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APPLICATION OF FAILURE MODE & EFFECT ANALYSIS (FMEA) FOR CONTINUOUS QUALITY IMPROVEMENT – MULTIPLE CASE STUDIES IN AUTOMOBILE SMES

Abstract: *Failure Mode and Effects Analysis (FMEA) is a quality tool used to identify potential failures and related effects on processes and products, so continuous improvement in quality can be achieved by reducing them. The purpose of this research paper is to showcase the contribution of FMEA to achieve Continuous Quality Improvement (CQI) by multiple case study research. The outcome research conducted by implementing FMEA; one of the Auto Core Tools (ACTs), in the automobile Small and Medium Enterprises (SMEs) in Gujarat, India is presented in this paper which depict various means of Continuous Quality Improvements. The case study based research was carried out in four automobile SMEs; all of them are supplied to automotive Original Equipment Manufacturer (OEM). The FMEA was implemented with the help of Cross Functional Team (CFT) to identify the potential failure modes and effects, in overall effect on Continuous Quality Improvement. The outcome of FMEA at four companies' reveals the scope of improvement exists in the manufacturing process. Implementation of those improvement points shows the definite signs of continuous improvement of the quality of process and product as well. The FMEA and subsequent implementations had reduced the quality rejections around 3% to 4% in case companies.*

Keywords: *Failure Mode and Effects Analysis (FMEA), Continuous Quality Improvement (CQI), Automotive Core Tools (ACT), Small and Medium Enterprises (SMEs)*

1. Introduction

Continuous improvement of product and processes is very important nowadays to have an edge over others in the competitive manufacturing market and that is becoming more commanding in highly competitive industries like automotive. Unfortunately, continuous quality improvement has not been successfully implemented in small scale manufacturing industries, it remains a concept to be endeavored for. There are many quality tools available which make more difficult to choose the right tool to achieve improvement. If the wrong tool selected then it may lead to failure of the

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improvement project or may not produce the intended results. It is, therefore, important to know how, when and which tools should be used in problem-solving or improve processes. Failure Mode and Effects Analysis (FMEA) is one of the tools used for continuous quality improvement. FMEA is a structured analysis used for identification of failure modes and their effects (Pickard et al., 2005). It is a very prevailing tool, extensively used in manufacturing processes design, to scrutinize failure modes and to reduce effects of respective failures. Hence it helps in identifying measures necessary to improve the product and processes by concentrating on failure modes and its impact (Xiao et al., 2011). Continuous quality improvement can be achieved by initiating quality improvements which may be identified based on the implementation of quality tools. Six sigma and lean tools are extensively used in the automobile industries, but very minimum work has been done in using ACTs – FMEA, SPC, MSA, APQP and PPAP (Doshi J A et al., 2014, p.245–255). The positive results achieved after the solution of problems leads to continuous quality improvement. FMEA can be deployed to find the causes of the problem, in some cases a potential problem, along with the solution to be implemented which may improve quality (Teixeira et al., 2012).

The objective of the research was to check the applicability of FMEA for continuous quality improvement in small-to-medium size enterprises. It is very important to establish the measurable performance parameters which depict the quality improvement on a continuous basis. One of the important performance indicators of quality improvement is rejection. Hence, the in-process rejection and customer return (rejection) were chosen to measure the quality improvement due to the application of Failure Modes and Effect Analysis tool. The research was commenced to recognize the effects of FMEA, as being a preventive tool, especially in automotive small-to-medium enterprises. The entire paper is structured as per the research was conducted in actual. The next section presents the literature review carried out to investigate the past work and support the research. Then methodology used for the research is presented followed by the application of FMEA in case companies. In the research, four companies were selected to strengthen the results and outcome. The application phase is also divided in Cross Functional Team (CFT) selection, FMEA implementation through brainstorming and process study, identification of improvement opportunities and its implementation. Next sections are of results, discussion, and conclusion.

2. Literature review

Methodology of continuous improvement in manufacturing is a well-known practice originated by the 'Japanese approach' to industrial production. However, some needs still exist for an easy implementation of the improvement procedures it involves. There are many hitches are come across while real-time applications in the manufacturing evidently detecting the existing loopholes to be taken care off (Federico et al., 2010). This indicates there is a need for the tool which detects the causes of hitches and offers the means for improvements. FMEA can be used to identify and reduce or sometimes eliminate causes of failures as well as potential failures (Liu et al., 2011). In 1949, FMEA was established as a military rule in the U.S. The method was used as a technique for reliability assessment in order to determine the effects of disturbances and management. Disorders were classified according to impact the outcome, people, and safety of equipment. FMEA was accepted and established in almost all industry since long, in fact, in 1963 NASA had used FMEA in Apollo project whereas in 1975 it's used in nuclear technology and in the automobile industry, FMEA was started by the Ford motors in 1973 (Korenko et al., 2012). FMEA application enhances chances of the improvements and advances integration of employees (Burlikowska, 2011).

FMEA can be of many types. FMEA's should always be done whenever failures would mean potential harm or injury to the user of the end item being designed. The different types of FMEA can be seen in Table 1 (Pathak et al., 2011). FMEA is conventionally carried out by a team of members from all processes of organizations. Using their knowledge and past data, risk priority number (RPN) value is assigned for each failure component (Zhang and Chu, 2011). Process FMEA concentrates on solving difficulties associated with manufacturing processes. The first step is to study and analysis of each step of the manufacturing process and preparing of the flow chart. Next is to identify potential failure modes and respective causes; then, the current controls are determined, followed by the effects of failures on the manufacturing line operators and product end-users. The risks of these effects are then assessed accordingly (Mariajayaprakash, 2013).

Table 1. Types of FMEA

FMEA-TYPES	USAGE
System	Focuses on global system functions
Design	Focuses on components and subsystems
Process	Focuses on manufacturing and assembly processes
Service	Focuses on service functions

RPN is the product of the occurrence (o), severity (s), and detection (d) of a failure, RPN = S x O x D. The three risk factors are evaluated using a ten-point scale. Failure modes with higher RPN values are assumed to be more important and are given higher priorities than those with lower RPN values (Wang et al., 2009).

The decision making in the situation of emergency is very important and the same becomes more crucial in manufacturing. FMEA has the ability to identify the associated risk with that option to be addressed in the manufacturing system and implementation phases (Almannal et al., 2008). The ultimate aim of the FMEA is to reduce failure modes and to produce required quality products. The financial impact of various possible problems in the processes is not directly considered, and therefore, it was necessary to create a method which would identify and give priorities to those failures that have the biggest (financial) impact on the operation (Popović et al., 2010). The lacunas in FMEA prioritization method is as: identical values of RPN may be produced as a result of severity, occurrence and detection indexes and the team may not agree on the ranking index then approving average or higher value (Sellappan and Palanikumar, 2013).

The reliability study was conducted for wind turbine system using FMEA, and evaluation was made between the quantitative results of FMEA and reliability field data. Based on the results, the relation between them was established which can use in future wind turbine designs (Arabian, et al., 2010). It is clear that results of FMEA can use for quality improvement, future designs, benchmarking, etc. In bearing manufacturing process, various difficulties had been removed by implementing FMEA. In the said case study, various causes and their effects had been assessed for improving the reliability of bearing. On the basis of the risk rating, some of the suggestions were proposed for avoiding the possible risk and ultimately decrease the loss to the industries in terms of money, time and quality (Thakore et al., 2015). Another research based on FMEA in foundry suggests a reduction in rejections. FMEA was conducted in core making process to identify the reasons for core rejections and detected most probable reasons for rejections. The remedies for the same were implemented and rejection was reduced to 4.2% of the total rejection (Pareek et al., 2012). The use of FMEA used with other tools is also very beneficial and informal. FMEA can also be used to authenticate the outcomes of the other tools and further risk can be remedied. FMEA was used as the beginning for a Diagnostic Service Tool to support in early in the design process than this being post production action (Casea et al., 2010). FMEA was used in combination of AHP analysis for shell moulding process and results show a significant reduction in rejection from 7.13% to 3.14% (Kamble and Quazi, 2014). The above literature suggests that FMEA can be used for improvement in processes and quality.

3. Research methodology

This objective behind choosing the multiple case study research was to gather in-depth, rich data to strengthen the results. Yin (2003) describes three types of case study: exploratory, explanatory and descriptive indicating that all three are valid approaches. The similarities and variances of the implementation can be compared to the multiple case study approach (Preeprem et al., 2008, p. 279-303).

As a part of multiple case study base research, four small-to-medium enterprises, situated Gujarat region of India, have been selected. The aim is to implement FMEA and to measure quality improvement in respective company. The details of the selected SMEs are given in Table 2.

Table 2. Details of Case Companies

Company	Product	Critical Measurement	Manufacturing method
CS – 01	AC Air Duct	Hole - Diameter	Blow Molding
CS – 02	Radiator	Radiator tube - Diameter	Various Mechanical (Manual cutting, bending, brazing, etc)
CS - 03	PVC sleeve	Outer Diameter	Extrusion
CS – 04	Bolt	Neck – Diameter	Various Mechanical (Turning, cutting, etc)

The methodology used for the case study based research is described in Figure 1. The case-study method allows an investigator to retain the holistic and meaningful characteristics of real-life events.

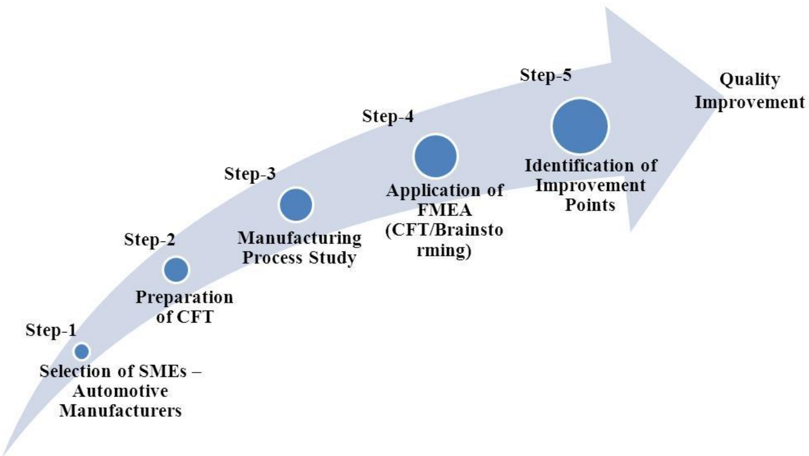


Figure 1. Research Approach (Flow chart)

While identifying companies care is taken that all case companies are suppliers to automotive OEMs, having the same range of employees and situated in the similar region. Cross functional team (CFT) has been formed in each of four SMEs and they have to conduct FMEA. Then, the detailed manufacturing process has been studied to understand the related characteristics of the process in detail and documented the same in FMEA sheet. FMEA sheet used is as per the AIAG guidelines (FMEA Manual, AIAG). Then identification of potential failure modes and their effects for each process steps have been the outcome of various brainstorming sessions conducted by CFT. The ranking method has been deployed to priorities the each failure using severity, occurrence and detection method. The identified risks as a result of FMEA also noted down and their remedies have been discovered through brainstorming sessions.

4. Application of FMEA

The implementation of FMEA at identified each of companies was started with taking inputs from the management of their concerns related to the process and their focus areas.

4.1 Preparation of CFT (Cross Functional Team)

The based on the competence of personnel available at each company, the CFT were formed as per Table 3.

Table 3. CFT members

Company	CFT members
CS - 01	Manufacturing, QC, Maintenance, Director (Marketing/Sales & Purchase), Authors
CS - 02	Manufacturing, QC, Maintenance, Director (Marketing/Sales), Purchase, Authors
CS - 03	Manufacturing, Maintenance, Director (Marketing/Sales & Purchase), Authors
CS - 04	Manufacturing, QC, Maintenance, Director (Marketing/Sales & Purchase), Authors

The involvement of personnel from different department/ processes was different for each company. The competence of employees is one of the major concerns in small and medium companies in India, to overcome that initial training to CFT was given for FMEA.

4.2 Manufacturing process study

The detailed manufacturing process study has been conducted by CFT formulated at each of the case companies and documented in FMEA spreadsheet. Each step of the process, starting from receipt of raw material to the dispatch of finished goods, has meticulously studied for their effect on the next step, product and process characteristics and concerns. It is important to have detailed knowledge of the processes while conducting FMEA.

In the case of CS-01 Company, the air duct is comprised of three subparts, namely center duct, side-duct LH & RH. After the manufacturing of individual parts through blow molding, they get assembled and then the whole product can be supplied to the OEM. Sometimes OEM may order individual parts as well. While in the case of CS-02 Company, Radiator manufacturing process where three simultaneous processes are taking place, namely fin making, core channel making, header plate making, assembly and the brazing process follows the earlier processes. Corrugated tube manufacturing, the case of CS-03 Company, which is mainly an extrusion process following cutting and winding. And in the case of CS-04 Company, Bolt Manufacturing, forging is followed by the machining process.

4.3 FMEA execution

The execution of FMEA was initiated by calling an initial meeting of CFT, formed at each case company as mentioned in the table: 03. The team members have been trained on the process of FMEA, mainly FMEA worksheet to be used and brainstorming sessions to be conducted to find out the potential failures and effects. The team was presented the each manufacturing process steps, the outcome of manufacturing study, for refreshing the manufacturing process. The potential defects associated with each step have been identified after detailed brainstorming. The assignment of causes to each defect was followed. In some of the brainstorming sessions, customers and suppliers have been also invited to understand their point of view. The multiple meeting, brainstorming sessions, have been conducted at each case company. Team leader – authors have kept records of each of the meeting.

The risk rating associated with each of the failure modes and effects were calculated based on below formula.

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

S- Severity, O- Occurrence, D- Detection

The rating is scaled from 1 to 10 for each category. If calculated RPN of process step was more than 100 then it was considered as a significant risk. It is always necessary to reduce the significant risk from the process by taking appropriate actions. For that, proper preventive and detective actions were thought of by CFT and documented in the FMEA workbook. The FMEA workbook of each of the case company is presented from Annexure - 1 to 4, only key process steps are shown here due to space limitation.

4.4 Identified improvement points

The expected outcome of the FMEA is to have a list of things, called action recommended, which reduced the risk of failure from the process. The reduction of risk from the process may improve the product and process quality and indicators of the same may be a reduction in rejection, reduction in customer return goods, cost of poor quality, etc. The exhaustive brainstorming sessions were conducted at each of the case company for FMEA implementation, in which each CFT member had contributed healthy. The list of recommended points for improvement for each case company is mentioned below Table 4 to 7 with their action plan.

Table 4. Identified Improvement Opportunities for CS-01

Identified Risk	Action Plan for Improvement
Short filling, parting line or flashes on the product surface, less weight of the product	A] Access control mechanism to be set in the panel so process parameters cannot be altered without prior approval. B] Process parameters for each product shall be set and validated.
Watermark on product	A Tool Maintenance system shall be introduced.
Excessive or less de-flashing of the parts along the parting line.	A] Fixture shall be developed and implemented for cutting excessive parts B] Defective samples of the product shall be made available (sample bank) to improve the awareness of employees.
Moulding / Dimensional defects in the component	Go/No Go Fixture shall be developed and implemented for easy inspection.
Improper Assembly due to less heating and wrong fitment of parts	A] Visual signage of process to be displayed in the assembly area B] Documented SOP for the assembly to be prepared C] Regular training to workers for assembly shall be given
Rejection of product from customer	The Final product Inspection fixture shall be developed and implemented to improve the pre-dispatch inspection.

Table 5. Identified Improvement Opportunities for CS-02

Identified Risk	Action Plan for Improvement
Rejection due to improper fin ends cutting and variation in length	A] Application for First piece inspection at tube cutting station. B] Introduce fixture for proper setting – doweling
Cracking of AL sheet in forming process	Proper RM Testing through reputed laboratory
Non-uniform embossing height in forming process	Fixture with measuring scale on both sides for online measurement of height
Fin opening and fin bend problem during core assembly	Clamp maintenance system to be introduced
Leakage head plate area due to faulty corner radius	Introduce a gauge with dimples on it to fit with the HP material

Table 6. Identified Improvement Opportunities for CS-03

Identified Risk	Action Plan for Improvement
Dimensional defects in the product	Go/No Go Fixture shall be developed and implemented for easy inspection.
In-process rejection due to improper parameters in the extrusion and set up	A] Process parameters shall be finalized and validated B] Control plan shall be prepared and displayed at the machine C] Training to the operators for online inspection
Rejection due to improper product specification – due to improper die selection	A] Proper identification of dies, Pins Mold set as per the size and storage area B] First piece inspection and approval shall be done
Rejection of product from customer due to damage	A] Transporters selection and approval process shall be implemented B] 100% visual inspection while loading the material shall be started C] Loading and unloading work instruction with visuals shall be prepared for transporters

Table 7. Identified Improvement Opportunities for CS-04

Identified Risk	Action Plan for Improvement
Rejection due to improper process parameters in upsetting process	Standardize process parameters by scientific method and verify against standards (validation of parameters)
Contamination of Finish goods	A] Define separate storage area with proper staking system B] Material handling and storage work instruction shall be prepared
Rejection due to improper forging pressure (Less or excessive both), improper threading and inspection	A] Trained workers shall be allotted work only B] Worker competency shall be monitored
Rejection due to improper shape in forging	Die maintenance system shall be implemented

CFT of all case companies had also an emphasis on the repetitive training for the workers and staff, which plays an imperative role in continuous quality improvement.

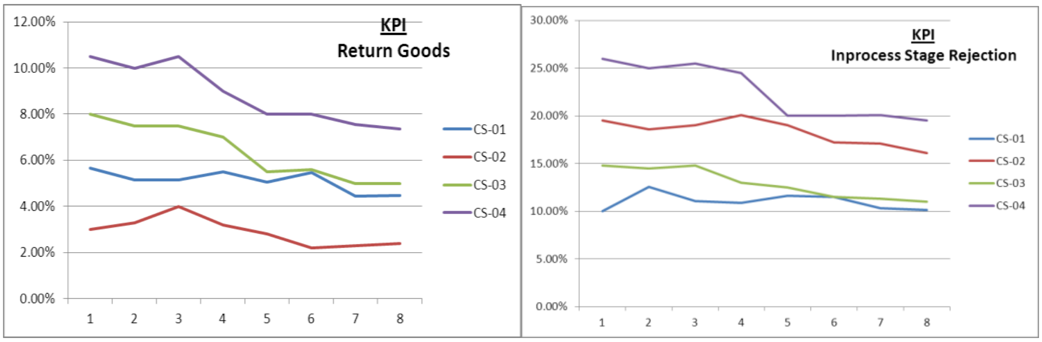
4.5 Implementation of recommended actions & quality improvement

The identified improvement points along with their action plans were the outcome of the detailed FMEA at each of the case companies and the same is explained in the above tables. The outcome of FMEA at each company was signifying an improvement in product and process after the implementation of them. Each of the company had implemented some of the points, not all, during the implementation duration of six months. The result of the implementation of the same was visible qualitatively and quantitatively as well. The quantitate indicators, also called as Key Performance Indicators are rejection percentage and return goods. The data of before FMEA and after FMEA with interim implementation are shown in Table 8 and Graph 1.

Table 8. Quantitative data (KPIs) for Quality Improvement

Company	**KPIs**	**Before Implementation**			**During Implementation**					
		M1	**M2**	**M3**	**M1**	**M2**	**M3**	**M4**	**M5**	**Average**
CS-01	Reduction in In-process stage Rejection	10.04%	12.55%	11.08%	10.90%	11.60%	11.50%	10.30%	10.14%	10.89%
	Reduction in return goods	5.66%	5.16%	5.13%	5.50%	5.04%	5.48%	4.44%	4.46%	4.98%
CS-02	Reduction in In-process stage Rejection	19.50%	18.60%	19.00%	20.10%	19.00%	17.20%	17.10%	16.10%	17.90%
	Reduction in return goods	3.00%	3.30%	4.00%	3.20%	2.80%	2.20%	2.30%	2.40%	2.58%
CS-03	Reduction in In-process stage Rejection	14.80%	14.50%	14.80%	13.00%	12.50%	11.50%	11.30%	11.00%	11.86%
	Reduction in return goods	8.00%	7.50%	7.50%	7.00%	5.50%	5.60%	5.00%	5.00%	5.62%
CS-04	Reduction in In-process stage Rejection	26.00%	25.00%	25.50%	24.50%	20.00%	20.00%	20.10%	19.50%	20.82%
	Reduction in return goods	10.50%	10.00%	10.50%	9.00%	8.00%	8.00%	7.55%	7.35%	7.98%

Note: M – Month; M1- Month 1, M2 – Month 2 and so on.



Graph 1. Effect of FMEA implementation of KPIs

The improvement is seen from the data even though it is not significant because of few improvement opportunities are still under the implementation.

5. Discussion and conclusion

Multiple case study based research has its own advantages; results of one case study support the others, even though single case study can also produce the results excellently and add the value of research. Here, the research noticeably demonstrates that continuous quality improvement can be achieved by effective implementation of FMEA in automotive SMEs. The identified improvement points and their effects were different for individual case companies, but all of them were showing continuous quality improvement. The improvement was seen qualitatively as well as quantitatively. The improvement in quantitative data - KPIs were also different in case companies, ranging from 2-3%. Very significant improvement in rejection and return goods were seen in each case companies as shown in Table 8 and Graph 1. The improvement observed in each case company is in a progressive manner and monitored for five months. The overall improvement before implementation and after implementation of FMEA in each case company is shown in Table 9.

Table 9. % improvement in each case company after application of FMEA

KPIs	CS-01	CS-02	CS-03	CS-04
Reduction in In-process stage Rejection	0.34%	1.13%	2.84%	4.68%
Reduction in return goods	0.33%	0.85%	2.05%	2.35%

The reason behind different % improvement in each case company may be the complexity of processes, nature of the product, and competence of people and availability of resources. The further improvement is still possible in each of case companies if they will implement all identified improvement points and overcomes their constraints of time, money and competence. The purpose of steering case study in four automotive companies of almost the same size is flourishing as all companies showing significant signs of quality improvement. One can clearly depict that FMEA is one of the important tools for continuous quality improvement in automotive SMEs.

The implementation of FMEA shall be monitored for time and efforts given against the benefits achieved. The FMEA will definitely identify the risk associated with the process and their remedies, but the implementation of the same need to be monitored. Identified all improvement opportunities which will reduce the risk, shall be treated as project – small, medium and big. The monitoring of each project and timely completion of the same is important. This Multiple case study, presented here, has provided the platform for continuous quality improvement and provided an opportunity to take up the project on other auto core tools – SPC, MSA, APQP, to study effects on continuous quality improvement.

6. Future scope of work

The FMEA has been implemented and improvement points have been identified in each of the case company. The companies were not able to implement all points due to time and resource constraints so companies have scope for further improvement in quality if they will implement all the points. Since this has been the first ever exercise carried out in the case companies, defining continuous quality improvement became difficult, but repetitive exercises and implementation of all points definitely achieves the continuous quality improvement. This kind of exercises shall be carried out at least three to four times in a year to achieve continuous improvement (Desai, 2008). More key performance indicators may be considered in the future to achieve continuous quality improvement; such KPIs can be Cost of Quality, Rejection at the final inspection stage, customer satisfaction, etc.

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Annexure

Annexure 1. FMEA worksheet of CS-0

Sr No	30						40	
Process	Blow moulding of center duct						De-flashing of the part	
Potential Failure Mode	Flashes / Parting line Flashes		Short Moulding / Fill		Part weight less or more		Excessive / less de-flashing of the parts along parting line / Flashes in the fitment	
Potential Effect(s) of Failure	**Next Operation** - Part may reject / poor appearance. **Assly** - Difficulty in assly with the mating part. **Customer** - Part rejected due to poor appearance. **End Customer** - Dissatisfaction		**Next Operation** - Part get rejected / poor appearance. **Assly** - Difficulty in assly with the mating part. **Customer** - Part rejected due to poor appearance. **End Customer** - Dissatisfaction		**Next Operation** - Part get rejected / fitment issues. **Assly** - Part gets rejected / fitment issues. **Customer** - Part gets rejected. **End Customer** - Dissatisfaction		**Next Operation** - Part get rejected / fitment issues / poor appearance. **Assly** - Part gets rejected / fitment issues / poor appearance. **Customer** - Part gets rejected. **End Customer** - Dissatisfaction	
Sev	9		9		9		7	
Potential cause(s) / Mechanism of Failure	High blow speed	Low holding time and pressure	Blow speed low	Barrel temperature low / Air pressure low	Wrong core & punch size	less or more parison length	Excessive or less de-flashing due to Unskilled operators /	
Occur	4	3	4	3	5	5	7	
Current Process controls Prevention	Standard Process Parameter Sheet		Standard Process Parameter Sheet		Standard Process Parameter Sheet		--	
Current Process controls Detection	First piece approval and in-process inspection sheet.		First piece approval and in-process inspection sheet.		First piece approval and in-process inspection.		Operator awareness and training.	
Det	4	4	4	4	4		4	
RPN	144	108	144	108	180	180	196	
Recommended Action(s)	Parameter setting panel to be modified to stop alteration without access rights						1) Cutting Fixture is to be developed and implemented	2) Defective sample display.
Responsibility & Target Completion Date	Production In charge						Production In charge	

Annexure 2. FMEA worksheet of CS-02

#	2						3			
Process Function (Step)	Tube Cutting						Shearing			
Potential Failure Modes	Tube length variation			Tube burrs			dimensional variation		Bent piece	
Potential Failure Effects	Finishing not proper	Leakage from HP to Tube	Tube opening problem	HP fixing problem	Tube damage	Excessive manpower requirement	Material wastage	total scrap of material	manpower wastage	
SEV	8	8	8	6	6	6	5	5	5	
Potential Causes of Failure	Tube stopper misalignment	Operator error		Blunt cutter	Improper alignment of cutter	Insufficient air pressure	Improper length setting		blade alignment improper	Blunt blade
OCC	3	5		2	5	2	7		3	2
Current Process Controls Prevention	Realign stopper	Operator training		Resharpening	realign the cutter	adjust air pressure	Readjust length setting		realign the blade	regrind the blade
Current Process Controls Detection	First piece inspection by the supervisor and dimensional check by operators at regular interval	Inspection by supervisor at every hour		Visual detection in hourly check	Visual check when problem detected	Pressure gauge detection	First piece and last piece inspection by supervisor		during first piece or last piece inspection	Visual check when problem detected
DET	2	7		4	4	2	3		4	4
RPN	48	280		48	120	24	105		60	40
Recommended Actions	Nil	1. Only trained operators to work with online checking 2. Operators competence mapping to be		Introduce fixture for proper setting -doweling			Introduce fixture -shearing table		nil	nil
Responsible Person		Production		Production			Production			

Annexure 3. FMEA worksheet of CS-03

PROCESS	**30** Extrusion, corrugation, and Inspection	**90** logistics			
Function	Extrusion of materials using proper extrusion line with relevant dies, Pins and Mold size as per production Plan	Transporter			
Potential Failure Mode	The wrong die, Pins, and Mold set selected	Finished good damaged / dusty			
Potential Effect(s) of Failures	Next operation: rejection due to the wrong size Subsequent: reject End User - reject Line -Line disruption , manpower re-planning of line-reject Operator /Equipment nil	Next operation: nil subsequent: nil End User - rework and Customer dissatisfaction Line -Line disruption , manpower re-planning of line-rework			
Sev	8	6			
Potential Cause(s)/Mechanism (s) of Failures	Die, Pins & Mold set not identified	1) Poor vehicle condition	2) Incorrect stacking	3) Vehicle not covered with a weatherproof sheet.	4) Vehicle not as per dispatch qty due to that overloaded
Occ	5	5	3	5	5
Current Process Control Prevention		Nil			
Current Process Control Detection	First piece approval	Nil			
Det	5	7			
RPN	200	210	210	210	210
Recommended Action(s)	1. Proper identification of dies, Pins Mold set as per the size 2. Operator training and work instruction	Work instruction for logistic	100% visual inspection	Proper selection of transporter	
Responsibility	Plant In charge	Plant In charge	QC person	Purchase	

Annexure 4. FMEA worksheet of CS-04

#	20	30		40	
Process	Storage of raw material	Upsetting		Forging	
Potential Failure Mode	Wrong storage practices	Improper current setting - Upsetting		Improper die condition / Improper die setting - Forging	
Potential Effect(s) of Failure	**Next Operation** - Difficult to handle the material **Assly** - -- **Customer** - Rejection at customer end. **End Customer** - --	**Next Operation** - Part may reject **Assly** - **Customer** - Rejection at customer end (Spot welding not possible, nut fitment may be not possible) **End Customer** - Field failure		**Next Operation** - Part may reject **Assly** - **Customer** - Rejection at customer end (Spot welding not possible, nut fitment may be not possible) **End Customer** - Field failure	
SEV	5	9		10	
Potential cause(s) / Mechanism(s) of Failure	Mixing of the RM with previous lot or different grade raw material	Unskilled operator.	Un-calibrated ampere meter. Ampere is not maintained as per process specification.	Die not maintained properly or Damaged die used.	Unskilled operator
OCC	4	3	3	3	2
Current Process controls Prevention	--	--	--	-	
Current Process controls Detection	--	First piece approval and in-process inspection sheet.		First piece approval and in-process inspection sheet	
DET	8	4		4	
RPN	160	108	108	120	80
Recommended Action(s)	Define area / location for Incoming material storage & tagging of material when lot received.	Standard Process Parameter Sheet		Die maintenance & regular monitoring of die condition.	
Responsibility	Production Supervisor	Plant Incharge		Production Supervisor	