International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 01, January-2016

FMEA Methodology for Quality Improvement in Sheet Metal Industry

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***Abstract* - Every automobile industry is striving for growth in today's competitive world and for that each brand is developing new techniques and tools to deliver defect free products to the customer at minimum cost. Failure mode effect analysis (FMEA) is one of the effective documented tools used in every automotive industry to avoid defects in design or manufacturing of the product. This FMEA when applied to process of the production then it is called as Process Failure Mode and Effect analysis. PFMEA is the integral standard document of all automotive companies in the world. This was developed first time by NASA in 1960 for Apollo project to avoid any accident of spaceship in space and on earth. After that it was developed for automobile industries and today every automotive industry is using it as a standard tool.**

An FMEA is analytical technique employed by a team as a means to assure that, to extent possible, potential failure mode and their causes have been consider and address. This paper will give a brief view of rules and flow of FMEA to apply it in sheet metal industry.

Keywords: Failure mode effect analysis (FMEA), Risk priority number (RPN).

I. INTRODUCTION

An FMEA is a document included in quality requirement of automotive OEMs for their supplier. Some supplier establishes the standard procedure to prepare FMEA in a format and is always available with them. Preparation of FMEA is a team work and is a before an event document. The purpose of FMEA is to build a rigid and effective quality improvement system to produce high quality and reliable products [1]. FMEA is a team oriented quality tool used to predict the possible failure modes, their effects and causes in the design and manufacturing processes [2].

One of the most important factors for the successful implementation of an FMEA is timeliness. An FMEA is meant to be a 'before-the-event' action, and not an 'after-the-fact' exercise. To achieve the greatest value, an FMEA must be done before a design or process is converted into a product. An FMEA can reduce or eliminate the chance of implementing a corrective change that would create an even larger concern.

R.S.Mehtre et al. [2] have considered FMEA in a Precision sheet metal company for bending process. They have used Ishikawa diagram for root cause analysis of sheet metal bending process problems and implemented FMEA procedure successfully.

M.Dudek-Burlikowska[3] have suggested integration of quality management and quality control system for success of companies. An FMEA is a strong tool which can help companies to improve the product quality.

H. Arabian-Hoseynabadi et al. [4] have implemented FMEA for different failure modes of wind turbine like mechanical failure, electrical failure and material failure.

Rakesh R. et al. [5] have also implemented FMEA in life care product manufacturing industry to reduce the breakdown of sub system components.

II. DEFINITION OF FMEA

Failure Mode & Effects Manual (FMEA) is one of the QS-9000 Quality Systems Requirement Supplement's. "An FMEA can be defined as a systematized group of activities intended to recognize and evaluate the potential failure of a product / process and its effect, identify actions which could eliminate or reduce the chance of the potential failure occurring, and document the process"

III. TYPES OF FMEA

FMEA can be done in different stages of product life cycle and can be classified as follows:

1. Concept FMEA (CFMEA)
2. Design FMEA (DFMEA)
3. Process FMEA (PFMEA)
4. Machinery FMEA (MFMEA)

Concept FMEA is done during the concept building stage so that all potential failure modes in concept design can be addressed with action. Design FMEA is done before actual design phase of the product so that all design failure modes can be addressed prior to design issues and action can be finalised. Process FMEA is done after finalising design and before production run so that all manufacturing process failure modes and action can be listed out. Machinery FMEA is done for the machine parts failure modes and listed out with action to be taken before it goes for production.

IV. PURPOSE OF FMEA

1. To identify potential failure modes with severity ranking, that may adversely affect safety, government regulation compliance or customer satisfaction.
2. To identify critical characteristics & significant characteristics.
3. To help Engineers focus on eliminating product and process concerns and helps to prevent problems from occurring.
4. Identify potential design deficiencies before releasing hardware to production.
5. To identify potential process deficiencies before production begins and ranking all failure modes.

V. WHO PREPARES FMEA?

The team approach to preparing FMEAs is recommended. Although responsibility for the "preparation" of the FMEA must, of necessity, be assigned to an individual, FMEA input should be a Team effort. A Team of knowledgeable individuals should be assembled: e.g., Engineers with expertise in design, manufacturing, assembly, service, quality, and reliability. The responsible System, Product or manufacturing / assembly engineer leads the FMEA Team. The responsible design or process engineer is expected to involve representatives from all affected activities. Team members should include design, manufacturing, assembly, quality, reliability, service, purchasing, testing, the supplier and other subject matter experts as appropriate and the members will vary as the concept, product & process designs mature.

For proprietary design and process, suppliers are responsible. Supplier should handle respective FMEA for product and process before first dispatch.

VI. FMEA FORMAT

Format for FMEA consists of number of columns in which appropriate information is to be filled. Above the table company name, part name, date of FMEA, responsible engineers and other introductory information is written.

TABLE I
FORMAT OF FMEA

Item / Process Step / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) Of Failure	Occur	Current Process Controls		Detec	RPN	Recommended Actions	Response & Traget Complete Date	Action Results					
							Prevent	Detect					Action Taken	SEV	OCC	DET	RPN	

1. Process Step/Function: This include operation name.
2. Potential Failure mode: The failure of the respective function is mentioned second column.
3. Potential effect of failure: Effect of failure mode is listed in third column of the format.
4. Severity: The seriousness or how much severe the effect of failure mode is listed in fourth column. 1-10 rating is given to the potential effect. Higher the severity higher is the rank.
5. Class: In this column the product or process characteristics is mentioned as CC-critical characteristics or SC-Significance characteristics.
6. Potential cause of failure: The root cause of failure mode is mentioned in sixth column. Ishikawa diagram or why-why analysis may be used to find exact root cause.
7. Occurrence: Occurrence rating is mentioned with respect to given cause. 1 to 10 rating is given higher the occurrence of cause higher will be number.
8. Current Process control: It is the description of control of the processes which either prevent the failure mode or detect the failure mode.
9. Detection: It is measured in ranking 1-10. If failure mode is very hard to detect then ranking is higher and if failure mode is easy to detect its ranking is low.
10. Risk Priority Number (RPN): It is the final ranking of the issue to decide the required action. Higher RPN issues must have well prepared action plan. RPN is the product of Severity (S), occurrence (O) and detection (D).
RPN=S*O*D
11. Recommended actions: When the failure modes have been ranked by RPN, corrective action should be first directed at the critical items. If for example, the causes are not fully understood, a recommended action might be determined by statistical designed experiment (DoE). The intent of any recommended action is to reduce the Severity, Occurrence, and / or Detection Ratings.

VII. RANKING SYSTEM IN FMEA

The effect, cause and detection of the problem are ranked in the range of 1 to 10. Level of the ranking indicates the criticality of the issue and decides the priority of the action. The potential failure mode having high risk priority number must be considered first for permanent corrective action.
1. Occurrence ranking: Occurrence ranking is given as per the frequency of failure mode. Following table can be referred for the occurrence ranking.

Table II
Occurrence ranking criteria

Frequency	Possible failure rates	Ranking
Very high	≥100 per thousands of items	10
	≥50 per thousand items	9
Frequent failure	20 per thousand items	8
	10 per thousand items	7
Moderate failure	5 per thousand items	6
	2 per thousand items	5
	1 per thousand items	4
Low failure	0.5 per thousand items	3
	0.1 per thousand items	2
Very low failure	≤ 0.01 per thousand items	1

2. Detection Ranking: The detection ranking is given on the basis of ability of the current process control to detect the possible failure mode.
Following table can be referred for giving detection ranking.

Table III
Detection ranking criteria

Detection	Criteria	Ranking
Absolutely uncertain	Process control is unable to detect problem	10
Very remote	Very rare chance of detection	9
Remote	Remote chance of detection	8
Very low	Very low chance of detection	7
Low	Low chance of detection	6
Moderate	Moderate chance of detection	5
Moderately high	Chances of detection of failure mode is moderately high	4
High	High chance of detection	3
Very high	Very high chance of detection	2
Almost possible	Detection is always there	1

3. Severity ranking: Severity ranking is given according to the seriousness of effect of the failure mode. Following table can be referred for the severity ranking.

Table IV
Severity ranking criteria

Effect	Criteria	Ranking
Hazardous without warning	Potential failure mode affects the safety norms involves noncompliance with government regulations without warning	10
Hazardous with warning	Failure mode affects government norms with warning	9
Very high	Loss of primary function	8
High	Performance reduction and customer dissatisfaction due to failure mode	7
Moderate	Item is operable and customer dissatisfaction	6
Low	Item is operable but customer is not comfort	5
Very low	Defect noticed by 75% customers	4
Minor	50% of the customers are not comfort with failure mode	3
Very minor	Less than 25% of the customer noticed the defect	2
None	No noticeable defect	1

VIII. CASE STUDY

This case study is about preparation of process FMEA for the sheet metal part. The operation includes blanking and piercing operation of progressive die. The process FMEA was carried out for blanking and piercing process.
The potential failure modes for blanking and piercing process considered from the previous experience.
1. Incoming material grade wrong: If supplier's dispatched process is not fool proof they may dispatch wrong raw material.
2. Dent and damages to sheet: Wrong design of rack may result in material damage or material may get damage during transportation.
3. Lateral shifting of blank: At the time of placing blank in die the blank may be shift which will result in incorrect dimensions. For avoiding this locating pin need be checked.
4. Burr problem: If the die and punch clearance is not proper it will result in burr at the edges. Insufficient cutting force also leads to burr problem in blanking. Burr at the edges and holes will result in fitment issue and may lead to downtime.
5. Incomplete piercing operation: If cutting force is not sufficient it will result in incomplete piercing operation.

Preparation of PFMEA: All failure modes are listed in table and their causes and effect are mentioned.

Table V
Severity ranking

The seriousness of the problems is ranked as follows:

Operation No.	Failure mode	Effect	Severity
1	Wrong material grade	Not suitable for further operation	7
2	Dent and damage	Rejection	7
3	Incomplete piercing	Rejection	7
3	Burr in piercing	Fitment problem	8
4	Blanking burr	Fitment problem	8

Table VI
Occurrence ranking

The frequency of the occurrence of the problem is ranked as follows:

Operation No.	Potential cause	Occurrence rating
1	Bad control on inspection	4
2	Bad pallets and handling	8
3	Low cutting force	4
3	Punch clearance not ok	8
4	Die Clearance not ok	8

Table VII
Detection ranking

The process control ability of the detection of the problem is ranked as follows.

Operation No.	Process control (Detection)	Detection ranking
1	Dispatch report	4
2	Visual inspection	8
3	Visual inspection	2
3	Visual inspection	6
4	Visual inspection	6

Table VIII
Calculation of Risk Priority Number (RPN)

Operation No.	Calculation of severity (S*O*D)	RPN
1	4*4*4	64
2	8*8*8	512
3	4*4*2	32
3	8*8*6	384
4	8*8*6	384

Highest RPN issue should be resolved immediately with permanent corrective action and recommended action should be mentioned on sheet. These recommended action and all process control must be mentioned in the control plan and standard operating procedure.

IX. LINKAGE OF THE PFMEA WITH OTHER DOCUMENTS

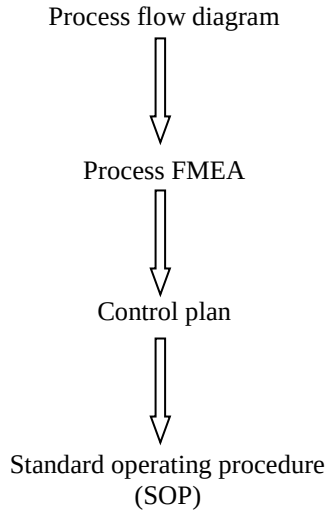

Fig.1 Linkage of quality standard documents

The process sequence is listed in the process flow diagram (PFD). From this PFD the failure modes of each process are recorded in FMEA format as per sequence in PFD. The process controls and recommended actions for respective problems from FMEA entered in control plan with same operation sequence as in PFD and then the operating procedure is prepare as per control plan. In this way each process and its problem is interlinked through PFD, FMEA, Control plan and SOP. PFMEA acts as a connecting link between PFD and control plan and SOP is the output of all these three documents.

X. CONCLUSION

FMEA gives us the point of action for any issue before an error occurs with the help of RPN number. This avoids further rework and time consuming corrective action. FMEA is a team oriented tool used to analyse and evaluate potential failure modes of each process in design and manufacturing stage for the sheet metal parts. FMEA provides a standard methodology for documenting all these failure modes, their causes, effect, control and ranking. The aim of the FMEA is to improve the current production process for high quality and reliability of the product. It is necessary for any automotive industry to implement FMEA for striving in competitive market and producing world class products.

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