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APPLICATION OF FAILURE MODE AND EFFECT ANALYSIS (FMEA) CONCEPT IN AN ELECTRONIC COMPANY

Muhamad Zameri b. Mat Saman
Cheow Yin Leong

Department of Manufacturing & Industrial Engineering,
Faculty of Mechanical Engineering
Universiti Teknologi Malaysia
81310 UTM Skudai Johor.
E-mail: zameri@fkm.utm.my

ABSTRACT

This paper is about analyzing the failures and improving the quality of a product called 'Audio-box' using Failure Mode and Effect Analysis (FMEA). Audio-box is a box that contains a speaker and an amplifier fixed together as a product. FMEA is one of the quality tools used especially on a newly designed product. It should be an integral part of the early design and process evaluation and should be periodically updated to reflect changes in the design and processes or when new failure modes are discovered in subsequent or field testing. FMEA also identifies corrective actions required in order to prevent defects from reaching the customer, thereby assuring the highest durability, quality and reliability possible in a product. The first part of this paper describes the defects and failures of the products that occur during the study period. At the end of this paper, the suggested solution will be discussed and then validated using FMEA method.

Keywords: *Quality Improvement, Failure Mode and Effect Analysis (FMEA)*

1.0 INTRODUCTION

A primary concern of any company or organization should be the quality of its products and services. Most companies prefer higher quality standards in order to produce a better product and increase their productivity. Therefore in order to be successful, a company or organization must offer products or services that meet a well defined need, use or purpose, satisfy customer's expectation, comply with applicable standards and specifications, comply with statutory (and other) requirements of society, make products available at a competitive price and involve cost which would yield profit.

In order to meet its objectives, a company should organize itself in such a way that technical, administrative and human factors affecting the quality of its products and services would be under control. All such controls should be oriented towards the reduction, elimination and most important the prevention of

quality deficiencies. A quality management system should be developed and implemented for the purpose of accomplishing the objectives set out in the company's quality policies.

Each element or requirement in a quality management system would vary in importance from one type of activity to another and also from one product or service to another. In order to achieve maximum effectiveness and to satisfy customer's expectations, it is essential that the quality management system should be appropriate to the type of activity, product or service being offered. It is the objective of this project to demonstrate the improvement of the quality of a product in an electronic company using FMEA concept.

FMEA is a key method on the way from correction to prevent of defect [9]. The method is an integral component of preventive quality assurance in development and production. The aim is to achieve qualitative evaluation and avoidance of risks in systems, products and processes, concentrating on detecting potential weak spots as well as their possible causes and effects.

This simple and straightforward approach can be technical (quantitative) or very non-technical (qualitative), by calculating either a criticality number or a risk priority number (RPN). For manufacturing industries, the RPN method is preferred. It utilises three main factors for the identification of a specific value. The three factors are,

i. the occurrence of the failure
ii. the severity of the failure
iii. the detection of the failure

2.0 QUALITY IMPROVEMENT CONCEPT

Several papers have been written about quality management, both conceptual and practical. Most quality improvement programs aim to [5]

i. understand and improve continuously the organizational process
ii. refocus the organization on the customers' needs
iii. involve and motivate the employees in achieving quality output

Quality and reliability of products and manufacturing processes are absolutely critical to the manufacturing outcome (the functional performance of the final products). To ensure good product quality, efficient and comprehensive quality system should be established in the very early stage of the product design. All engineers involved in a project should consider the process or product quality and reliability while performing their tasks. For example, product and design engineers should embed quality and reliability into part design, since even the most advanced and reliable manufacturing operation would not be able to improve the product reliability over the design reliability.

The best product reliability is the designed reliability specified in the product design. Therefore, if there is a reliability problem in the product, engineers should examine two things. Firstly, the production team should check the adequacy of

the product design. The design may not meet the customers' reliability requirement. Secondly, the production team should examine the possible flaws in the manufacturing operations. In this case, system reliability should be evaluated and also improved. Besides, quality control has to be performed at a satisfactory level.

3.0 PRINCIPLE AND CHARACTERISTICS OF FMEA METHOD

FMEA is a method of analyzing and minimizing potential risk. It is intended as a method of thinking ahead in order to analyze all potential types of defects as well as their causes and effects. By employing a qualitative evaluation of the severity of a defect's influence (S), its occurrence probability (O) and its detection probability (D), weak spots or risks can be detected with the aid of the risk priority number (RPN = S x O x D). After the definition and introduction of suitable remedial actions, occurrence of a defect's cause can be made. Therefore, FMEA is an effective method of preventive quality assurance [8].

3.1 Advantages of FMEA

The advantages of the FMEA are as follows:

i. Based on the FMEA result, every failure mode is controlled by a process control plan under a day-to-day control routine to make sure that no non-conforming products will be shipped to the customers.
ii. With the feedback from the inspection tally sheet and the process capability report, the data in the probability column of the FMEA spreadsheet could be accurately estimated and revised. The data in this column would no longer be just numbers of which no one really knows the accuracy. The use of this real probability indices for the particular failure mode could also help engineers design fixtures and tools for the equipment used. Meanwhile, they are good indices for future equipment or product development.
iii. Using both design FMEA and process FMEA to institute fault tree analysis could help engineers eliminate the voids (such as some unknown failure modes and high probability failures) in between these two FMEAs. Design engineers not only design for the product function but also design for manufacturing. For example, some grade of steel may be very suitable for the product function, but is impossible to process.

3.2 Types of FMEA

There are many ways of classifying FMEA, but for manufacturing, it is generally accepted that there are three types of FMEA. They are as follows:

i. System FMEA

   On the basis of a system's target specifications, system FMEA analyzes functionality-oriented interaction between system components and their connections in order to avoid defects in the system selection and design as well as risks in the field.

ii. Design FMEA

Design FMEA analyzes the styling and design of products or components in orientation to the target specification in order to avoid the development and process defects that could be influenced by the design.

iii. Process FMEA

Process FMEA analyzes process planning and manufacture of products or components in orientation to the drawings in order to avoid planning and production defects. At the same time, it is intended to ensure that the quality of the final product conforms to the customer's expectation.

This paper focuses on the process FMEA.

4.0 METHODOLOGY OF THE PROCESS FMEA

The sequence of the process FMEA is shown in Figure 1.

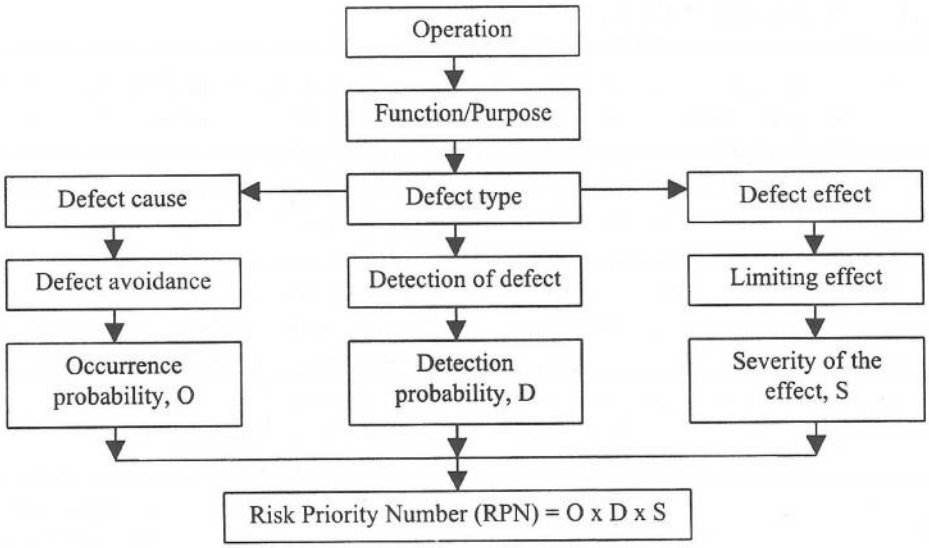

Figure 1 Sequence of the process FMEA

5.0 ANALYZING THE PROCESS FMEA

In analyzing the process FMEA, severity, occurrence and detection indices are used. It shows how serious a process failure is, according to American Institute of Automotive Group (AIAG) ranking. Table 1 shows the rank of seriousness of the failures in the FMEA table analysis. Meanwhile, Table 2 shows the rank of how often the failures occur in the FMEA table analysis. Lastly, Table 3 shows the rank of the ability to detect the failures in the FMEA table analysis. Based on this

FMEA table analysis, the RPN index number can be determined. Table 4 shows the extreme cases of risk assessment index. Referring to Table 4, it enables the user to determine whether any action should be taken in improving the failures that exceed the RPN index number.

Table 1 Severity of effect

Class	Severity of effect	Ranking
Very high	Very high severity ranking when a potential failure mode affects safe vehicle operation and/or involves non-compliance with government regulation (9 with warning, 10 without warning)	9-10
High	High degree of customer dissatisfaction due to the nature of the failure such as an inoperable vehicle (e.g., engine fails to start) or an inoperable convenience subsystem (e.g., air conditioning system, power sunroof), does not involve vehicle safety or non-compliance to government regulations.	7-8
Moderate	Moderate ranking because failure causes some customer dissatisfaction. Customer is made uncomfortable or is annoyed by the failure (e.g., compressor rumble, sunroof leak). Customer will notice some subsystem or vehicle performance deterioration.	4-6
Low	Low severity ranking due to nature of failure causing only a slight customer annoyance. Customer will probably notice a slight deterioration of the system or vehicle performance.	2-3
Minor	Unreasonable to expect that the minor nature of this failure would cause any real effect on the vehicle or system performance. Most customers will probably not event notices the failure.	1

Table 2 Occurrence of effect

Class	Occurrence of effect	Ranking
Very high	Failure almost inevitable	9-10
High	Generally associated with processes similar to previous processes that have often failed.	7-8
Moderate	Generally associated with processes similar to previous processes, which have experienced occasional failures, but not in major proportions.	4-6
Low	Isolated failures associated with similar processes.	3
Very low	Only isolated failures associated with almost identical processes.	2
Remote	Failure is unlikely. No failures ever associated with almost identical processes.	1

6.0 CASE STUDY

Audio-Box is one of the new products from the speaker department in an electronic company. This product is a box that contains a speaker and an amplifier. Accuracy and quality control are needed to make sure that the early design of this Audio-Box would not have recurring problems.

Table 3 Detection of effect

Class	Detection of effect	Ranking
Absolutely certainty of non-detection	Controls will not or cannot detect the existence of a defect	10
Very low	Controls probably will not detect the existence of a defect.	9
Low	Control has a poor chance of detecting the existence a defect.	7-8
Moderate	Controls may detect the existence of a defect.	5-6
High	Controls have a good chance of detecting the existence of a defect. (Process automatically detects failure).	3-4
Very high	Controls will almost certainly detect the existence of a defect. (Process automatically prevents further processing).	1-2

Table 4 Risk assessment index

Assessment ranking			Situation	Action taken
O	S	D		
1	1	1	Ideal situation (goal)	No
1	1	10	Assured mastery	No
1	10	1	Production down and/or operator injury	Yes
1	10	10	Production down and failure reach user	Yes
10	1	1	Frequent failures and detectable but costly	Yes
10	1	10	Frequent failures, reach user	Yes
10	10	1	Frequent failures with major impact	Yes
10	10	10	Trouble	Yes

FMEA has been implemented and some problems have been detected on this product. The problems were mostly caused by the handling and carelessness of operators. For example, some screws that should be fixed onto the box were missing while others were loose and thus cause the product to be defective. The operators sometimes complained about the jig and fixtures that caused these failures to occur.

Machines used in the assembly process were also among the cause of failures. Most of the machines were not accurate and not well calibrated. Therefore, they need to be carefully calibrated until they meet the requirement for the product. Tools designed by the vendors sometimes need to be modified to suit the purpose of each station.

The glue mixture and the Audio-Box cover were also important parameters to be considered in order to avoid failures. If the glue was wrongly mixed or did not mix within the specified percentage, it might cause the rear and front cover of the product to be detached. The alignment of the Audio-Box cover drainage was also important. Some covers moulded by the vendors were not properly aligned and accurate. This causes difficulties to the gluing machine to apply glue onto the rear cover drain. The glue would flow out of the drain and the product would then be considered a defect item. Another failure is caused by the working environment

especially at the operators' stations. Noise and disturbance should be reduced especially at the function test and inspection stations. All these problems are summarized in Table 5 and Figure 2.

Table 5 Failure and their causes

Failure	Cause of failure
Improper torque of the pneumatic screwdriver	Loose and overturned screw
Overturned screw on the rear cover to amplifier	Torque too high in the process of screwing
Method of handling in process of gluing	Wrong quantity required
Cannot assemble the slot bracket to groove	Wrong orientation of the bracket
Cover not properly connected or loose	Wrong method used and insufficient heat
Vibrating sound produced	Inner speaker failure or loose cover
No sound produced	Inner wiring connection or speaker failure
Missing part of fabric fleece on the Audio-Box	Carelessness of the operator
Missing identification stickers	Handling method of the operator
Wrong arrangement of the Audio-box set	Handling method during packing
Missing or improperly stamped	Improper stamp

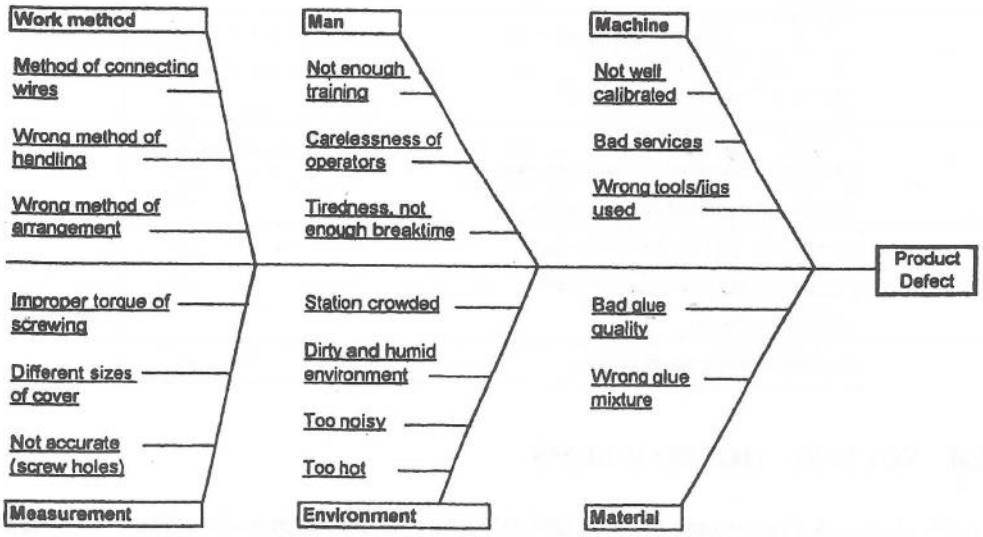

Figure 2 Cause and effect diagram for Audio-Box failure

7.0 REVIEWING THE PROBLEM

Basically, all the failures in Table 5 occur in every process. Table 6 shows the procedure for producing the product, including the Risk Priority Numbers (RPN) to show the value of failures for each process. It is then summarized into the Pareto Chart as shown in Figure 3. It shows the number of failures arranged according to the highest RPN. The process with highest RPN number will then be improved.

Table 6 RPN for each process

Process	RPN
Cleaning	63
Assemble wire to amplifier	192
Amplifier to jig	8
Rear cover to amplifier	8
Screw rear cover to amplifier	60
Turn rear cover	60
Screw rear cover to seal cap	126
Apply two component glue and groove	126
Assemble rear cover to front cover	-
Plastic welding front cover to rear cover	60
Apply rudol glue on bracket groove	126
Slot bracket to groove	126
Screw bracket to rear cover	126
Assemble fabric fleece to set	126
Affix clamp on the set	126
Assemble speaker cover to speaker	48
Assemble speaker to compartment	12
Screw speaker cover to speaker	-
Screw front cover to amplifier	60
Function check	-
Stamp on the export carton	12

8.0 SOLVING THE PROBLEMS

Table 7 shows the process causes and failures that occur in each station. It is then improved by introducing some solutions or countermeasures that could be used to improve the process. These countermeasures are only outlined for processes that have RPN number in exceess of 125

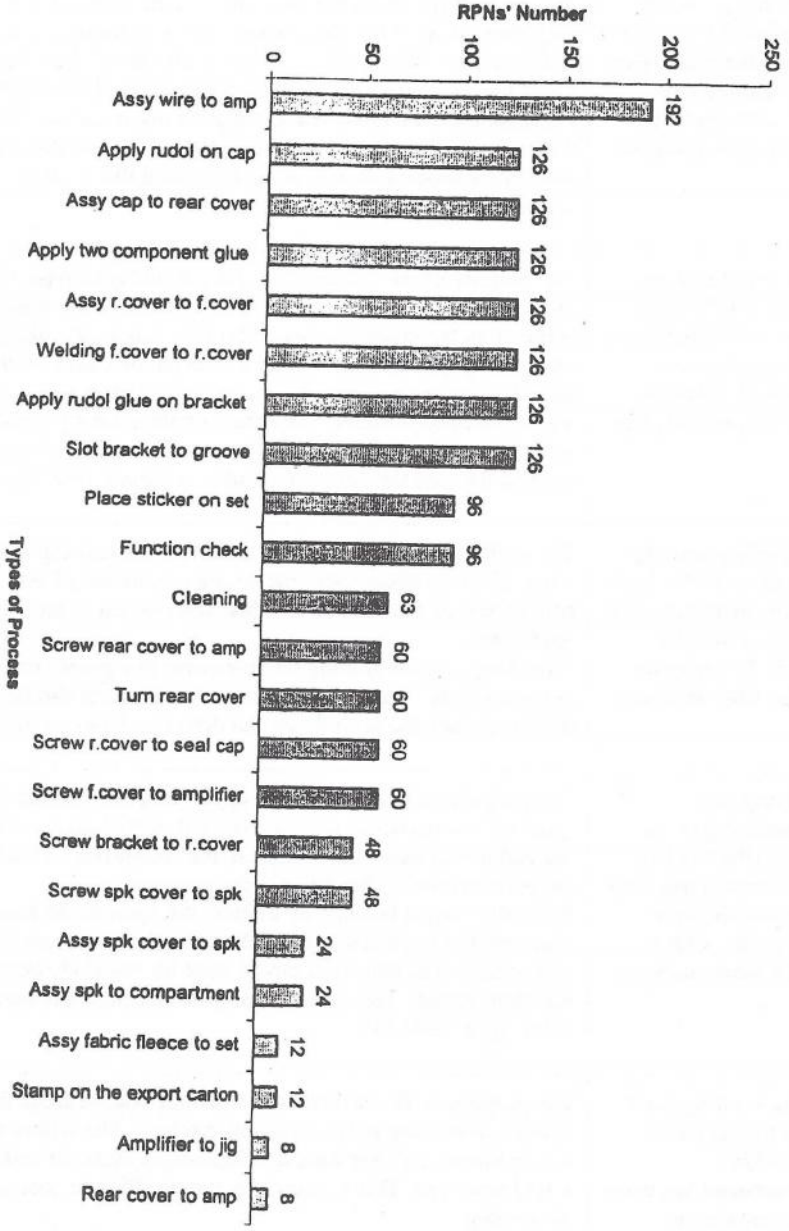

Figure 3 Pareto chart

Table 7 Causes, Failures and Improvements

Process	Countermeasure
Assembling wire to amplifier (RPN=192). Improvement has been made and the new RPN is 72. (refer to FMEA table analysis)	The purpose of this station is to connect the wire harness to the amplifier. Most of the failures are caused by loose connection and this may aflect the reliability of the Audio-Box. These failures may cause intermittent sound and non-functioning of the amplifier. Prevention can be made introducing the insert and pull method on the wire connector to the amplifier. Rechecking of the connection after every process should be done to avoid this problem from happening. (see Table 8)
Applying Rudol on seal cap (RPN=126). Improvement has been made and the new RPN is 45. (refer to FMEA table analysis)	The purpose of this station is to apply Rudol (one type of glue) on the seal cap. The failures mostly occur when wrong quantity of glue is mixed in the gluing process. This may cause air leakage on the cap and vibrating sound will be heard. Prevention could be done by introducing a type of tool design for tool mixture that is operated by a computerized machine. Inspection on the gluing process should also be done from time to time, for example visual checking. By this method the rank on detection number is reduce. (see Table 9)
Assembling seal cap to rear cover (RPN=126). Improvement has been made and the new RPN is 45. (refer to FMEA table analysis)	The purpose of this station is to assemble the seal cap to the rear cover. Failures occur when the wrong orientation of seal caps was being fixed on the rear cover. This may also cause air leakage on the Audio-box. Providing a jig for holding the rear cover in a proper position could prevent failure. Visual checking and function test should also be done to reduce the occurrence and detection index as in Table 10.
Applying two - component glue on groove (RPN=126). Improvement has been made and the new RPN is 60. (refer to FMEA table analysis)	The purpose on this station is to apply the glue onto the Audio-box groove. Failures occur when wrong quantity of glue is mixed and thereafter may cause air leakage to the Audio-box. This failure is cause by method of handling of the operator. Prevention could be done by training the operator on handling the glue gun and prepare an epoxy changing the glue from Nipac glue to Dopac glue. The detection can be done by visual checking and function testing. This could reduce the detection and occurrence index. (see Table 11)
Plastic welding front cover to rear cover (RPN=126). Improvement has been made and the new RPN is 75. (refer to FMEA table analysis)	The purpose on this station is to assemble and weld the front cover to rear cover using plastic welding machine. The failure mode is the loose connection after welding. This might cause air leakage to the sound produced. This is caused by the insufficient heat and method of welding. Prevention can be done by visual checking and function testing on the welding machine. Side grips can be added to fix the rear cover tightly to avoid movement during spot welding processes. Each side of the cover should be checked after the welding process. (see Table 12)

Table 7 (continued)

Process	Countermeasure
Applying Rudol on bracket groove (RPN=126). Improvement has been made and the new RPN is 75. (refer to FMEA table analysis)	The purpose on this station is to apply Rudol glue on the bracket groove. Most failure is caused by wrong quantity of glue mixed in the gluing process. The handling method is also the cause of this failure. This might loosen the bracket. Prevention could be done by visual checking after every process. Function test could also be done to detect this failure. The operator working in this station should be trained to avoid this failure from occurring. (see Table 13)
Slotting the bracket to groove (RPN=126). Improvement has been made and the new RPN is 75. (refer to FMEA table analysis)	The purpose of this station is to slot the bracket to the groove. The failure occurs when the bracket is slotted at the wrong side or with a wrong orientation. The bracket couldn't be assembled if it were slotted in wrong orientation. Prevention could be done by visual checking after every process and visual should be provided at every station. The failure will also be detected when the Audi-box cannot be assembled at the customer's place. (see Table 14)

9.0 CONCLUSIONS

The aims in performing FMEA are to develop an effective quality control system, to improve the current production processes and to ensure high quality and reliability of the product. This paper has focus on the process FMEA in order to improve the existing process and at the same time to increase the quality and productivity of the Audio-Box. Based on the data collected, seven processes were found to give RPN index numbers of more than 125. The countermeasures to improve the process have been suggested and the result shows that the new RPN index number was less than 125. With these recommendations it can be ensured that the occurrence and the severity of failures will be reduced and the detection of the failures increased. Lastly, in order to bring more success to the company, the integration of the FMEA process to product design and process control should be considered.

9.0 ACKNOWLEDGEMENTS

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Table 8 Process of connects wire harness to amplifier

Type of defect: Loose connection

Analysis	Cause of defect	Prevention of defect	Effect of defect	Detection of defect	O	S	D	RPN	Comment
Current System	Intermittent and no function	Method (Insert and pull)	Reliability	Cable come out during pulling	8	8	3	192	
Counter-measure	How occurrence of the defect be avoided or made?		How can severity be reduced	How can defect detection be reduced	What are the resulting lowest RPN?				Cost and introduction deadline
1.				Training on workers (3)	8	8	3	192	
2.			Longer training of workers (4)	Visual check on every product (3)	8	4	3	96	
3.			Introduce a better connector on insert and pull method (3)	Function test on all products and check for sound product (3)	8	3	3	72	Chosen – to update instruction card

Table 9 Gluing process

Type of defect: Wrong quantity

Analysis	Cause of defect	Prevention of defect	Effect of defect	Detection of defect	O	S	D	RPN	Comment
Current System	Air leakage	Visual	Air leakage	Function test	3	7	6	126	
Counter-measure	How can occurrence of the defect cause be avoided or made difficult?		How can the severity of the effect be reduced	How can defect detection be reduced	What are the resulting lowest RPN?				Cost and introduction deadline
1.	Change glue material. Change Nipac to Dopac glue because it is more adhesive (3)		Improve the gluing machine. Program the machine accuracy of gluing tools movement (7)	Visual checking should be done (4)	3	7	4	84	
2.	Mixing different types of glue (3)		Training on operating the gluing machine (5)	Frequent checking on every product (4)	3	5	4	60	
3.	Mixing different types of glue (3)		Introduce special glue for gluing. Changing it to Depac glue (5)	Frequent inspection. Increasing to 50 product/shift (3)	3	5	3	45	Chosen – to implement visual aid

Table 10 Assembly process

Type of defect: Wrong orientation

Analysis	Cause of defect	Prevention of defect	Effect of defect	Detection of defect	O	S	D	RPN	Comment
Current system	Air leakage	Visual	Air leakage	Function test	3	7	6	126	
Counter-measure	How can occurrence of the defect cause be avoided or made difficult?		How can the severity of the effect be reduced	How can defect detection be reduced	What are the resulting lowest RPN?				Cost and introduction deadline
1.				Visual checking should be done (4)	3	7	4	84	
2.			Training should be done (6)		3	6	6	108	
3.	Training on operators in each station (3)		Provide tools and fixtures orientated the product (5)	Instruction card and visual aid applied (3)	3	5	3	45	Chosen – to update instruction card

Table 11 Process of gluing on groove

Type of defect: Wrong glue quantity

Analysis	Cause of defect	Prevention of defect	Effect of defect	Detection of defect	O	S	D	RPN	Comment
Current system	Method and handling	Visual	Air leakage	Function test	3	7	6	126	
Counter-measure	How can occurrence of the defect cause can be avoided or made difficult?		How can the severity of the effect be reduced	How can defect detection be reduced	What are the resulting lowest RPN?				Cost and introduction deadline
1.	Training on operators (3)			Visual and function check (5)	3	7	5	105	
2.	Gluing materials will be changed (3)		New tools in mixing the glue will be introduced. A two-in-one mixing glue tools (5)	Inspection needed. Check for glue colour, should come out green colour (4)	3	5	4	60	Chosen – to implement visual aid

Table 12 Assembly and welding process

Type of defect: Loose

Analysis	Cause of defect	Prevention of defect	Effect of defect	Detection of defect	O	S	D	RPN	Comment
Current system	Method and insufficient heat cap	Visual	Air leakage	Function test on temperature	3	7	6	126	
Counter-measure	How can occurrence of the defect cause be avoided or made difficult?		How can the severity of the effect be reduced	How can defect detection be reduced	What are the resulting lowest RPN?				Cost and introduction deadline
1.			Increasing the pressing pressure on the set. Increase to 6 bar (6)		3	6	6	108	
2.			Calibrate the machine regularly. Calibrate it once a week for accuracy (6)	Inspection on every set (5)	3	6	5	90	
3.			Put more side clamps on the machine. Extra clamps to hold the set (5)	Function test on set. Test for vibrating sound (5)	3	5	5	75	Chosen -- to update instruction card

Table 13 Gluing process

Type of defect: Wrong quantity

Analysis	Cause of defect	Prevention of defect	Effect of defect	Detection of defect	O	S	D	RPN	Comment
Current system	Method and visual	Visual	Loose	Function test	3	7	6	126	
Counter-measure	How can occurrence of the defect cause be avoided or made difficult?		How can the severity of the effect be reduced	How can defect detection be reduced	What are the resulting lowest RPN?				Cost and introduction deadline
1.	Mixing the types of glue. Types of glue suitable will be Gluemac315 because it is more adhesive (3)			Visual checking. Extra glue will come out from the groove (5)	3	7	5	105	
2.			Increase pressing pressure on cover. Pressing pressure is about 6 bar (5)	Inspection on glue. Stated in SPC check after weighing the quantity (5)	3	5	5	75	Chosen – to update instruction card

Table 14 Finish goods assembly process

Type of defect: Wrong orientation

Analysis	Cause of defect	Prevention of defect	Effect of defect	Detection of defect	O	S	D	RPN	Comment
Current system	Cannot assemble	Visual	Cannot assemble	Cannot assemble at customer's place	3	7	6	126	
Counter-measure	How can occurrence of the defect cause be avoided or made difficult?		How can the severity of the effect be reduced	How can defect detection be reduced	What are the resulting lowest RPN?				Cost and introduction deadline
1.			Training of operators (6)	Training of workers (3)	3	6	6	108	
2.			Mark on every set of the slot bracket (5)		3	5	6	90	
3.			Introduce jigs and fixtures (5)	Visual checking and inspection. By looking at the position of the bracket (5)	3	5	5	75	Chosen – to implement visual aid

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