Implementation of FMEA in Injection Moulding Process

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***Abstract*- FMEA is set of guiding principle for identifying and prioritizing the probable failures or defects. It is focused on preventing problems, enhancing safety, and rising customer satisfaction. This Project was carried out to determine the risk associated with defects in the injection moulding process using FMEA method and reduce the defects to ensure that the same kind of defects should not arise in the future. Thereby reducing the total cost of production and increasing customer fulfilment.**

Keywords – **FMEA, Occurance, seviarity, detection, RPN**

1. INTRODUCTION

FMEA is set of guidelines for identifying and prioritizing the major defects. It is focused on preventing problems, increasing safety, and increasing customer satisfaction. Usually, FMEA's are conducted in the product design or process development stages, conducting an FMEA on existing products or processes may also yield benefits

Failure Mode and Effect Analysis (FMEA) was first developed as a formal design methodology in the 1960s by the aerospace industry with their noticeable reliability and safety requirements. The FMEA is used to analyse concepts in the early stages before hardware is defined (most often at system and subsystem). It focuses on major failure modes linked with the proposed functions of a concept proposal. The cause and effect diagram is used to discover all the possible or real causes (or inputs) that result in a single effect (or output) (1). Causes are set according to their level of significance, resulting in a portrayal of relationships and hierarchy of events. This can help us to search for root causes, identify areas where there may be problems, and compare the relative importance of different causes.

Later, its use spread to other industries, such as the oil, automotive and natural gas. FMEA aims to recognize and prioritize possible imperfections in products and processes. FMEA (1) analyses potential failure modes, main effects, main causes, assesses current process controls and determines a risk priority factor. FMEA to be effectual, the FMEA must be iterative to correspond with the nature of the design process itself. The extent of effort and complication of approach used in the FMEA will be dependent upon the nature and requirements of the individual program.

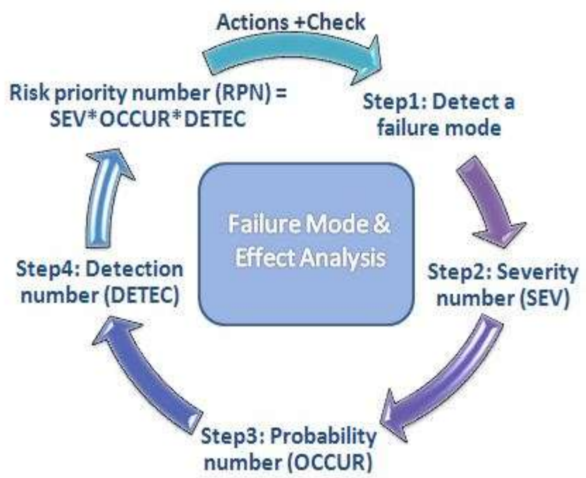


Fig: 1 flow chart of FMEA

2. FMEA VARIABLES

Severity of effect (S):- Severity measures the seriousness of the effects of a failure mode. Severity categories are estimated using a 1 to 10 scale.

Probability of occurrence(O):- Occurrence is related to the probability of the failure mode and cause.

Detection (D):- The assessment of the ability of the "designcontrols" to identify a potential cause. Detection of preforms are generated on the basis of likelihood of detection by the relevant company design review, testing programs, or quality control measures.

Risk Priority Number (RPN):- The Risk Priority Number is the product of the Severity (S), Occurrence (O), and Detection (D) ranking. The RPN is a measure of design risk and will compute between "1" and "1000."

3. DATA COLLECTION

Before design and implementation of FMEA to preform making process it is required to have careful knowledge of the process, therefore the same is studied by using process flow chart. The first phase of the work was to collect the preform rejection data, information about preforms, preform making machines through visits to the production plant. Percent average preform rejection of one month is gathered from QC reports and the most common problems due to which preforms are rejected are noted before the start of the study.

A. Rejection Data: Rejection of water bottle preforms has been collected from the **Transparent Polymers Ltd. Hubli.**

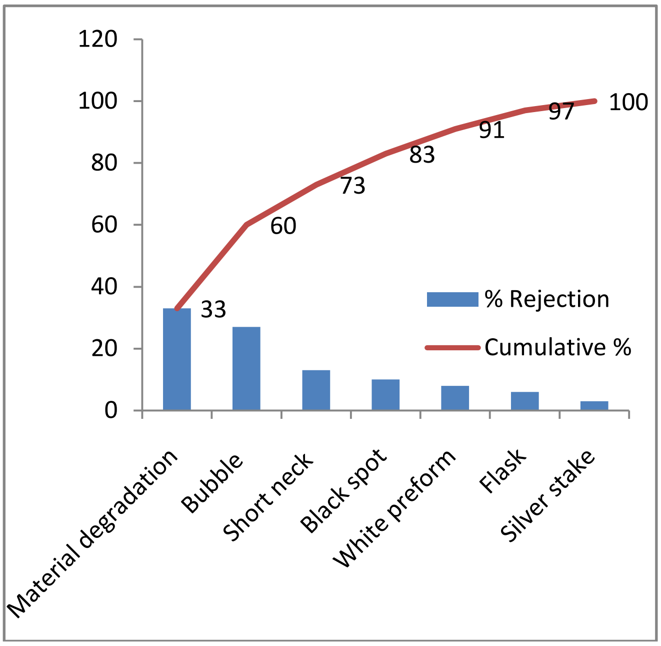
Sr. No	Problem Description	Quantity Rejected	Loss
1	Material Degradation	15,840	39,600
2	Bubble	12,960	32,400
3	Short neck	6,240	15,600
4	Black Spot	4,800	12,000
5	WhitePreform	3,840	9,600
6	Flask	3,120	7,200
7	Silver stake	1,440	3,600
		Total = 1,20,000 Rs	

Table:1 Rejection data of defect preforms before implementing FMEA

Sr.No	Problem Description	% Rejection	Cumulative%
1	Material Degradation	33	33
2	Bubble	27	60
3	Short neck	13	73
4	Black Spot	10	83
5	White Preform	8	91
6	Flask	6	97
7	Silver stake	3	100

Table:2 Cumulative percentage of Rejection of Defects

B. Pareto Diagram:



The above graph shows the percentage rejection of defects and also cumulative percentage of defects. According to FMEA we are going to concentrate 80% of defects first. By above graph we can easily analyze how much defects come under 80 percent. So let us going to find solutions for defects Material Degradation, Bubble, Short neck, Black spot & white perform. After finding solution for these defects we can go for the defects Flask & Silver stake.

4. ANALYSIS OF DATA

Once the preform rejection data is gathered the areas where concentration is required are finalized so that the rejection of preforms will come down. Accordingly efforts have been put to reduce the rejection. I started analysis of the data to identify causes of occurrence of each problem and effects of these problems on quality characteristics of the preforms.

Once I obtained all the information available about the problems of preform rejection or potential failures of the preform making process, it moved the operative phase of risk evaluation through definition of the FMEA form. The form used in this work is based on the reference manual. The form reported the detected rejection typologies and some additional information associated with them: potential causes, failure effects that detect the failures, evaluation of three risk parameters and calculation of RPN of each cause of the problem. The evaluation of the three risk parameters is done on the numerical scale defined by the FMEA team created on the basis of reference manual. The numerical scales are shown in the table. They are based on the needs of the high pressure molding line of the company or final product. The cause having higher RPN is given priority.

Finding of RPN involves 3 steps.

- Occurrence Evaluation Criteria
- Severity Evaluation Criteria
- Detection Evaluation Criteria

RPN = (Occurrence Evaluation Criteria)*(Seviority Evaluation Criteria)*(Detection) Evaluation Criteria)

Occurrence Evaluation Criteria

The probability that a failure will occur during the expected life of the system can be described in potential occurrences per unit time. Individual failure mode probabilities are grouped into distinct, logically defined levels.

Probability of failure	Likely failure rates	Occurrence
Very high	100/1000	10
	50/1000	9
High	20/1000	8
	10/1000	7
Moderate	5/10000	6
	2/10000	5
Low	1/1000	4
	0.5/1000	3
	0.1/1000	2
Remote	0.01/1000	1

Table:3 FMEA Occurrence Evaluation Criteria

Severity Ranking Criteria Calculating the severity levels provides for a classification ranking that encompasses safety, production continuity, scrap loss, etc. There could be other factors to consider (contributors to the overall severity of the event being analyzed).

Effect	Rank	Criteria
None	1	No effect
Very Slight	2	Negligible effect on performance. Some Users Notice.
Minor	3	Minor effect on performance User is slightly dissatisfied.
Moderate	4	Reduced performance with gradual performance degradation
Severe	5	Degraded performance, but Safe usable. User dissatisfied.
High Severe	6	Very poor performance. Very Dissatisfied user.
Very High Severe	7	Inoperable but safe
Extreme Severe	8	Probable failure with hazardous effect
Maximum Severe	9	Unpredictable with hazardous effect

Table :4 Severity Ranking Criteria

Detection Evaluation Criteria

This section provides a ranking based on an assessment of the probability that the failure mode will be detected given the controls that are in place. The probability of detection is ranked in reverse order. For example, a "1" indicates a very high probability that a failure would be detected before reaching the customer; a "10" indicates a low – zero probability that the failure will be detected

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 Likely	4	Operation controls are moderately effective.
Medium Likelihood	5	Operation controls have an even chance of working.
Moderately Low Likelihood	6	Operation controls may miss the problem
Low Likelihood	7	Operation controls are likely to miss the problem
Very Low Likelihood	8	Operation controls have a poor chance of detection
Extremely Unlikely	9	Unproven, unreliable chance for detection

Table :5 Detection Evaluation Criteria

Sl No	Problem Description	Cause	S	O	D	RPN
1	Bubble	Variation in Drier Temp	7	9	3	189
2	Short Neck	Variation in Injection speed	8	7	3	168
3	Material Degradation	Variation in barrel Temp	8	8	5	320
4	White perform	Variation in Screw speed	2	6	2	24
5	Black spot	Variation in MoldTemperature Control Temp	3	5	4	60

Table : 6 Calculation of Existing RPN

Calculation of Existing RPN: RPN is calculated by multiplication of rankings of Severity, Occurrence and Detection as shown below [6]. Now we can find causes for defects first whose RPN value is more i.e material degradation and follow in descending manner

5. DATA INTERPRETATION & SOLUTION

DOE is used to find the significant factors for potential failures. After discussion with employee by brain storming it was concluded that the following 3 factors were responsible,

1. Men 2. Material 3. Temperature/ Injection Speed / Screw Speed

Defects	Factors	Fisher Value	Significant/Non Significant
Material Degradation	**Barrel Temperature**	**7.59**	**Significant**
	Men	1.25	Non Significant
	Material	0.14	Non Significant
	Combined	0.01	Non Significant
Bubbles	**Drier Temperature**	**148.96**	**Significant**
	Men	1.91	Non Significant
	Material	0	Non Significant
	Combined	0.05	Non Significant
Short Neck	**Injection Speed**	**220.81**	**Significant**
	Men	0.07	Non Significant
	Material	0.61	Non Significant
	Combined	0.07	Non Significant
Black Spot	**Screw Speed**	**86.12**	**Significant**
	Men	0.16	Non Significant
	Material	0.16	Non Significant
	Combined	0.18	Non Significant
White Preform	**MTC Temperature**	**129.55**	**Significant**
	Men	**0.25**	Non Significant
	Material	**0.16**	Non Significant
	Combined	**0.18**	Non Significant

Table: 7 data interpretation & solution

By applying DOE, the results shown in Table7 are obtained in which the Fisher values are high for the factors Barrel Temperature, Drier Temperature, Injection Speed and Screw Speed. So these factors are Significant concerns with defects Material degradation, Bubbles, Short Neck and Black spot respectively respectively.

6. Solution

By operating the Injection Molding Machine for different operating variable we found the number of defects as shown in Table No 8. For the factors Temperature, Injection speed and Screw speed there are Two levels out of which we took readings for number of defects.

In obtained defects which level has minimum defects that level have been selected and freezed the respected variable.

Defects	Temperature/Injection Speed/Screw Speed	Number of Defects/hr	Cause	Solution
Material Degradation (Barrel Temp)	170 degree C	32	Variation in Barrel Temp	Standard Temp freeze to180 degree C
	180 degree C	24		
Bubble (Drier Temperature)	140 degree C	28	Variation in Drier Temp	Standard Temp freeze to160 degree C
	160 degree C	21		
Short Neck (Injection Speed)	65 mm/sec	17	Variation in Injection Speed	Freeze Injection speed to 65 mm/sec
	75 mm/sec	12		
Black Spot (MTC Temp)	260 degree C	13	Variation in MTC Temp	Freeze MTC Temp to 280 degree C
	280 degree C	7		
White Preform (Screw Speed)	60 rpm	12	Variation in Screw Speed	Freeze Screw speed to 80 rpm
	80 rpm	5		

Table: 8 Solution table

7. CALCULATION OF NEW RPN

After finding solution for causes let us head towards calculating the new RPN after taking actions and percentage decrease in RPN value. Calculations are shown below

Sl No	Problem Description	S	O	D	New RPN	Old RPN	% Decrease in RPN
1	Material Degradation	8	7	3	168	320	47.5
2	Bubble	7	8	2	112	189	40.74
3	Short Neck	8	6	2	96	168	42.85
4	White perform	3	5	1	15	24	45.5
5	Black spot	2	5	2	20	60	12

Table 9: New RPN table

After taking actions there is change in RPN Value that is reduced by almost 50 percent. Now we are going to collect data after implementing as shown in below table 10.

Sr.No	Problem Description	Quantity Rejected	Loss
1	Material Degradation	9840	24,600
2	Bubble	7,960	19,900
3	Short neck	4,260	10,650
4	Black Spot	3,500	8,750
5	WhitePreform	2.540	6,350
6	Flask	2,120	5,300
7	Silver stake	940	2,350
		Total	77,900

Table: 10 Data Collection after Implementing

8. CONCLUSION

- The FMEA methodology is allowed to study and analyze every single step of preform making process and to achieve the improvement in product and process quality. The improvements obtained by the implementation of the recommended actions thus reduce the individual RPN and the risk level associated with each defect is reduced.
- After implementation of FMEA the RPN value has been reduced for each of the defect as mentioned in the table no.9 And the defects are reduced from 48,540 to 31,160 per month and total cost associated with the defects is reduced from 1,20,000 Rs to 77,900 Rs as shown in table no 10
- By this way the number of defects, development time and cost has been reduced and also there is less chance of occurring same kind of failure in future.

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