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Analysis of Product Reliability using Failure Mode Effect Critical Analysis (FMECA) - Case study

Sivasankaran.P[1] and Baskaran.P [2]

[1]Associate Professor, Department Of Mechanical Engineering,Manakula Vinayagar Institute Of Technology ,Pondicherry – 605 107

[2]Professor & Head, Department Of Management studies, Manakula Vinayagar Institute Of Technology, Pondicherry – 605 107

ABSTRACT

The components and subassemblies are to be produced with more accuracy and reliability to ensure effective performance in the fully assembled final product. In this article a product namely washing machine has been selected for case study to identify its quality requirements by measuring its parameters such as spinning speed, maintenance, water level controller etc by using tool called Failure Mode Effects and Criticality Analysis (FMECA), which is derived from the Quality tool called Failure Mode Effect Analysis. The main aim of this tool is to critically examine the different parameters of product for finding the causes and effects of product failures. So FMECA (Failure Mode Effects and Critical Analysis) is one of the effective tools to categorize the various methods of failures based on the risk involved.

Keywords: FEMCA, Failures risks, operations and Maintenance.

1. INTRODUCTION

FMECA (Failure Mode Effects and critical Analysis) is the tool used to detect the potential failures experienced in the product's performance. Failure modes, effects and criticality analysis would be undertaken to identify the critical maintenance or renewal as well as the consequences of critical failures with respect to any component / device /machine / Asset. FMECA ranks the potential failures through classifying its severity and probability of occurrence identified with the help of the available data. Thereby it facilitates the plans formulated for maintenance, capital expenditure and investigation activities for screening the potential failures (Sydney water, 2010).
In this paper the analysis on performance experienced by the washing machine is presented as case study. Product reliability is studied using this tool namely FMECA. Based on that engineer can predict the causes of failures at three different levels namely medium, average and catastrophic failure. Based on the types of risks one can focus on the severity or critical aspects of failures in order to minimize it. So, Failure Mode Effect and Critical Analysis enables reduction of the occurrences of defects by improving its efficiency. This tool considers the customer concern as primary information for improving reliable and robust products which works for long service period.

2. LITERATURE REVIEW

This section represents the various research articles focused on national and international levels on FMECA tools.
Cristiano Fragassa& Martin Ippoliti (2016) This article represents the use of Failure Mode Effects and Criticality Analysis (FMECA) as a aid for improving quality in cleaning process. In particular, FMECA was used to assess potential defects in the original plant design, to recognize the inner causes of some failures actually occurred during operations and, finally, to recommend definitive re-design actions. Changes were implemented and the new UMCS offers a better quality in term of higher availability and productivity

Andrés A. Zúñiga et al (2020) In this paper, a reliability approach is addressed by using the failure modes of power and cyber network main components is suggested to evaluate risk analysis in smart electrical distribution systems. In this article the authors introduced the application of Failure Modes and Effects Analysis (FMEA) method in future smart grid systems in order to establish the impact of different failure modes on their performance. A smart grid test system is defined and failure modes and their effects for both power and the cyber components are presented.

Kapil dev sharma et al (2018) In this article the authors have focused the application of FMECA tool in sectors like Manufacturing, Food industries etc. The successful FMECA team will identify the potential failures and hazards present in the product.

Nurul Ain Ahmad et al (2014) In this paper authors have focused about the importance of defects occurring in the product during production processes. A defect measured in the product means that the value is not added to fulfil the functional requirements. So in order to reduce the level of defect the company has to rework the product again by fulfilling the functional requirements.

Xiaoqing Cheng et al (2013) In this work authors have focused on Failure Mode Effects and Critical Analysis (FMECA) for failure of metro door system used in metro rails. In the initial stage the failure components of the metro door are analyzed statistically. In the second phase of study the failures are classified according to the nature and potential impacts. Then in the final stage the failure modes are described by having 12 failure modes based on that failure modes are discussed to bring the most significant effect.

Isam A.Q. Elbadawi et al (2018) This article describes about the methods of fault finding and failure detection in various components. Also it involves forecasting failures, their effects and occurrences. In the present study the authors have focused about the failure occurring in automated conveyor system. The analysis concludes that FMECA (Failure Mode Effects and Critical Analysis) tool is highly effective for automated conveyor system.

S.O.Ananza et al (2021) In this paper reliability of security system is studied with the help of FMECA Tool (Failure Mode Effects and Critical Analysis). Each component of security systems are analyzed based on the degree of failures, number of occurrence and detection. The risk priority number (RPN) used to detect and classify various modes of failures.

Ahmed .M.El .Assal et al (2016) This paper illustrates the use of failure mode effects and critical analysis and fishbone diagram tools are used to illustrate the failure of components in detailed manner with the help of both the methods. The proposed tools are implemented in glass bulb factory in order to measure the frequent breakdowns and malfunctioning problems.

3. METHODOLOGY

3.1 Introduction to the concept:

In the section 3.1 the importance of FMECA (Failure mode Effects and Critical analysis) is discussed with its basic nature and role of significant importance. FMEA mainly identifies the ways in which the product, process or service fail to meet the requirements of the customer. It also ranks and prioritizes the related risks associated with identified failure modes (Zigmund Bluvband, et.al, 2009). But, FMECA considers the score quantified for severity, Probability and detection ability of the potential failures for calculating Risk Priority Number (RPN) which in turn enables the prioritization of remedial measures (Sydney water, 2010).

Failure Mode and Effects analysis (FMEA or FMECA) analyzes the potential problems and hazards present in the system. Thus recommended actions are taken to reduce the potential problems. FMECA team determines the failure mode analysis and identifies the single failure point that is critical. Generally FMECA results with two stages namely:

1. FMEA (Failure Mode Effects Analysis)
2. CA (Critical Analysis)

There are many flavours of FMEA as listed below:
1. Functional FMEA
2. Design FMEA
3. Process FMEA
1. Functional FMEA sometimes termed as system FMEA, analyze and brainstorm the functions of system.
2. Design FMEA identifies specific functions, failure mode and their potential effects with severity ranking.
3. Process FMEA methodology used to discover potential risks with associated process changes including failure that impacts quality, customer non perception and safety

3.2 Risk evaluation methods:

Commonly there are two methods used to predict the risks namely

1. Risk Priority Number
2. Criticality Analysis

1. Risk Priority Number :

This method helps to analyze the risks in various ways such as listed below:

a. Rate the severity based on the effect of failure.
b. Rate the occurrence for each potential cause of failure.
c. Rate the problem for cause of the failure before it reaches to the hands of customer.
d. Calculate the RPN by obtaining the product of three ratings:
RPN = Severity *Occurrence*Detection

RPN number used to prioritize the different problems based on that corrective action can be taken.

2. Criticality Analysis:

There are two different methods used to describe failure outcomes they are as listed below:

a. Quantitative analysis
b. Qualitative analysis

To use the quantitative method the following things are carried out as listed below:

- Define the reliability of each item to measure the expected number of failure modes.
- Identify the item's unreliability that can be attributed to each failure modes.
- Rate the loss of probability for each potential failure modes.
- Estimate the criticality index for each potential mode of failure by considering the product of three things
  Criticality Index = Expected failures * Ratio of unreliability * probability of loss
- Calculate the criticality of each item by summing the mode of criticalities
  Item Criticality = Sum of Mode Criticalities

To use the Qualitative method the following procedures are listed below:

- Rate the severity of potential effects of each failure modes.
- Rate the occurrence of each potential failure modes.
- Compare the failure modes which measures severity on x axis and occurrence on y axis.

4. CASE STUDY:

In this section the potential failure and its effects can be illustrated with a product by example called washing machine. Here various types of failures are addressed due to defects observed during manufacturing process of various components used in the washing machine. Some of the failures are addressed here

Problem 1: washer making vibrations or sound.
Problem 2: washer stops in mid cycle.
Problem3: Water won't drain properly.
Problem 4: water is not pumping out during spinning cycle
Problem 5: Basket is slow or not spinning properly
Problem 6: water leakage in pipe channel

These are the main problems noticed in the washing machine based on the above issues suitable method is identified to tackle above problems namely FMECA (Failure Mode Effects and Critical Analysis) . Using this tool we can able to observe the pattern of various failure modes such as mild, medium and severe failures. Failure pattern can be categorized based on RPN (Risk Priority Number)

Modes of Failures	**Effect**	**Severity**	**Causes**	**Occurrences**	**Detection**	**RPN**	**Recommended Action**	**S**	**O**	**D**	**RPN**
Washer making Vibration	Washing Machine not functioning properly	8	Due to unbalanced load	5	2	80	Sensor	8	5	7	280
Washer stops in mid cycle	Switch may malfunction	4	More detergents is used	5	7	140	-	-	-	-	-
Water not draining properly	Water level may be faulty	2	Pump may get broken	5	2	20	Sensor to monitor the water level	2	5	6	60
Water is not pumping out during spinning cycle	Pump may get jammed or stuck	2	Some obstacle may present inside	6	4	48	-	-	-	-	-
Basket is slow	If too much clothes are stacked inside	6	Broken or failed gear case can prevent agitation	4	7	168	-	-	-	-	-
Water leakage	Tub may get broken	1	Forget to install valve packing	6	2	12	Sensor is used to measure the leakage	6	2	7	84

The following are the scales that are rated as per type of failure modes as given below:

S.NO	**Description of failures**	**Rating out of 10**
1	Very low	9 -10
2	Low	7-8
3	Moderate	4-6
4	High	2-3
5	Very high	1

Table.1. Severity rate of failures

From table 1 it is clearly understood that severity of failures can be categorized into various groups from very low to very high. According to that level risk priority number is evaluated.
The following are the scale that lists out detection of failure modes as given below:

S.NO	Description of failures	Rating out of 10
1	Extremely low	9 -10
2	Low	7-8
3	Moderate	4-6
4	High	2-3
5	Very high	1

Table.2. Detection rate

5. RESULTS AND DISCUSSIONS

Thus the detailed analysis is carried out in section 4 by understanding the different types of failures based on severity, occurrences and detection. Under each failure modes the RPN is calculated as shown above.

From fig 1. It is clear that various modes of failures along with respect to X axis and RPN is taken along with respect to Y axis. From the graph it is mentioned that some of the major risks are classified as:

1. Washer makes sound due to vibration.
2. Water not draining properly.
3. Water leakage.

These are the highest risks found as per RPN value. Based on the further recommendation revised RPN values are tabulated.

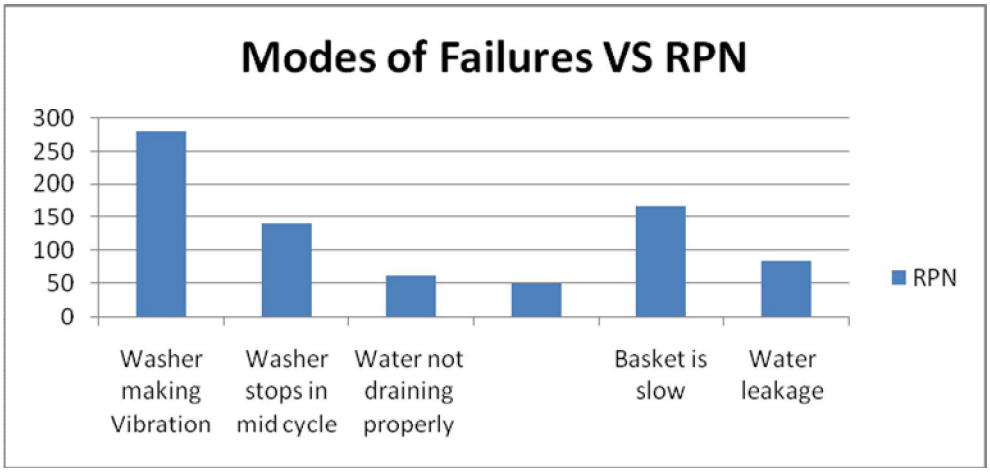

Fig1. Modes of failures versus RPN

6. CONCLUSION

In this research work the usage of failure mode effect analysis is taken as tool to examine the potential failures experienced in washing machine due to various effects and causes listed in the problem. In this paper the case study is presented in order to understand the characteristics of product reliability with respect to RPN value. So FMECA is reliability tool which measures the quality and performance of the product in terms of usage and maintenance of various components within the whole product assembly.

The application of Expanded FMEA, improves the effectiveness of FMEA by providing solutions for RPN Prioritization and comparison of Corrective actions (Zigmund Bluvband, et.al, 2009).

FMECA can be further revised to monitor the product failures after launch, as complaints analysis are constantly controlled by members in quality assurance. So, changes could be incorporated in the practice, rather in the quality verification document used for risk analysis approach. Even though FMECA has the well defined structure, still other criteria like quality systems, subjectivity and ratings has own crucial role in the analysis along with drivers like Experience, Knowledge and Team members. Its commonly teams that leverages the database, applies useful tools to limit subjectivity and takes up responsibility to provide best classification of risks, severity and occurrence probability. Ultimately, shared opinions facilitate the key choice of alternatives and implementation of decisions (Rosella Onofrio, et.al., 2015).

As, FMECA uses RPN method, which has it intrinsic weakness in identifying risk priorities and hence the RPN can be modelled using fuzzy logic, ANOVA, ANP and gray theory methods. Based on FMECA fuzzy analysis, it has been declared that the equipment with medium level of risk need to be prioritized for preventive maintenance and low risk level equipment can be subjected to planned corrective maintenance (Siswantoro, et.al, 2020).
Thereby, this paper justifies the usage of FMECA as the Reliability tool to take up appropriate remedial measure in terms of maintenance, to handle the device/product failures.

References:

[1.] Cristiano Fragassa& Martin Ippoliti ," Failure Mode Effects And Criticality Analysis (FMECA) As A Quality Tool To Plan Improvements In Ultrasonic Mould Cleaning Systems" , International Journal for Quality Research 10(4) 847–870 ,2016.
[2.] Andrés A. Zúñiga et al , "A Fuzzy-Based Failure Modes and Effects Analysis (FMEA) in Smart Grids", A Fuzzy-Based Failure Modes and Effects Analysis (FMEA) in Smart Grids : Proceedings of ICITS 2019 .
[3.] Kapil dev sharma et al , "Failure Mode and Effect Analysis (FMEA) Implementation: A Literature Review", Journal of Advance Research in Aeronautics and Space Science , Volume 5, Issue 1&2 - 2018, Pg. No. 1-17 .
[4.] Nurul Ain Ahmad et al **, "**Analysis of Product Defects using Failure Mode Effect and Criticality Analysis (FMECA)", 8th MUCET 2014,Melaka,Malaysia, 2014.
[5.] Xiaoqing Cheng et al , **"**Reliability Analysis of Metro Door system based on FMECA" **,** Journal of Intelligent learning systems and Applications , 5, 216-220,2013.
[6.] Isam A.Q. Elbadawi et al , "Application of Failure Mode Effect and Criticality Analysis (FMECA) to a Computer Integrated Manufacturing (CIM) Conveyor Belt", Engineering Technology and Applied Science Research ,Vol:8,NO:3,3023-3027,2018.
[7.] S.O.Ananza et al, "Risk Assessment of RFID –GSM based Lock system Using FMECA Technique", International Journal of Engineering Applied sciences and Technology, Vol: 5, 10, PP NO: 44-54, 2021.
[8.] Ahmed .M.El .Assal et al, "Implementation of FMECA and Fishbone Techniques in Reliability centred Maintenance planning ", International Journal of Innovative research in Science, Engineering and Technology,5,11, 2016.
[9.] Siswantoro, Priyanta, M B Zaman and Semin (2020), Failure mode and Effect Criticality analysis (FMECA) Fuzzy to Evaluate critical level on Main engine Supporting Systeme , Paper presented in Maritime Safety International Conference : Earth and Environmental Science. *Sci*. **557** 012036.
[10.]Rosella Onofrio, Francesco Piccagli, Fredrica Segato (2015), Failure Mode Effects and Critcality Analysis (FMECA) analysis for medical devices: Does standardization foster improvements in the practice?, 6th Intenational Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the affiliated conferences – Procedia Manufacturing (Science Direct) 2015 p43 to p50.
[11.]Sydney water corp., Australia (2010), Failure Mode Effects and Criticality Analysis (FMECA) Version 03 IssueJune2010https://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdq2/~edisp/dd_046414.pdf
[12.] Zigmund Bluvband, Pavel Grabov, Oren Nakar, (2009), Expanded FMEA (EFMEA), Conference Paper, 2009 IEEE Xplore https://www.researchgate.net/publication/224441904

AUTHOR

Sivasankaran. P received the B.E, M.E. and PhD. degrees in Mechanical Engineering from Pallavan College Of Engineering in 2008, Thiagarajar College Of Engineering in 2010 & Anna University. During 2011-2015, he stayed in various engineering colleges with different abilities and he is now currently working in Manakula Vinayagar Institute Of Technology, Pondicherry from 2015 till date. His area of interest includes Simulation of Manufacturing systems, TPM, Lean Manufacturing, CIM and Manufacturing systems.

Baskaran.P received the BBM, MBA and PhD degrees in Management studies from reputed universities .He stayed in the field of management studies from various engineering, Arts & Science college for so many years and he is now currently working in Manakula Vinayagar Institute Of Technology in the department of Management studies as Professor and Head right from 2018 till date. His area of Interest includes TQM, Banking laws, Engineering Management, Marketing Management, Operation Management, and Engineering Economics & Financial Accounting.