Process FMEA Analysis for Reducing Breakdowns of Mixed Model Assembly Line in Automobile Industry

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Abstract: ***This paper aims to identify and eliminate potential and current problems from a manufacturing process of mixed model assembly line in automobile industry through the application of failure mode and effect analysis (FMEA).A Process Failure Mode Effect Analysis (PFMEA) is a analytical tool used by an organization ,business unit to identify and evaluate the potential failures of a process .PFMEA helps to establish the impact of the failure ,and identify and compute the action items with the goal of mitigating risk. It is a dynamic document that should be initiated before process of production and maintained through the life cycle of the product. In this some parameters needed to define such as severity values ,occurrence number ,detection and risk priority number (RPN).Furthermore ,some actions are proposed which require to be taken as quickly as possible to avoid potential risks which aid to improve efficiency. Thus the various possible causes of failure and their effects along with the prevention are discussed in this work.***

Keywords: FMEA, RPN, Severity, Occurrence

1. Introduction

Failure Mode and Effects Analysis (FMEA) is a methodology for risk Assessment and quality improvement focused at identifying potential causes of failure of products and processes, their evaluation by risk assessment, ranking of the problems identified according to their importance, to the determination and implementation of corrective actions .[1]
Failure Mode and Effect Analysis (FMEA) was first developed as a formal design methodology in the 1960s by the aerospace industry with their obvious reliability and safety requirements. With the appearance of jet planes in 1950s, the U.S.-based Grumman Co. developed the FMEA method to address the reliability of main controlling system of the ever-complicated jet planes. In 1977, Ford Motors introduced FMEA to address the potential problems in the R&D and the early stage of production and published the Potential Failure Mode and Effects Analysis Handbook in 1984 to promote the method [2]

2. FMEA

Failure Mode Effect Analysis (FMEA) is a method of identifying and preventing system, process and product problems before they occur. It is focused on preventing problems. Further improve the safety and increasing customer satisfaction. preferably FMEA„s are co nducted in the product design or process development stages. PFMEA is a tool that allows us to prevent System, Process and Product problems before they occur. It reduces costs by identifying system, process and product improvements early in the development stages. FMEA arrange actions that minimize risk of failure.

2.1 Types f FMEA.

i) Design (DFMEA): It is technique used by a Design Engineer as a means to assure potential failure modes, causes and effects which have been addressed for design characteristics

ii) Process (PFMEA): It is technique used by Manufacturing Engineer/Team as a means to assure potential failure modes, causes and effects which have been addressed for process characteristics.

2.2 FMEA Components: [3]

For calculating the risk, following three components are calculated and multiplied to produce risk priority number (RPN)

1) Severity(S): It is described on 10 point scale. It evaluates the seriousness of the effect of a failure mode on the customers.
2) Occurrence (O):It is described on 10 point scale. It assesses the likelihood that a particular cause will happen and failure mode will occur.
3) Detection (D): It is described on 10 point scale It is an assessment of the likelihood that the current controls will detect the cause of the failure mode thus preventing it from reaching the customer.

RPN=S*O*D .Overall RPN should be low. RPN is computed for entire Process and once it is calculated it is easy to focus on areas of greater concern.

2.3 PFMEA should be conducted during following situations

1) When there is new Technology /Design/process Implemented.
2) If there is Design/process changes.
3) New Applications Installed.
4) Quality Issues.
5) Safety concerns.
6) Capability studies.
7) Field history.

2.4 Detail Procedure of conducting PFMEA is explained with the help of following flowchart

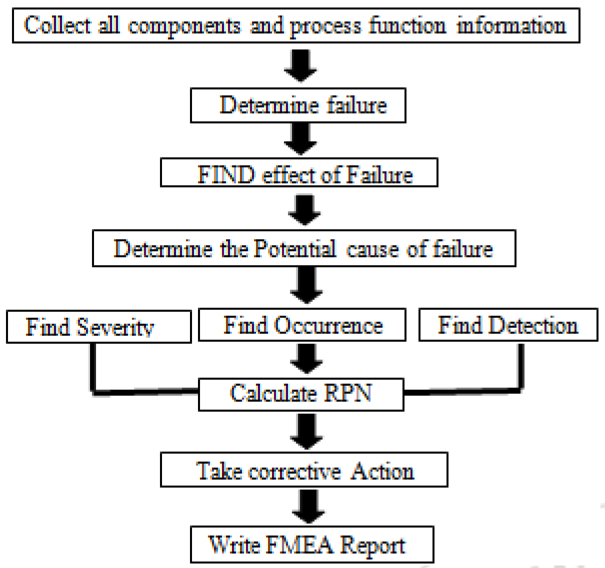

Figure 1: Flowchart for Process of conducting PFMEA

2.5 PFMEA Check list for General assembly of Automobile industry are as below:

1. Incorrect part
2. Part not correctly fitted (Gap and flushness out of spec)
3. Part not correctly fitted-clip /screw not fully engaged
4. Part not correctly fitted-clip missing
5. Part not correctly fitted interference with other part
6. Part damaged-scratch or dig
7. Damage /Interference with other part(wiring harness)
8. Part orientation /more than one possible fitment
9. Part missed
10. Fastener/ bolt-Incorrect torque
11. Fastener/ bolt-Missing
12. Fastener/ bolt-Incorrect
13. Fastener/ bolt-Crossed threaded

2.6 Description of the FMEA Worksheet Field is explained in following table

Process function	This is column is used to clarify the specific process purpose
Potential failure Mode	A concise description of how a process may potentially fail to perform its functions (specific loss of a function).
Potential Effects of Failure	A description of what the customer or end user might notice or experience
Severity	It evaluates the seriousness of the effect of a failure mode on the customers
Potential Cause/ Mechanism of Failure	It is an indication of how failure could occur
Occurrence	It is described on 10 point scale. It assess the likelihood that a particular cause will happen and failure mode will occur
Detection	It is an assessment of the likelihood that the current controls will detect the cause of the failure mode thus preventing it from reaching the customer.
RPN	RPN=Severity* Occurrence* Detection
Recommended Actions	The intent of any recommended action is to reduce the RPN.

2.7 Severity criteria chart

Severity of effect on Product	*Rank*
Potential failure mode affects safe vehicle operation and involve noncompliance with government regulation without warning	10
Potential failure mode affects safe vehicle operation and involve noncompliance with government regulation with warning	9
Loss of primary function (vehicle inoperable, does not affect safe vehicle operation)	8
Loss of primary function (vehicle operable, but at reduced level of performance)	7
Loss of secondary function (vehicle operable, but comfort/convenience function inoperable)	6
Degradation of secondary function (vehicle operable ,but comfort /convenience function at reduced level of performance)	5
Audible noise, vehicle operable, item does not conform Defect noticed by most customers (75%)	4
Audible noise, Vehicle operable, item does not conform .Defect noticed by many customers(50%)	3
Audible noise ,Vehicle operable ,item does not conform .Defect noticed by discriminating customers	2
No discernible effect	1

2.8 Occurrence criteria chart

Likelihood of failure	*Criteria :occurrence of cause (incidents per items/vehicle)*	*Rank*
Very High	≥100 per thousand ≥1 in 10	10
High	≥50 per thousand ≥1 in 20	9
	≥20 per thousand ≥1 in 50	8
	≥10 per thousand ≥1 in 100	7
Moderate	≥2 per thousand ≥1 in 500	6
	≥0.5per thousand ≥1 in 2000	5
	≥0.1 per thousand ≥1 in 10,000	4
Low	≥0.01 per thousand ≥1 in 100,000	3
	≥0.001 per thousand ≥1 in 1,000,000	2
Very Low	Failure is eliminated through preventive control	1

2.9 Detection criteria chart

Likelihood of Detection by Process control	*Rank*
No current process control, cannot detect ,not analyzed	10
Failure mode is not easily detected	9
Failure mode detection post processing by operator through visual/audible means	8
Failure mode detection in-station by operator through visual /tactile /audible means	7
Failure mode detection post processing by operator through use of variable gauging	6
Failure mode detection in station by operator through use of variable gauging	5
Failure mode detection post processing by automated controls	4
Failure mode detection in station by automated control	3
Cause(error) detection in station by automated controls	2
Cause(error) prevention as a result of fixture design ,machine design or part design	1

3. Case Study: Error Proofing Of Steering Column

The steering column fixture with two clamps is used to attach the Ignition Key Cylinder Housing and shaft to the steering column. The bolt used to connect the shaft to the steering column is given torque by using a DC tool. The DC tool is further connected to a Torque tool. The Torque tool gives the required torque value to the DC tool. The Torque tool is common for both Job A (for S2 model of vehicle)and Job B (For M3 model of vehicle). There is a proximity sensor on both fixtures. The sensor senses when a job is put on either fixtures and sends a signal to the LEP. The LEP gives torque value to the DC tool based on the origin of signal.

3.1 Error Proofing

One of the manual clamps on the fixture is replaced with a pneumatic cylinder clamp. The pneumatic cylinder clamp works according to the signal provided by a relay logic circuit.

The following relay logic circuit is used to operate the Pneumatic Cylinder Clamp:-

The main power supply 230V AC is given to a 2P Miniature Circuit Breaker (MCB). The MCB is connected to a SMPS. The SMPS gets the 230V AC supply from MCB and gives output of 24V DC. This output is connected to a gray connector, 24V DC – 7 Connector and 0V DC – 7 Connector. The two lines 24V DC and 0V DC are used for signal generation and operation. A lamp control is given to indicate the status of the system.

The CLAMP SOLENOID1 JOB A is connected to two push buttons PB1 & PB2. The 24V DC is given to PB1 & PB2 as input. The 0V DC is connected to PB2. When PB1 & PB2 are closed JOB A clamps. The operator gives torque to the NUT of shaft. A pulse is generated from NUT RUNNER which is given to relay RL1 and RL1 closes and JOB A declamps. Similarly, the CLAMP SOLENOID2 JOB B is connected to two push buttons PB3 & PB4. The 24V DC is given to PB3 & PB4 as input. The 0V DC is connected to PB4. When the two push buttons on JOB B PB3 & PB4 are closed JOB B clamps. The operator gives torque to the NUT of shaft. A pulse is generated from NUT RUNNER which is given to relay RL2 and RL2 closes and JOB B declamps.

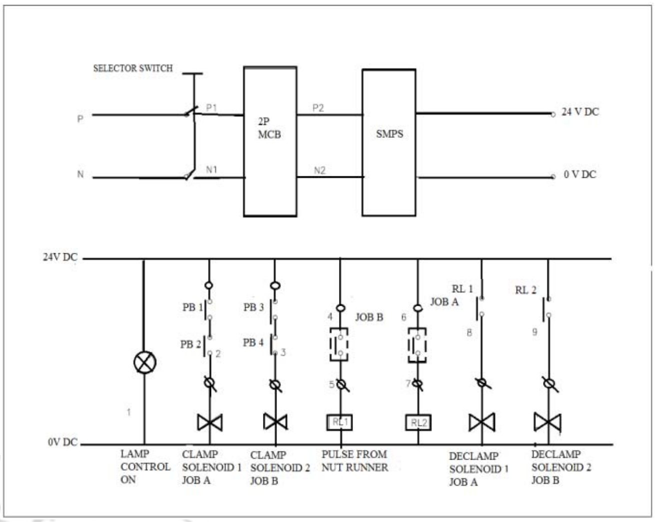

Figure 2: The relay logic circuit diagram

The advantage of this error proofing is that unless and until the torque to the bolt is not given the declamping will not take place. Hence the error proof.

3.2 Assembly Process – Before Error Proofing

1. Put the Ignition Key Cylinder Housing on the fixture.
2. Put the steering column on the fixture and clamp it with the two manual clamps.
3. Put bolts and pre tighten them.
4. Using EBT tight the bolts of Ignition Key Cylinder Housing to the steering column till the bolt heads break off.
5. Attach the shaft to the steering column, put bolt and pre-tighten it.
6. Using the DC tool give torque to the bolt.
7. Remove clamps and put the steering column on the stand.

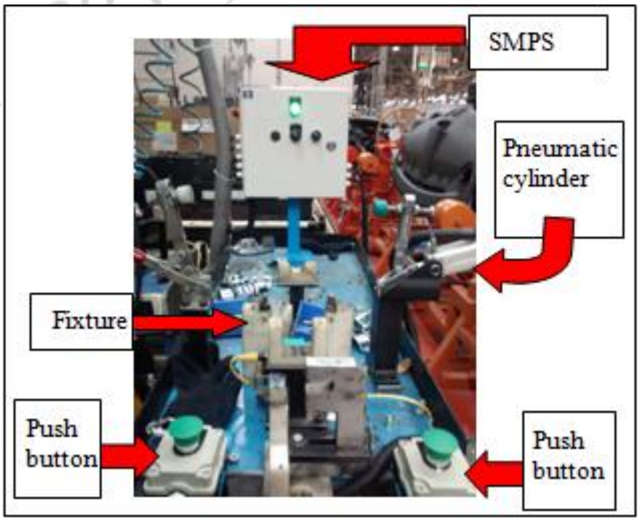

Figure 3: Fixture of steering column with error proofing

3.3 Assembly Process – After Error Proofing

1) Put the Ignition Key Cylinder Housing on the fixture.
2) Put the steering column on the fixture and clamp the manual clamp.
3) Press the two buttons simultaneously to actuate the pneumatic cylinder clamp.
4) Put bolts and pre tighten them.
5) Using EBT tight the bolts of Ignition Key Cylinder Housing to the steering column till the bolt heads break off.
6) Attach the shaft to the steering column, put bolt and pre-tighten it.
7) Using the DC tool give torque to the bolt.
8) Remove the manual clamp, the pneumatic cylinder clamp will automatically release.
9) Remove steering column and put the steering column on the stand.

3.4 Advantages of Error Proofing

The following are the advantages of error proofing:-
1) The torque of the bolt connecting steering column and shaft will not be missed.
2) It ensures that the fitment between column and shaft will stay intact.
3) It ensures the safety of the customer.

Table 5: FMEA Chart for mixed model assembly line in automobile industry

SR. NO.	*Operation*	*Process Function/ Req.*	*Potential Failure Modes*	*Potential Effect(s) of Failure*	*Sev*	*Potential Cause/ Mechanism of*	*Occ*	*Current Process Controls Detection*	*Det*	*RPN*	*Recommended Actions*	*Action Results*				
												Actions Taken	*Sev*	*Occ*	*Det*	*RPN*
1	Steering Column Sub-Assembly	Install and secure steering column to universal shaft with screws and bolts	No torque	1. SAFETY and/or REGULATORY REQ not met - NO Warning(10) VTS requirement not met	10	Missed Operation	4	SINGLE SENSORY check	7	280	Error Proofing required	Error Proofing done	10	4	3	120
2	HVAC Module install	Load HVAC Module to beam with Fasteners	Wrong Screw /Bolt selected	Annoyance Appearance of noise >75% of customer	5	Multiple Screw in same area	4	Single sensory check - 100% in station visual	7	140	Commonize screws between separate operations	Commonized the screws between separate operations	5	4	1	20
3	HVAC Duct install	Connect IP harness to HVAC module	Partial connection	Console light not illuminating	5	Coupler Partially fitted	4	Single sensory check - 100% in station	10	200	Add Check point at next station	Check point added at shower test	5	4	7	140
4	Horn Installation	secure horn with screws/bolts/nuts then route and connect	Wrong horn installed (wrong model)	NCE (vehicle is still operable) Appearance / Noise >	4	Insufficient Operator training (Wrong Product Selected	3	SINGLE SENSORY CHECK - 100% IN STATION	7	84	Error Proofing required	Use of Pick light for multiple options	4	3	4	48
5	Fastening	LOOSE ASSEMBLE OR SECURE FASTENER (continued): PNEUMATIC TOOL For Standard Care	OVER TORQUE/ UNDER TORQUE-WRONG TOOL USED (same size head	DEGREDATION of PRIMARY Function vehicle operable reduced level of performance	7	WRONG TOOL USED(same size head) SIMILAR FASTENER ON JOB MAKING OPERATOR CHOOSE BETWEEN SIMILAR TOOLS (UNINTENTIONAL	3	Random Audit (once per month)	9	189	NO SAME HEX SIZE IN THE SAME STATION WITH DIFFERENT TORQUES (SPLIT INTO DIFFERENT STATIONS)	Same hex size is splitted to different stations	7	1	1	7
6	Doors removal & loading on pallet resting Processing	Handle bracket into opening in door outer panel, **install handle bracket locating tool to ensure bracket is fully rearward,** drive POA screw to secure.	positioned fully into place (or slid into place	DISRUPTION 100% reworked off-line	9	Operator may not be able to detect part is positioned	4	SINGLE SENSORY CHECK - 100% IN STATION	7	252	, use hand tool to ensure proper positioning of handle to dooradd errorproofing tied to line stop to ensure tool is used.		9	2	3	54

4. The Risk Priority Numbers

The risk priority numbers of different processes are found out. The RPN of different process are shown in the following bar chart

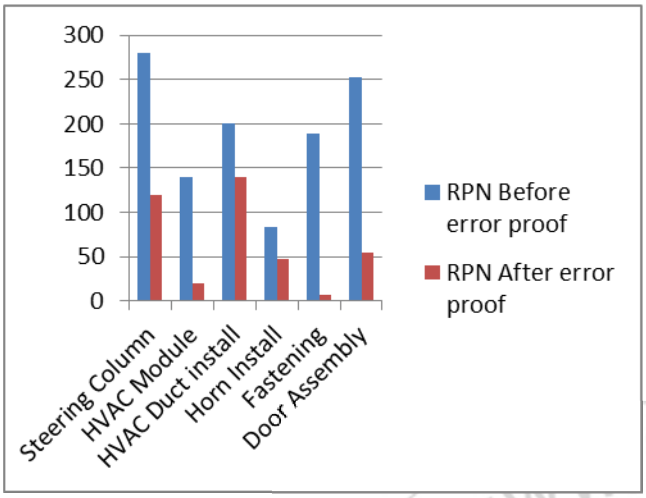

Figure 4: RPN chart

5. Conclusion

The present work deals with the PFMEA study of Mixed Model assembly Line in Automobile industry . The basic manufacturing process is studied and failure modes are identified. Potential effects of failures are evaluated with their severity value and then the causes and their prevention are calculated along with their occurrence value .The Detection value was assigned to the failure mode, and finally the R.P.N value is calculated. FMEA analysis helps in reducing down time of the Assembly Line by Error Proofing.

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