A Case Study on Failure Mode and Effect Analysis of Ball Bearing

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Abstract*- This Paper is an attempted to represent the potential tool for evaluates the problem of manufacturing process by implementing the process FMEA. This study has a goal to concentrate and eliminate the potential problem for manufacturing process of bearing in company through executing the Failure Mode and Effect Analysis.*

Keywords- Failure mode effect analysis (FMEA), Potential effect of failure, Potential failure mode, Risk priority number, Ball Bearing Failure

I. INTRODUCTION

The failure mode and effect analysis is used to identify and analyzed: (a) all failure mode of different parts of the system, (b) effects of these failure mode on the system and (c) how to circumvent the failure and/or moderate the effect of the failure system. FMEA is a step by step methodology for identifying all potential failures with in the process."Effect Analysis" denotes to studying the consequences or impact of those failures [12]. The motivation for undertaking a Process FMEA is to continually develop products and process consistency thereby increasing customer satisfaction. FMEA is a very efficient method which is needed to be engaged with in companies and manufacturing industries for an engineering design, production process and new product in production and planning sphere in product life cycle. Purpose of FMEA is founding links between causes and effects of failures, as well as searching, solving and drawing the best decisions regarding solicitation of applicable action. Concept of FMEA Failure mode and effect analysis is an analytical technique (a paper test) that combines technology and experience of people in identifying probable failure mode of product or process and planning for its abolition. FMEA is a "before-the-event" action requiring a team effort to easily and inexpensively alleviate changes in design and production. FMEA can be explained as a group of events projected to

- Recognize and evaluate the potential failure of a product or process and its effects.
- Identify actions that could eliminate or reduce the chance of potential failures.
- Document the process.

FMEA can be used as an individual project tool. However, it is strongly recommended that use to generate corrective action in a process improvement project. An FMEA is not a trivial tool rather it requires significant effort from a diverse team. FMEA method use at:

- Formation of the product concept, for checking whether all prospects of the customer are included in this concept.
- Define the product, in order to check whether projects, service, supplies are appropriate and controlled in the right time.
- Process of production, in order to check whether documentation primed by engineers is fully carried out.
- Assembly, for checking whether the process of the assembly is compatible with documentation.
- Organization of the service, in order to check whether the product or the service is pleasant with recognized criteria.

II. FMEA PREREQUISITES

The prerequisites of FMEA are given below.

(i) Select proper team and organise members effectively.
(ii) Select team for each product/services, process/system
(iii) Create a ranking system
(iv) Agree on format for FMEA
(v) Define the customer need
(vi) Design/process requirement
(vii) Develop the process flow chart

III. UPDATING FMEA TABLE

FMEA table is to be updated when

(i) a new product or process is being designed or introduced.
(ii) a critical change in the operating conditions of the product or process occurs.
(iii) the product or process itself undergoes a change
(iv) a new regulation that affects the product or process
(v) customer complaints about the product or process are received
(vi) an error in the FMEA table is discovered or new information that affects its contents comes to light.

IV. CLASSIFICATION OF VARIOUS FMEA PROCESS

4.1. System FMEA

A system FMEA identifies potential failure modes, effects, and causes that may prevent a system from meeting all of its system objectives. The system FMEA is a process that analyzes the customer's requirements/characteristics relative to their intended function to ensure that the resultant product meets customer needs and expectations. When potential failure modes are identified, action must be initiated to eliminate or reduce their occurrence. Risk assessment via the use of risk priority numbers is completed in order to prioritize the actions. When listing components or subassemblies include details such as component part number, supplier, etc. which will be helpful to others reading or revising the System FMEA in the future.

4.2. Design FMEA

A Design FMEA identifies potential failure modes, effects, and causes that may prevent a new design from meeting all of its design objectives. The design FMEA is a process that analyzes the product's design characteristics relative to their intended function to ensure that the resultant product meets customer needs and expectations. When potential failure modes are identified, action must be initiated to eliminate or reduce their occurrence. Risk assessment via the use of risk priority numbers is completed in order to prioritize the actions. When listing components, include details such as component part number, material, etc. which will be helpful to others reading or revising the DFMEA in the future.

4.3. Process FMEA

A Process FMEA identifies potential failure modes, effects, and causes that may prevent the manufacturing processes from producing a new design that meets all of its design objectives. It is a process that identifies potential process variables in order to focus controls for prevention or detection of potential failures. The process FMEA is to be considered a living' document that is changed and updated as the process evolves and matures. Risk assessment via the use of risk priority numbers is completed in order to prioritize preventative and detection actions.

V. KEY TERMS USED IN FMEA

(i) Criticality

Criticality rating is the mathematical product of severity and occurrence ratings. This number is used to place priority on items that require additional quality planning.

(ii) Critical characteristics

Critical characteristics are the special characteristics defined by Ford Motor Company that affect customers' safety and/or could result in noncompliance with government regulations and thus require special controls to ensure 100% compliance.

(iii) Causes

A particular element of the design or process results in a failure mode, due to a cause.

(iv) Failure mode

Failure modes are sometimes described as categories of failure. A potential failure mode describes the way in which a product or process could fail to perform its function (design intent or performances requirement) as described by the needs, wants and expectations of internal and external customers.

(v) Severity

Severity (S) is an assessment of how serious the effect of the potential failure mode is. A rating of 1 to 10 is chosen based on the severity.

(vi) Occurrence

Occurrence (O) is an assessment of the likelihood that a particular cause will happen and result in failure mode during the life and use of a product. Occurrence rating is given from 1 to 10.

(vii) Detection

Detection (D) is an assessment of the likelihood that the current control (design and process) will detect the causes of failure mode or the failure mode itself, thus preventing it from reaching the customer.

(viii) Current control

Current control (design and process) are the mechanisms that prevent the causes of failure mode from occurring, or which detect the failure before it reaches the customer.

(ix) Risk Priority Number (RPN)

The RPN is the mathematical product of the Severity (S), Occurrence (O) and Detection (D).

RPN = S x O x D

VI. FMEA PROCEDURE

The process for conducting FMEA can be divided into following steps. These steps are briefly explained as follows.

- Step 1: Collect the functions of system and build a hierarchical structure. Divide the system into several subsystems, having number of components.
- Step 2: Determine the failure modes of each component and its effects. Assign the severity rating (S)of each failure mode according to the respective effects on the system.
- Step 3: Determine the causes of failure modes and estimate the likelihood of each failure occurring. Assign the occurrence rating (O) of each failure mode according to its likelihood of occurrence.
- Step 4: List the approaches to detect the failures and evaluate the ability of system to detect the failures prior to the failures occurring. Assign the detection rating (D) of each failure mode.
- Step 5: Calculate the risk priority number (RPN) and establish the priorities for attention.
- Step 6: Take recommended actions to enrich the performance of system.
- Step 7: Conduct FMEA report in a tabular form.

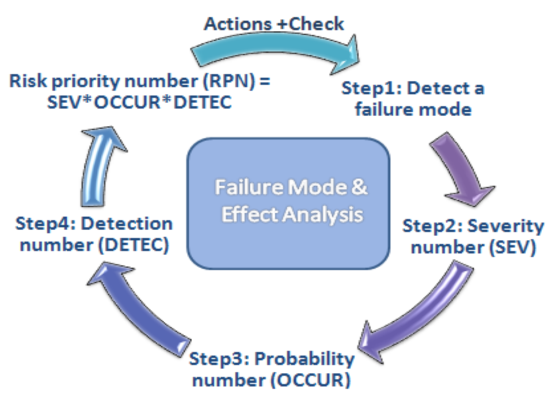

Fig.1.Steps in FMEA

VII. DOCUMENTATION PROCEDURE FOR FMEA

Specify all the functions of an item, including the environment in which it has to operate.

7.1. Potential Failure Mode

- Considering past failures, present reports, brainstorming.
- Describe in technical terms and not as customers will see.
- For e.g. cracked, deformed, loosened, short circuited, fractured, leaking, sticking, oxidized etc.

7.2. Potential Effects of Failure

- As perceived by the customer (internal/end user).
- For e.g. erratic operation, poor appearance, noise, impaired functions, deterioration etc.

7.3. Severity

Severity is the assessment of the seriousness of the effect of the potential failure mode. In this we have to determine all failure modes based on the functional requirements and their effects. An example table of severity is given below.

Table 1: Table of severity

Code	Classification	Example
10	Hazardous without warning	Very High ranking affecting safe operation
9	Hazardous with warning	Regulatory non compliance
8	Very High	Product become inoperable with loss of function, Customer very much dissatisfied
7	High	Product remain operable but loss of performance, customer dissatisfied
6	Moderate	Product remain operable but loss of comfort/convenience
5	Low	Product remain operable but loss of convenience and customer slightly dissatisfied
4	Very low	Non-conformance noticed
3	Minor	Non-conformance by certain-Noticed
2	Very Minor	Non-conformance bycertain item- Noticed
1	none	No effect

7.4. Occurrence

Occurrence is the chance that one of the specific cause/mechanism will occur. In this step, it is necessary to look at the cause of a failure and how many times it occurs. Looking at similar products or processes and the failures that have been documented for them can do this. A failure cause is looked upon as a design weakness. An example for occurrence rating is given in following table.

Table 2: Table of occurrence

Code	Classification	Example
10 and 9	Very High	Inevitable Failure
8 and 7	High	Repeated Failures
6 and 5	Moderate	Occasional Failures
4,3 and 2	Low	Few Failures
1	Remote	Failure Unlikely

7.5. Current Design Control

The control activities generally include Prevention Measures, Design Validation, and Design Verification Supported by physical tests, mathematical modeling, prototype testing, and feasibility reviews etc.

7.6 Detection

- Relative measures of the ability of design control to detect wither a potential cause/mechanism or the subsequent failure mode before production.
- Supported by physical tests, mathematical modeling, prototype testing

Table 3: Table of detection

Detection	Rank	Criteria
Extremely Likely	1	Can be corrected prior to prototype/ Controls will almost certainly detect
Very High likelihood	2	Can be corrected prior to design release/very high probability of detection
High Likelihood	3	Likely to be corrected/high probability of detection
Moderately	4	Design controls are moderately effective
Medium likelihood	6	Design controls may miss the problem
Low Likelihood	7	Design controls are likely to miss the problem
Very low likelihood	8	Design chance of detection
Very low likelihood	9	Unproven, Unreliable design/poor chance of detection
Extremely unlikely	10	No design techniques available/control

7.7 Risk Priority Numbers (RPN)

RPN is the indicator for the determining proper corrective action on the failure modes. It is calculated by multiplying the severity, occurrence and detection ranking levels resulting in a scale from 1 to 1000.After deciding the severity, occurrence and detection numbers, the RPN can be easily calculated by multiplying these 3 numbers:

RPN = Severity ×Occurrence ×Detection.

The small RPN is always better than the high RPN. The RPN can be computed for the entire process and/or for the design process only. Once it is calculated, it is easy to determine the areas of greatest concern. The engineering team generates the RPN and focused to the solution of failure modes.

7.8 Recommended Actions

Beginning with high RPN and working in descending order

- The objective is to reduce one or more of the criteria that make up the RPN.
- Typical actions are design of experiments, revised test plans, revised material specifications, revised design etc.
- Important to mark “None” in case of no recommendation for future use of FMEA document.

Responsibilities and Completion Dates

Individual or group responsible for the recommended actions and target completion date to be entered.

7.9 Actions taken

Brief descriptions of the action taken to be entered after actual actions are taken by the team.

7.10 Revised RPN

Recalculation of Severity, Occurrence and Detection rankings after implementation of recommended actions and thus calculation of revised RPN.

Revised RPN=revised (*Severity*× *Occurrence* ×*Detection*)

VIII. ADVANTAGES OF FMEA

FMEA is designed to assist the engineer to improve the quality and reliability of design. Properly used FMEA provides the engineer several benefits and they are given below.

i. Improves product/process reliability and quality
ii. Increases customer satisfaction
iii. Helps for early identification and elimination of potential product/process failure
iv. Priorities product/process deficiencies
v. Captures engineering/organisation knowledge
vi. Emphasis problem prevention
vii. Documents risk and actions taken to reduce risk
viii. Provides focus for improved testing and development
ix. Minimizes late changes and associated cost
x. Serves as a catalyst for teamwork and idea exchange between functions.

IX. LIMITATIONS OF FMEA

i. If used as a top-down tool, FMEA may only identify failure modes in a system. Instead Fault tree analysis (FTA) is better suited for “top-down” analysis.

ii. When used as “bottom-up” tool FMEA can augment or complement FTA and identify many more causes and failure modes resulting in top level symptoms.

iii. It is not able to discover complex failure modes involving multiple failures within a subsystem, or to report expected failure intervals of particular modes up to the upper level subsystem or system.

iv. The multiplication of the severity , occurrence and detection rankings may result in rank reversals , where a less serious failure receives a higher RPN than a more serious failure mode.

Case Study of FMEA of Ball Bearing

A Bearing race is very critically fabricated using planned process sequences. The FMEA for the Inner race of the bearing is shown in the below Table 1.

Part/Product No					Key Contact Person : ****			Doc. No : X/FMEA/**		
Part/Product Description :					Key Contact No : *****			Rev. No :		
Customer Name(if Any) : ****					Case Team : *****			Revision Data		
Customer drawing No : ****										
Other Details (if Any)										
Opera -tion No	Process Description	Potential Failure Mode	Potential Effect of Failure	SEV	Potential Causes	OCC	Current Control Prevention	Current Control Detection	DET	RPN
1	Internal Diameter Grinding(Inner Race)	Inner Diameter ± then specification	Size Variation	8	Previous machine variation follow	5	Setup CNC programmed process, First piece Inspection	In process Inspection	4	160
					Poor Grinding Wheel Quality	4	Setup CNC programmed process, First piece Inspection	In process Inspection	4	128
					Outer Diameter size variation	3	Process Drawing work instruction, First piece Instruction	100% inspection	3	72
		Concentration variation	Ovality & Out of Roundness	7	Improper mounting and Clamping system	6	machine specification details	100% inspection	3	126
					Miss match of wheel and bearing race	3	Setup CNC programmed process, First piece Inspection	In process Inspection	2	42
					Wheel spindle not in centre	2	Setup CNC programmed process, First piece Inspection	In process Inspection	3	42

		Surface Roughness+ than Variation	Grinding Marks	6	Coolant Problem	5	Temperature Sensor	Temperature Sensor	5	150
					High Grinding wheel R.P.M.	7	Setup CNC programmed process, First piece Inspection	In process Inspection	3	108
		Surface Roughness+ than Variation	Cracks on Rings	8	Excessive Feed Rate	3	Setup CNC programmed process, First piece Inspection	In process Inspection	3	72
					Improper dressing	5	Tool and work piece material Inspection	In process Inspection	3	96
					Improper Heat treatment	1	Material hardness testing	In process Inspection	7	56
2	Centre less Grinding	External diameter ± then specification	Square ness	5	Inner diameter having squareness	5	Process Drawing work instruction, First piece Instruction	100% inspection	2	50
		Ovality and Out of roundness	Wall thickness variation	6	Clamping system	7	machine specification details	In process Inspection	3	126
					Type of Cut	7	Machine maintenance instruction	In process Inspection	2	84
3	Deburing, cleaning, Inspection, Packing	Dust and rust inside	Fictional problem at customer end	6	Improper cleaning	2	Work Inspection	Pre dispatch Inspection	3	36

X. CONCLUSION

FMEA is a methodology for documenting the various failure modes and its potential effect analysis for future use in same industry or it will become valuable for other industries of similar sectors. It comprises the systematic approach to failure detection, occurrence and its possible impact on the process. By following standard steps, it will reduce the set up time and improve the quality of product and ultimately customer satisfaction can be increased. FMEA are continuously concentrates on the improvement of the efficiency of manufacturing process and quality of the product by reducing the non-conformance rate of the production system.

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