Analysis of Flex PCB Failures in Hearing Aid Chargers

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Abstract—**This research aims to analyze and identify the main cause of the disconnection of the line on the flex PCB which resulted in the LED on the hearing aids charger not working. This problem has an impact on the disruption of the main function of the device and reduces the level of costumer confidence in product quality. To understand the root of the problem, this research uses the Fishbone Diagram and Failure Mode and Effect Analysis (FMEA) methods as analytical tools. The research stages include identification of potential causes, failure risk analysis, and improvement planning through the preparation of effective Work Instruction (WI). This research is expected to provide strategic steps in reducing the reject rate in the production prosses and support the improvement of product quality at PT. XYZ.**

Keywords: Fishbone Analysis, FMEA Analysis, Work Instruction.

Penelitian ini bertujuan untuk menganalisis dan mengidentifikasi penyebab utama terputusnya jalur pada PCB fleksibel yang mengakibatkan LED pada pengisi daya alat bantu dengar tidak berfungsi. Masalah ini berdampak pada terganggunya fungsi utama perangkat dan mengurangi tingkat kepercayaan pelanggan terhadap kualitas produk. Untuk memahami akar masalahnya, penelitian ini menggunakan metode Fishbone Diagram dan Failure Mode and Effect Analysis (FMEA) sebagai alat analisis. Tahapan penelitian meliputi identifikasi potensi penyebab, analisis risiko kegagalan, dan perencanaan perbaikan melalui penyusunan Instruksi Kerja (WI) yang efektif. Penelitian ini diharapkan dapat memberikan langkah strategis dalam menurunkan tingkat kegagalan pada prosses produksi dan mendukung peningkatan kualitas produk di PT. XYZ.

Keywords: Fishbone Analysis, FMEA Analysis, Work Instruction.

I. INTRODUCTION

QUALITY improvement is essential to meet customer needs, improve customer satisfaction, and achieve business success. Defect reduction is an important aspect of quality improvement because it directly affects product and service quality, cost, and customer satisfaction[1]. Defects are problems that can decrease product results and customer satisfaction and trust in the results [2].

PT.XYZ is a manufacturer of high-quality plastic molded components and mechanical assemblies serving the medical, automotive, transportation, and industrial sectors. PT. XYZ is able to produce a wide range of innovative products for global needs. One of the products produced by this company is a hearing aid charger. A hearing aid charger is a charging device specifically designed to recharge hearing aids. In this system, the hearing aid is placed on a charging pad located at the bottom of the charging case. The pad serves to transfer power from the power bank to the hearing aid device. On the outside of the charging case there is an additional indicator light that serves to indicate the status of the power capacity[3].

However, in the production process, problems were found with the external indicator lights that did not function as they should. This issue not only affects the main functions of the device, but it can also lower customer confidence in the overall quality of the product. reject on this LED indicator is caused by the PCB Flex strip.

Flex PCB is a type of printed circuit board that is widely used commercially due to its ability to adapt to the shape of devices, including hearing aid chargers. Flex PCBs support and provide flexible connections between components. Nonetheless, repeated dynamic activities, such as mechanical stress during use, can cause excessive stress on the flex path of the PCB, thus causing damage to the interconnection[4].

To identify the main causes of path disconnection in flex PCBs, the author uses three methods, namely fishbone analysis, Failure Mode and Effect Analysis (FMEA), and the preparation of Work Instruction.

Fishbone Analysis or often also called Cause Effect Diagram is a method used to help solve problems with the cause and effect analysis method of a condition or situation in a diagram that looks like a fishbone [5],[6]. The fishbone diagram itself is widely used to help identify the root cause of the problem and help find ideas for solutions to a problem[7].

Failure Mode and Effect Analysis (FMEA) is a method to identify all potential defects that can occur in the manufacturing process to the production of a product and to analyze the consequences of each failure [8],[9].

The FMEA method has the advantage, namely being able to describe the existing risks more broadly and in depth [10]. FMEA is usually prepared in the form of a table document [11], which contains information on the failure mode, cause of failure, effect of failure, severity, occurrence, detection, and Risk Priority Number (RPN) [12].

The next step is to prepare a work instruction as a work instruction that provides everything needed in detail to do the work specifically and according to standards. In addition, work instructions are also used as a means of training employees during work to reduce the level of defects that occur during the production process [13],[14]. Work instructions must be clear and accurate[15].

It is hoped that this research can make a positive contribution in efforts to reduce the rejection rate of hearing aid charger products.

II. METHOD

To determine the cause of the path damage in flex PCB, several structured analysis methods are applied. The methods used are Fishbone Diagram, FMEA (Failure Mode and Effect Analysis) and WI (Work Instructions). The fishbone diagram will map out potential failure modes that may be the cause of damage to the Flex PCB path. Then the FMEA analysis will assess what are the potential causes of failure and the potential effects of failure caused and provide an RPN assessment. Furthermore, the creation of Work Instructions will be set to reduce the RPN value in FMEA.

A. Analysis Fishbone Diagram

Fishbone diagrams are used to identify the root cause of a risk (as shown in Figure 1), thus allowing prediction of potential path failure in flex PCBs and allowing for preventive action to be taken before such risks occur. This diagram illustrates the various factors that contribute to flex PCB damage, by identifying the potential causes of various aspects in the production process. Influencing factors include human, machine, method, material, and environmental aspects, which are described as follows:

1. Man
   The human factor that is the root of the problem is the occurrence of operator error in the process of assembling Flex PCB to battery connectors. This error can cause a mismatch in the connection, leading to malfunction of the device.
2. Method
   The main cause of the method is the improper way of mounting the Flex PCB, which can result in the path on the Flex PCB being cut off. Non-standard or poorly documented work procedures contribute to this potential failure.
3. Material
   Materials as the basic material of electronic devices, especially Flex PCB, can be the root cause of damage. Low material quality can affect the performance and durability of the device, thereby increasing the risk of functional failure.
4. Environment
   Environmental factors that can cause damage to Flex PCBs are physical environmental conditions, such as temperature and humidity. As is well known, electronic devices have temperature tolerance limits, and exposure to extreme conditions can accelerate the degradation of components.
5. Machine
   The main machine of PCBA (Printed Circuit Board Assembly) as the core of the hearing aid charger assembly process has a high potential to experience technical problems. The source of the problem can come from a malfunction or damage to the PCBA machine itself.

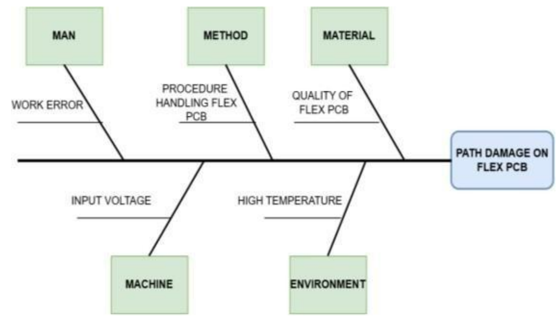


Figure 1. Fishbone Diagram.

The factors identified as the cause of failure in the Flex PCB line are further described in Table I, which contains the potential failure modes based on each category of cause. These categories include the aspects of Human, Method, Material, Machine, and Environment. This approach aims to classify the sources of problems systematically so that they can be used as a basis for formulating appropriate corrective actions.

TABLE I
POTENTIAL FAILURE MODE

Process	Potential Failure Mode
Man	Work Error.
Method	Procedure handling flex PCB.
Material	Quality of flex PCB.
Machine	Input voltage.
Environment	High temperature.

B. Analysis FMEA

Table II below presents the Failure Mode and Effect Analysis (FMEA) assessment guidelines in the form of a numerical scale from levels 1 to 10, which is used to evaluate each failure mode identified during the analysis process. This assessment includes three main parameters, namely Severity, which describes the extent of the impact of a failure on the functionality of a product or process, the frequency of occurrence which indicates how often the failure has the potential to occur and detection capabilities that indicate how likely failures are to be detected before they reach the end user or the final stage of production. This scale aims to provide a quantitative basis in calculating the risk priority number (RPN), so that it can be used as a reference in determining the priority of corrective actions systematically and objectively.

TABLE II
FMEA INDICATOR

Rating	Tingkat Keparahan	Deskripsi
SEVERITY		
1	Almost impossible to fail	No damage
2	Very low	cosmetic disorders
3	Low	The indicator lights up but delays
4	Relative low	The indicator is on but dim
5	Medium	Unstable indicators
6	Medium to high	One of the LED indicators is off
7	Relative high	All LED indicators are off
8	High	Charger is working unstable
9	Very high	Charger fails completely
10	Extrem	Damaging the hearing aid
OCCURRENCE		
1	Extremly Remote	Not found
2	Remote	Almost never happens
3	Very Low	1 unit per week
4	Low	1 unit every 2-3 days
5	Occasional	1 unit per day
6	Moderate	2 unit per day
7	Moderately High	3 unit per day
8	High	7-12 unit per day
9	Very High	13-30 unit per day
10	Almost Inevitable	More than 30 unit per day
DETECTION		
1	Extremly Remote	Almost Certainly Detected
2	Remote	Likely to be Detected
3	Very Low	Moderately Easy to Detect
4	Low	Possible to be Detected
5	Occasional	Remote Chance of Detection
6	Moderate	Very Difficult to Detect
7	Moderately High	Very Remote Chance
8	High	Almost Impossible
9	Very High	Not Detected
10	Almost Inevitable	No Detection Control

C. *Work Instruction*

The stage of making work instruction is the process of preparing work guidelines that aim to handle incidents or problems that occur during the production process, especially at the flex PCB assembly stage. This guide is designed so that every handling procedure is carried out in a standardized and consistent manner, so as to minimize errors and prevent the recurrence of similar problems in the future. There are three main stages in making work instructions, namely:

1. Preparation of work steps

   At this stage, the problems that occur in the production process are used as the main reference in the preparation of work instructions. This work instruction document contains systematic steps designed to handle the flexible PCB assembly process.

2. Verify and Validate Work Instructions

   After being prepared, the work instruction must go through a verification process to ensure that the content of the instruction is in accordance with applicable technical standards and procedures. Furthermore, validation is carried out through field trials to ensure that the instructions can be implemented effectively.

3. Implementation in the Production Process

   Once valid, the work instruction can be used officially in the production process. The use of this work instruction aims to ensure consistency of results, reduce the number of rejected products, and improve product efficiency and quality.

III. RESULT AND DISCUSSION

This chapter presents the results of an analysis of the causes of damage in the flex PCB line, with the main objective of identifying and comprehensively analyzing the factors that contribute to the occurrence of failures. The methods used include Fishbone analysis, which functions to identify potential failure modes and systematically map various causative factors. Furthermore, the Failure Mode and Effects Analysis (FMEA) method was applied to evaluate the impact and risk level of each identified failure mode, taking into account the severity aspect, the possibility of occurrence, and the ability to detect. Based on the results of the analysis, a work instruction was prepared as a follow-up step to overcome damage to the PCB flex line and minimize the risk of similar damage in the future.

A. *Analysis Fishbone*

Based on the results of mapping using fishbone diagrams, the analysis was focused on identifying potential causes that could cause damage to the flex pathway of the PCB. The causative factors that were successfully identified were then classified into several main categories, such as Man, Method, Material, Machine, and Environment.The results of the identification and classification process are presented systematically in Table III.

TABLE III
RESULTS OF FISHBONE DIAGRAM ANALYSIS

Process	Potential Failure Mode	Do?
Man	Work Error.	There was already an old WI as a general working guide for operators.
Method	Procedure handling flex PCB.	There are no special folding instructions for handling flex PCBs in WI at this time.
Material	Quality of flex PCB.	Material quality inspection has been carried out upon receipt (IQC)
Machine	Input voltage.	There is already an input voltage check before the assembly process starts.
Environment	High temperature.	The work area has air conditioning and daily manual room temperature monitoring.
SPV: HARYANTO		

Based on Table III, it can be seen that the most relevant and focus potential failure mode is the PCB flex handling procedure, as identified through fishbone analysis. This problem arises due to the lack of instructions that regulate the folding of flex PCBs in the work instruction (WI) that is currently used. Therefore, the next analysis is carried out using the Failure Mode and Effect Analysis (FMEA) method to evaluate the severity, frequency of events, and detection capabilities of the failure mode, so that appropriate corrective actions can be determined.

B. *Analysis of FMEA Results*

The FMEA analysis identified one major potential failure mode that contributed to PCB flex path damage, based on the findings of the fishbone analysis, namely the flex PCB handling procedure. This failure mode was chosen because there is no instructions that regulates the PCB flex folding angle in the current work instruction document.

The failure modes are further analyzed in Table IV using the FMEA method, taking into account the severity of the impact, the frequency of occurrence, and the system's ability to detect failures. The results of this analysis provide a quantitative basis for determining the priority of corrective actions necessary to minimize the risk of damage.

TABLE IV
FMEA RESULT

Process	Potential Failure Mode	Potential Failure Effect	S	Potential Causes	O	Current Control	D	RPN
Man	Work Error	PCB flex line is disconnected/damaged	6	Operators lack understanding of how to handle Flex PCBs	5	Th [illegible] old WI as a general working guide for operators	3	90
Method	Flexible PCB handling procedur errors	PCB flex line is disconnected/damaged	6	There are no clear folding instructions on flex PCB	8	Replacing a faulty flex PCB with a new one	3	144
Material	Quality of flex PCB.	PCB flex line is disconnected/damaged	6	Copper Adhesion on Flex PCB less powerful	3	Material quality inspection has been carried out upon receipt (IQC)	3	54
Machine	Input voltage.	Flex PCB is damaged due to voltage surge	9	The incoming voltage to the charger is not thoroughly controlled	1	There is already an input voltage check before the assembly process starts.	2	18
Environment	High temperature.	PCB Line brittle and easy to break	8	Room temperature not automatically controlled	2	There is already an input voltage check before the assembly process starts.	2	32

Flex PCB Handling Procedure Error

Based on Table IV, the FMEA analysis shows that the identified failure mode was a PCB flex handling procedure error, resulting in damage to the PCB flex path. The impact of this failure is that the indicator light on the charger does not turn on, even though the main function of charging remains normal. The Severity (S) value is given as 6, because the indicator that does not work can cause confusion for users in ascertaining the charging status of the hearing aid.

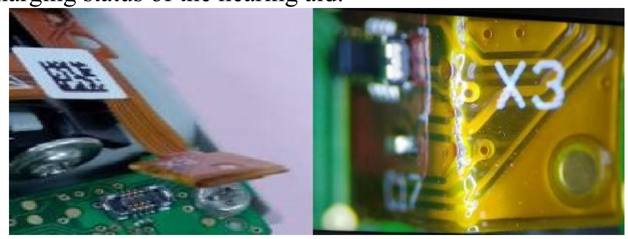


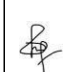
Figure 2. Defect Flex PCB

A potential cause of this failure is the absence of clear folding instructions in the assembly process, resulting in over-folding or incorrect handling of flex PCBs. The Occurrence (O) level is rated 8, as this problem is found quite frequently during the production process. Meanwhile, the current detection capability (Detection/D) is at a value of 3, Because the damage is usually only known during the final check or after the function test.

From this assessment, a Risk Priority Number (RPN) value of 144 was obtained, which indicates that this mode of failure has a fairly high level of risk and needs immediate action.

The recommended actions based on the results of the FMEA analysis have been formulated and shown in Table V. The purpose of these actions is to mitigate the risk of PCB flex line damage due to handling procedure errors during the assemb ly process, which has an impact on the malfunction of the charging indicator light.

TABLE V
ACTION RECOMMENDED

Potential Failure Mode	Action Recommended	Responsibility Person	Action Taken	Sign SPV
Flexible PCB handling procedure errors	Preparation of Work Instruction Flex PCB folding	Engineering	Implemented	

Based on Table V, the proposed preventive measures are the preparation of a Work Instruction document that contains technical guidance regarding flex PCB folding, including angle limitations, folding positions, and prohibited areas. The creation of this WI aims to provide clarity and consistency in handling components during the production process.

C. *Work Instruction*

This Work Instruction is prepared as part of a repair recommendation based on the results of the failure analysis of the Flex PCB in the hearing aid charger. The purpose of this WI is to provide standardized work guidance to minimize the potential failures that have been identified, especially in the installation and handling process of Flex PCB. The preparation of the WI refers to the findings of the FMEA and is designed to be easy to understand and apply by operators in the field.

Figure 3. Work Instruction Flex PCBA Before Update

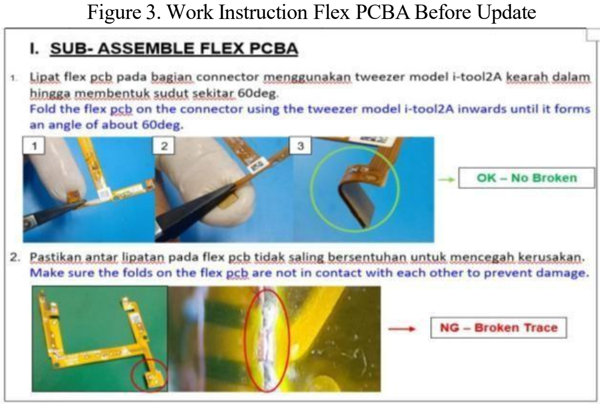


Figure 4. Work Instruction Flex PCBA After Update

After the preparation and implementation of the Work Instruction which focuses on the process of handling and installing Flex PCB on the hearing aid charger unit, the next stage is testing as a form of evaluation of the effectiveness of the work instruction. While the overall production workflow remained unchanged, the modification was applied solely to the handling instructions of the Flex PCB component. This evaluation aims to assess the extent to which the work instructions that have been designed are able to reduce the potential for technical errors in the field, improve the consistency and accuracy of operator work results, and reduce the likelihood of damage, especially on the Flex PCB line which previously often failed. WI effectiveness testing is carried out through the collection of production data and the number of failures observed over a given period, both before and after the implementation of the updated WI. The results of this monitoring are then presented systematically in Table VI and Table VII, which show a comparison of actual conditions in the two periods as a basis for assessing the success of the implementation of the new work procedures.

TABLE VI
BEFORE THE IMPLEMENTATION OF THE UPDATE WORK INSTRUCTION

Week	Unit Produced	Rejects – Flex PCB Trace Failure
Week 1	590 unit	36 unit
Week 2	550 unit	29 unit
Week 3	580 unit	34 unit
Week 4	570 unit	30 unit
Total	2,290 unit	129 unit

TABLE VII
AFTER THE IMPLEMENTATION OF THE UPDATE WORK INSTRUCTION

Week	Unit Produced	Rejects – Flex PCB Trace Failure
Week 1	550 unit	12 unit
Week 2	540 unit	6 unit
Week 3	525 unit	10 unit
Week 4	520 unit	8 unit
Total	2,135 unit	36 unit

Based on Table VI and Table VII, an analysis was carried out on the amount of damage to the Flex PCB line before and after the implementation of the updated Work Instruction. In the period before the repair, the number of rejects recorded for four weeks reached 129 units out of a total production of 2,290 units. After the implementation of the enhanced WI, the number of rejects decreased to 36 units out of a total production of 2,135 units.

To determine the degree of damage reduction, the following formula is used:

$$DR(\%) = \frac{Total\ Reject\ Before - Total\ Reject\ After}{Total\ Reject\ Before} X100\%$$

$$DR(\%) = \frac{129 - 36}{129} X100\% = 72{,}09\%$$

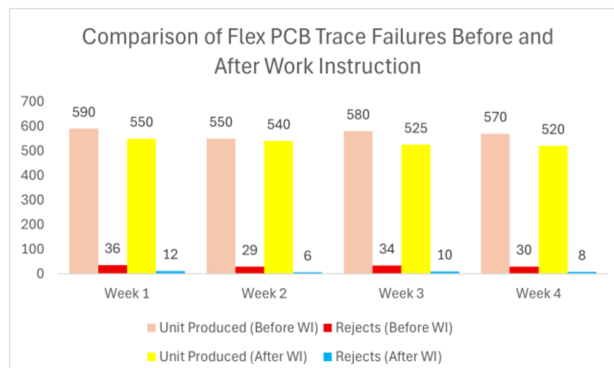


Figure 5. Comparison Diagram of the Number of Reject Flex PCBs Before and After Application of Work Instruction

The results of data analysis show that there has been a decrease in the number of products that have experienced *rejection* by 72.09% after the implementation of the updated Work Instruction (WI). This significant decrease gives a strong indication that there is a real improvement in the quality of the production process, especially in the installation and handling stages of Flex PCB in hearing aid chargers. The WI improvements made include adding procedure details, completing work steps, and emphasizing the aspect of caution when folding the Flex PCB line, which was previously one of the main sources of failure.

The effectiveness of the updated WI is reflected in the reduced frequency of damage to the product, which previously occurred due to poorly documented procedures. This shows that the preparation of clearer, structured, and systematic work instructions greatly contributes to reducing the production failure rate. Thus, the implementation of the improved WI not only serves as an operational guideline for operators, but also as a quality control strategy that is able to improve the reliability of the overall production process and encourage the achievement of more consistent and high-standard product quality.

IV. CONCLUSION

Based on the analysis conducted, it can be concluded that the primary cause of damage to the Flex PCB trace is improper handling procedures, particularly during the folding stage, which were not specifically addressed in the existing work instructions. Through the application of the Fishbone Diagram and Failure Mode and Effect Analysis (FMEA), it was found that this failure mode carries a significant level of risk, with a Risk Priority Number (RPN) of 144, indicating the urgent need for corrective action. The updated work instructions (WI) have been proven to directly prevent trace breakage on the Flex PCB and significantly reduce the reject rate, which decreased by 72.09%, from 129 units to 36 units during the observation period. This indicates that improving procedural standards not only enhances production quality but also directly contributes to minimizing the likelihood of similar failures in the future.

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