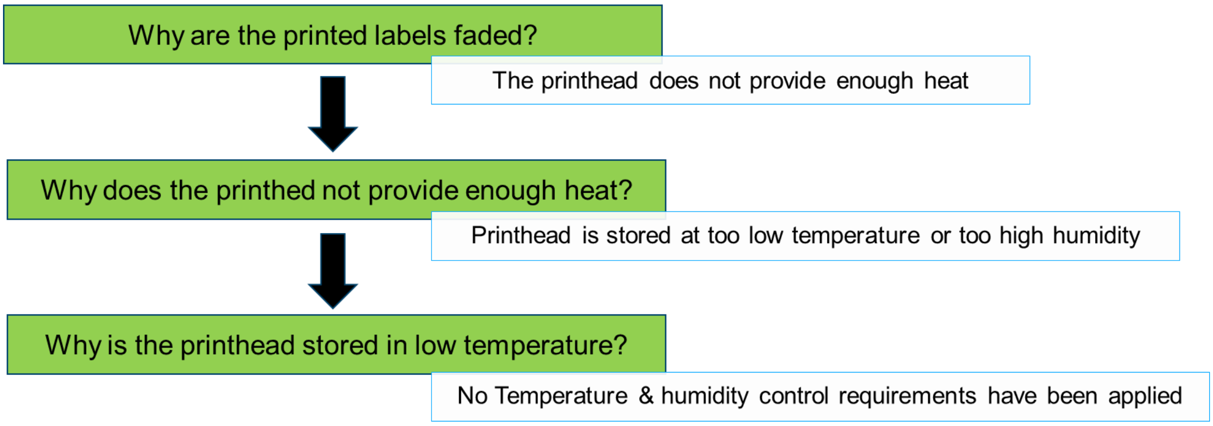

Figure 10. Root causes of printed labels faded issue

Force test was set up with the following conditions:

- ✓ Temp 18 OC: Current condition
- ✓ Temp 25 OC: Normal environment
- ✓ Humi 55%: Ideal Humidity
- ✓ Humi 75%: High Humidity

At each Condition 20 samples of PH would be tested. Number of replications are 20 times.

- ➢ The test results are as follows:

Temp	Humidity	PH Issue
18	55	11
25	55	4
18	75	7
25	75	6
18	55	8
25	55	1
18	75	10
25	75	4
18	55	4
25	55	2
18	75	5
25	75	4
18	55	6
25	55	2
18	75	4
25	75	6
18	55	6
25	55	2
18	75	12
25	75	1

➢ Analysis by minitab software shows that this issue is mainly affected by temperature. Because the printhead storage temperature is too low, the ability to print thermal labels is poor. Suggestion: Temperature Should be 25±1 (^{0}C)

Coded Coefficients

Term	Effect	Coef	SE Coef	95% CI	T-Value	P-Value	VIF
Constant		5.250	0.544	(4.096, 6.404)	9.65	0.000	
Temp	-4.100	-2.050	0.544	(-3.204, -0.896)	-3.77	0.002	1.00
Humidity	1.300	0.650	0.544	(-0.504, 1.804)	1.19	0.250	1.00
Temp*Humidity	0.700	0.350	0.544	(-0.804, 1.504)	0.64	0.529	1.00

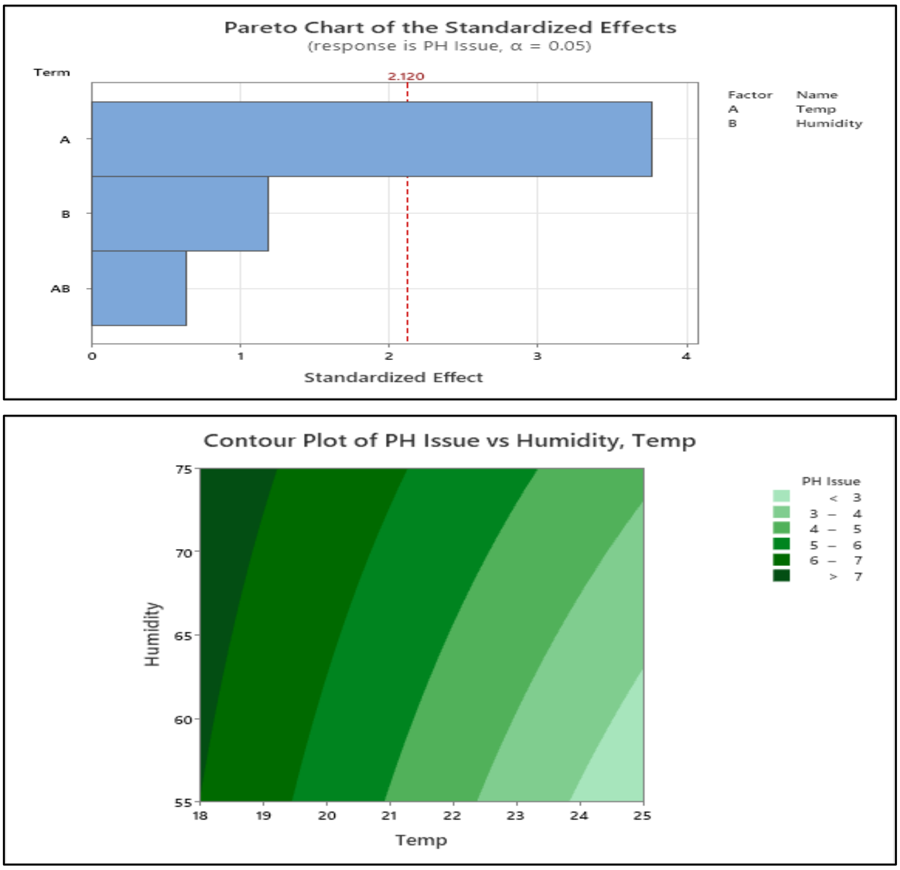

Figure 14 Mnitab analysis

5. Control Phase

The goal is to sustain the improvements achieved in the previous phases. For this project, control measures will be implemented to ensure the warehouse conditions and vendor performance remain within specified limits. First, humidity levels in the warehouse should be maintained at 55 ± 5%, with a monitoring system installed for real-time tracking and alerts when levels deviate. Similarly, the warehouse temperature must remain at 25 ± 1°C, with continuous temperature monitoring and regular maintenance of the HVAC system to ensure compliance. Lastly, the vendor must ensure that the gear bearing capacity meets or exceeds the minimum requirement of 55N (5.6kgf), with each batch undergoing quality checks and providing certification or testing reports for verification. These control measures will help maintain the improvements and ensure ongoing operational stability.

V. RESULTS AND DISCUSSION

The results of the study show significant improvements in product quality and material storage conditions. After implementing the improvements in the production process and storage, the number of product defects was reduced by up to 70%, significantly lowering repair costs and defective products. Reliability testing methods combined with DoE analysis, ANOVA, and SPC helped identify and address the main causes of defects, thereby improving production efficiency. In addition to reducing product defects, the material storage environment was also significantly improved, with the application of standards for temperature, humidity, and load capacity. This not only helped protect the quality of the materials but also contributed to maintaining product reliability throughout the production process.

These improvements have brought significant benefits to the company, not only in reducing costs and production time but also in enhancing the company's reputation and reliability in the market. By minimizing product defects and improving storage conditions, the company has been able to increase operational efficiency, ensure quality, and maintain long-term product stability. This is an important step in reinforcing the company's commitment to providing high-quality products and maintaining strong market competitiveness.

Table 1. Result summary

SN.	Factors	Type	Condition
1	Temperature	Environment	25±1(°C),
2	Humidity	Environment	55±5(%)
3	Bearing capacity	Durability	55N -> 5.6Kgf

VI. CONCLUSION

In conclusion, the study successfully demonstrated the effectiveness of using reliability testing combined with advanced analytical methods such as DoE, ANOVA, and SPC in improving both product quality and material storage conditions. By addressing the primary causes of defects, the research led to a significant 70% reduction in product issues, which not only optimized production efficiency but also enhanced the overall reliability of the products. Furthermore, the improvements made to the material storage environment, through the application of standards for temperature, humidity, and load capacity, contributed to better preservation of raw materials and further ensured product consistency throughout the manufacturing process.

The results of this study bring substantial benefits to the company, including reduced operational costs, shorter production cycles time, and enhanced product reliability. These outcomes not only improve the company's internal operations but also strengthen its reputation and competitive position in the market. The study highlights the importance of continuous improvement and the integration of reliability testing in manufacturing processes to meet both immediate production needs and long-term efficiency goals. The insights gained from this research offer a valuable framework for other manufacturing sectors aiming to enhance their product quality and operational performance.

ACKNOWLEDGEMENTS

We acknowledge Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for supporting this study.

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