Cost Based Failure Modes and Effect Analysis

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Abstract— Failure Modes and Effects Analysis (FMEA) is a method to identify and prioritize potential failures of a product or process. The traditional FMEA uses three factors occurrence, severity, detection, to determine the Risk Priority Number (RPN). The dissertation addresses major problem with the conventional FMEA approach The RPN is an inconsistent risk prioritization technique. The purpose of the dissertation is to improve the representation of failures, and to evaluate these failures with consistent and meaning full risk evaluation criteria to facilitate cost based decisions.

Key words: FMEA, RPN

I. INTRODUCTION

Process must be cost effective. It contains less number of failure modes so that cost incorporated in failure modes can be reduced. It is necessary to recognize the failure modes in process and minimize it. Every failure has cause and effect. If its cause is identified then after providing recommended actions the effects can be minimized. Failure Modes and Effect Analysis (FMEA) is a tool used for risk assessment of failure modes.

Now a day, FMEA is used in Aerospace, Automobile, Manufacturing, and Service Industries to measure the risk of failure. It uses Risk Priority Number (RPN) ranging from 1 to 1000. It defines the seriousness of the risks related with failure Modes. It is product of three numbers i.e. severity(S), occurrence (O) and detection (D).

$$RPN= S \times O \times D$$

Severity measures seriousness of failure Modes. It ranges from 1 to 10.

Occurrence is connected with probability of failures and its cause. It ranges from 1 to 10.

Detection number is associated with probability of detection of failure ranging from 1 to 10.

Three numbers used for RPN are rating to rank the risk of failure. These numbers are meaningless.

The New approaches of FMEA have recognized some of the problems in traditional

FMEA.Representation of risk of failure can be replaced from RPN by expected cost. Cost is a meaningful attribute to measure a risk.

The paper will introduce cost based FMEA that identifies limitations in traditional FMEA. The case study of this paper was done on process of Engine Mounting Braket of three wheeler chassis at Laxmi Auto Works Ltd, Aurangabad.

II. LITERATURE SURVEY

Seung Rhee and Cherill Spencer explained FMEA used to assist in identifying potential failure modes early in process of design. It also explains a step to guide to carrying out cost-based FMEA. It concludes that FMEA is most effective when there are inputs into it from all concerned disciplines of the product development team. However, FMEA is a long process and can become tedious and won't be effective if too many people participate[1].

B. Almannai, R. Greenough and J. Kay describe an integrated approach developed for supporting management in addressing technology, organization and people at the earlier stages of manufacturing automation decision-making. The approach uses both the quality function deployment (QFD) technique and failure mode and effect analysis (FMEA) technique. The principal concepts of both applications are merged together to form a decision tool; QFD in its ability to identify the associated risk with that option to be addressed in the manufacturing system design and implementation phases[2].

S.D. Rudov-Clark and J.Stecki, FMEA is a powerful tool for evaluating and enhancing system reliability that is used in a wide variety of industries including aerospace, automotive, medical, mining, offshore and power generation. Practical uses of FMEA include identification of potential design defects and safety hazards, maintenance planning and trouble-shooting. A FMEA report is often required to demonstrate compliance with safety and quality requirements such as ISO 9001, QS 9000 and ISO/TS 16949. When properly maintained and updated, the FMEA can be used as a Knowledge Base for Fault Detection and Isolation (FDI) and Condition Based Monitoring (CBM) applications. [4]

P C Teoh and K Case introduces the FMEA in the conceptual design stage so as to minimize the risk of costly failure. The method enables new knowledge to be formed using the limited available information in the conceptual design stage. A prototype has been created to evaluate the proposed method. [5]

According to Zigmund Bluvband, Pavel Grabov,Oren Nakar , the purpose of FMEA is to examine possible failure modes and determine the impact of these failures on the product, process and service.[6]

Fiorenzo Franceschini and Maurizio introduces and discuss the application of a new method to calculate the risk prority level for the failure mode in FMEA. [7]

Robert Gilioli Rotondaro and Claudio Lopez de Oliveira shows the use of FMEA as a prevention tool in the services offered by Medical clinic Restaurant. A group of employees was trained in prevention tools, they designed the process map, identified the critical points and applied the FMEA Method in order to prevent any failure during the service operation. The first results indicated that all the actions implemented were really effective in preventing errors.[8]

The paper objective to support cost attribute to failure modes and guide design decisions with more precise decision.

III. METHODOLOGY

To improve the representation of failures risk of Assembly process of "ENGINE MOUNTING BRAKET**"** of Auto Three Wheeler chassis.

A. Traditional Process FMEA (PFMEA)

The activities in the PFMEA are similar to those of the DFMEA but with focus on process failures

B. Ranking Criteria for FMEA

1) Occurrence (O)

Table 3.1 Suggested FMEA Occurrence Evaluation Criteria

Probability of Failure	Possible Failure Rates	Ranking
Very High: Persistent failures	≥ 100 Per thousand vehicles/items	10
	50 Per thousand vehicles/items	9
High: Frequent failures	20 Per thousand vehicles/items	8
	10 Per thousand vehicles/items	7
Moderate: Occasional failures	5 Per thousand vehicles/items	6
	2 Per thousand vehicles/items	5
	1 Per thousand vehicles/items	4
Low: Relatively few failures	0.5 Per thousand vehicles/items	3
	0.1 Per thousand vehicles/items	2
Remote: Failure is unlikely	0.01 Per thousand vehicles/items	1

Table 1: Gives FMEA Occurrence evaluation criteria [3]

2) Detection (D)

Detection	Suggested Range of Detection Methods	Ranking
Almost Impossible	Cannot detect or is not checked	10
Very Remote	Control is achieved with indirect or random checks only.	9
Remote	Control is achieved with visual inspection only	8
Very Low	Control is achieved with double visual inspection only	7
Low	Control is achieved with charting methods, such as SPC (Statistical Process Control).	6
Moderate	Control is based on variable gauging after parts have left the station, or Go/No Go gauging performed on 100% of the parts after parts have left the station.	5
Moderately High	Error detection in subsequent operations, OR gauging performed on setup and first-piece check (for set-up causes only).	4
High	Error detection in-station, OR error detection in subsequent operations by multiple layers of acceptance supply select install, verify. Cannot accept discrepant part.	3
Very High	Error detection in-station (automatic gauging with automatic stop feature). Cannot pass discrepant part	2
Very High	Discrepant parts cannot be made because item has been error-proofed by process/product design.	1

Table 2: Suggested Process FMEA Detection Ranking Criteria

3) Severity (S)

Table 3.3 Suggested FMEA Severity Evaluation Criteria

Effect	Criteria: Severity of Effect	Ranking
Hazardous without warning	Very high Severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation without warning	10
Hazardous with warning	Very high severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation with warning	9
Very high	Vehicle/item inoperable (loss of primary function)	8
High	Vehicle/item operable but at a reduced level of performance. Customer very dissatisfied	7
Moderate	Vehicle/item operable but Comfort/Convenience item(s) inoperable Customer dissatisfied	6
Low	Vehicle/item operable but Comfort/Convenience item(s) operable at a reduced level of performance. Customer somewhat dissatisfied	5
Very Low	Fit & Finish/Squeak & Rattle item does not conform. Detect noticed by greater than 75% of customers.	4
Minor	Fit & Finish/Squeak & Rattle item does not conform. Detect noticed by greater than 50% of customers.	3
Very Minor	Fit & Finish/Squeak & Rattle item does not conform. Detect noticed by greater than 25% of customers.	2
None	No dissemble effect	1

Table 3: gives FMEA Severity evaluation criteria [3]

C. Method of Cost-based FMEA

1) Expected cost as a measure of Risk

Probability is a universal measure of chance and cost is an accepted measure of consequences. For a given failure scenario, risk is calculated as Expected cost. Expected cost is used extensively in the fields of Risk Analysis.

Expected Cost = probability X cost = p X c

Total Risk for n scenarios

Total Expected Failure Cost $=\sum_{i=1}^{n} pc$

2) Comparing RPN to Expected Cost

This section shows a detailed comparison of the Risk Priority Number and expected cost. Our analysis is based on the following assumptions.

We can calculate the Risk Priority numbers (O x S x D) and expected cost (P x c).

The RPN has 1 to many relationships to expected cost.

1) Failures with the same RPN have different expected costs.
2) Failures with same expected cost have different RPNs.
3) RPN and expected cost give conflicting priorities.

Labor Rate = Rs 300/ day = Rs 37.5/ hr = Rs 0.625/min=0.010 Rs/sec

Labor Cost (LC) = Occurrence $\times$ $\{[Detection\ Time \times laborRate \times no\ of\ operators] + [Fixing\ Time \times labor\ rate \times no\ of\ operator \times quantity] + [Delay\ Time \times labor\ rate\ \times no\ of\ operator]\}$

Material Cost (MC) $= Occurrence \times Quantity\ of\ parts\ to\ replace\ \times Cost\ of\ part$

Cost of part = 52 Rs

Opportunity Cost (OC) = Loss time x Hourly opportunity cost

Loss time = Detection time + Fixing time + Delay time

Opportunity cost = 10000/hr

Detection Time: Time to realize and identify a certain type of failure that has occurred and diagnose the exact location and its root cause.

a) Fixing Time

Time to fix each individual component. Redesign, remanufacturing, and reinstallation are some examples of activities that lead to fixing time.

b) Delay Time

Time incurred for a non-value activity such as waiting for technicians to respond set up time, and mailing and shipping time

D. Traditional PFMEA of Engine Bracket Assembly:

Engine Braket Assembly is made up of three parts assembled by welding. The parts are:

1) Common Plate
2) Reinforcement LH & RH
3) Braket

Material is Hot rolled steel sheet as per IS: 513-1994, thickness 2.5mm

1) PFMEA of Assembly

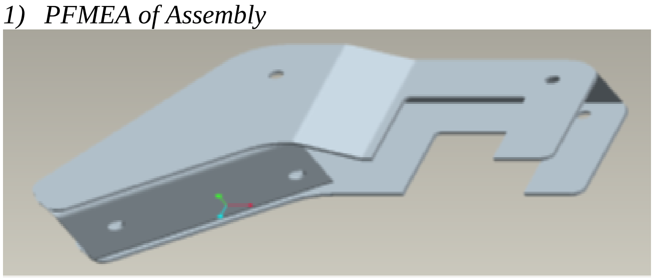

Fig. 1: Engine Bracket Assembly

E. Process Flow Diagram

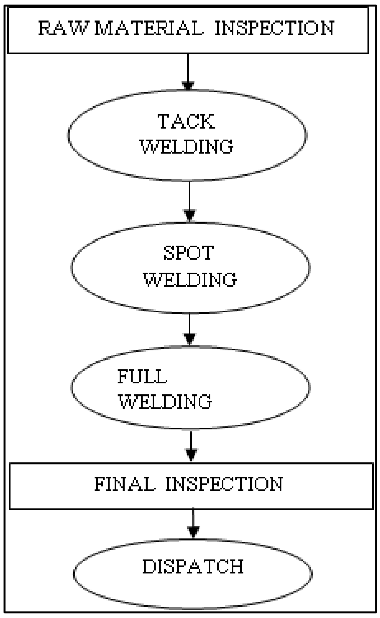

Fig. 2: PFD of Assembly

F. FMEA Effectiveness Evaluation

The effectiveness calculation is as follow

1) Traditional FMEA of Assembly

$$\text{TRE initial} = \frac{\sum RPNin}{n \times 1000} \times 100$$

$$= \frac{1412}{13 \times 1000} \times 100$$

$$= 10.86\%$$

$$\text{TRE after} = \frac{\sum RPNafter}{n \times 1000} \times 100$$

$$= \frac{608}{13 \times 1000} \times 100$$

$$= 4.68\%$$

$$\text{Percentage Reduction in RPN} = \frac{TREin\ - TREbefore}{TRE\ in} \times 100 =$$

$$\frac{10.86 - 4.68}{10.86} \times 100 = 56.91\%$$

Total Risk Estimate of Process of Assembly is changed by 56.91% after providing corrective action in traditional FMEA.

2) Cost Based FMEA of Assembly

Labor Rate = Rs 300/ day = Rs 37.5/ hr = Rs 0.625/min= 0.010 Rs/sec.

Labor Cost (LC) = Occurrence $\times$ $\{[Detection\ Time \times laborRate \times no\ of\ operators] + [Fixing\ Time \times labor\ rate \times no\ of\ operator \times quantity] + [Delay\ Time \times labor\ rate\ \times no\ of\ operator]\}$

Material Cost (MC) = $Occurrence \times Quantity\ of\ parts\ to\ replace\ \times Cost\ of\ part$

Cost of Assembly = 52 Rs

Expected Cost = $\sum_{i=1}^{13} p \times c$

Expected Cost before recommended action= 18.69 Rs/sec.

Expected Cost after recommended action= 5.68 Rs/sec.

% Expected cost reduction= $\frac{EC\ inital - EC\ Final}{EC\ Initial} \times 100$

= 69.60 %

IV. Results and Discussion

In Cost Based FMEA, Probability and cost have universal meaning, consistent definitions. Estimated ratio scales contain more information than estimated ordinal. FMEA can be used for cost- based decisions. It can incorporate uncertainty into probability and costs.

In Traditional FMEA, O, S, D values do not have meaning, definitions. Multiplication of ordinal scales is not valid.

V. Conclusion

In traditional FMEA risk reduction cannot be measured in measurable unit. It is overcome by implementation of cost based FMEA. It has been successful in reduction of risk by 69.60% and it saved the failure cost of 13.01 Rs/sec.

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