CHAPTER 1

INTRODUCTION

1.1 GENERAL

With the globalization of Indian Economy, India has moved from a highly protected market to a free market economy with competition from international manufacturers. India’s car market has emerged as one of the fastest growing in the world. The number of cars sold domestically is projected to double by 2010, and domestic production is skyrocketing as foreign makers are setting up their own production plants in India. The government’s 10-year plan aims to create a $145 billion auto industry by 2016, Tiku (2008).

Attention to the quality of products in terms of functionality, reliability, dependability and cost has increased in several industrial sectors. The failure rate of many mass produced products/parts has been reduced to a few parts per million (ppm). Percentage defectives are no longer acceptable and hence there is a need to practice tools and techniques, which would help in “Doing things right first time”.

To achieve this objective, industries employ concepts like Total Quality Management (TQM), Six Sigma, Total Productive Maintenance (TPM), Just in Time (JIT), Lean Manufacturing, and Agile Manufacturing. Many tools have been evolved and are being evolved for implementing these
concepts in day-to-day industrial practice. Process Failure Mode and Effect Analysis (PFMEA) is one such very important tool.

The PFMEA technique was first reported in 1920’s, but its use has only been significantly documented since the early 1960’s, Bell et al (1990). It was developed in the U.S.A in the 1960’s by National Aeronautics Space Agency, NASA, MIL STD 1629A (1980), as a means of addressing a way to improve the reliability of military equipments. It has been used in the automotive industry since early 1970’s, and its use has been accelerated in the 1990’s to address the major quality and reliability challenges caused by major car manufacturers. In addition, the recent changes in the law on corporate responsibility have led to companies reviewing their product design safely through the use of the PFMEA methodology.

Process failure mode and effects analysis (PFMEA) is an engineering technique used to define identify and eliminate known and/or potential failures, problems and errors in the manufacturing process before they reach the customer. Therefore PFMEA along with other quality tools support the practice and philosophy of failure prevention and continuous improvement, which are the key elements of any TQM system. Process FMEA is used to solve problems due to manufacturing processes. It starts with a process flow chart that shows each of the manufacturing steps of a product. The potential failure modes and potential causes for each of the process steps are identified, and 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.

PFMEA is carried out by a cross-functional team with experts drawn from various departments. Normally, a team is formed at the planning stage of a new product based on a concurrent engineering approach. The team
analyses each component and subsystem of the failure modes. Then, the potential causes and effects are determined. The risk of each failure is prioritized based on the Risk Priority Number (RPN). RPN is a decision factor based on the product of three ratings: Occurrence, Severity and Detection. These ratings are scaled with numbers from 1 to 10 (Appendix-II). Any improvement plan would be based on the indications from the RPN. Failure modes with high RPN values are selected. The corresponding current controls are implemented for these high RPNs.

1.2 PFMEA PROCEDURE

The process for carrying out a PFMEA can be divided into several steps as shown in Figure 1.1. These steps are briefly explained here:

1. Develop a good understanding of what the system is supposed to do when it is operating properly.
2. Divide the system into sub-systems and/or assemblies in order to ‘localize’ the search for components.
3. Use blue prints, schematics and flow charts to identify components and relations among components.
4. Develop a complete component list for each assembly.
5. Identify operational and environmental stresses that can affect the system. Consider how these stresses might affect the performance of individual components.
6. Determine failure modes of each component and the effects of failure modes on assemblies, sub-systems, and the entire system.
7. Categorize the hazard level (severity) of each failure mode (several qualitative systems have been developed for this purpose).
8. Estimate the probability. In the absence of solid quantitative statistical information, this can be done using qualitative estimates.
9. Calculate the risk priority number (RPN): the RPN is given as the multiplication of the index representing the probability, severity and detectability.

10. Determine if action needs to be taken depending on the RPN.

11. Develop recommendations to enhance the system performance. These fall into two categories
   a) Preventive actions: avoiding a failure situation.
   b) Compensatory actions: minimizing losses in the event that a failure occurs.

12. Summarize the analysis: this can be accomplished in a tabular form.

Generally, a PFMEA table will have a major row for each component. As these components may have multiple failure modes, the major row is sometimes divided into sub-rows where each sub-row summarizes a specific failure mode.

The table is organized into the following columns

a. Component: create a major row for each component.
b. Failure mode(s): identify failure modes and establish a sub-row for each mode.
c. Effects (by failure mode): describe the effects on safety and system performance resulting from the failure. List specific adverse outcomes.
d. Probability: if reliability data does not exist, estimate using qualitative ranks.
e. Hazard level (severity): if experience data does not exist, estimate using qualitative ranks.
f. Causes of failure mode (if known): this includes environmental and/or operational stresses that increase the likelihood of the failure mode.

g. Methods of detecting failure mode (if known): although this entry does not prevent a failure from occurring, it is important to discover that a failure has occurred. This column is used to present signs and symptoms that a component has failed.

h. Suggested interventions: hardware modifications and/or compensatory actions to minimize effects.

1.3 TERMINOLOGY IN PFMEA

Although there have been many variations of the PFMEA, the terminology used throughout the years has been maintained. Some of the common terms used in an FMEA include.

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 desired function (design intent or performance requirements) as described by the needs, wants, and expectations of the internal and external customers/users. Examples of failure modes are: fatigue, collapse, cracked, performance deterioration, deformed, stripped, worn (prematurely), corroded, binding, seized, buckled, sag, loose, misalign, leaking, falls off, vibrating, burnt, etc.

Potential cause(s) of failure: This is a list conceivable potential cause(s) of failure assignable to each failure mode. The causes listed should be concise and as complete as possible. Typical causes of failures are, incorrect material used, poor weld, corrosion, assembly error, error in dimension, over stressing, too hot, too cold, bad maintenance, damage, error
in heat treat, material impure, forming of cracks, out of balance, tooling marks, eccentric, etc.

Severity: Severity is an assessment of how serious the effect of the potential failure mode is on the customer/user.

Effect: An effect is an adverse consequence that the customer/user might experience. The customer/user could be the next operation, subsequent operations, or the end user.

1.4 NEED AND OBJECTIVE FOR PFMEA STUDY

Right from the days of competitive era, the field of total quality management (TQM) has been growing at a fast pace. The rapid development has been largely marked by the evolution of numerous powerful techniques. One of these techniques is the Failure Mode and Effect Analysis (FMEA), which emanated from the space programmes of NASA and subsequently absorbed into automotive industry for its quality improvement and failure prevention efforts. At the time of its emanation, it was classified into design and process FMEAs. Although many types of FMEAs emerged thereafter, the industry has been finding these two techniques as most powerful and compatible. Process FMEA (PFMEA) basically facilitates the capturing of manufacturing failures and quantifying them using a number called Risk Priority Number (RPN). Subsequently PFMEA envisages the task of taking actions for reducing the value of RPN and consequently mitigating the effect of failures. Thus PFMEA facilitates the achievement of continuous quality improvement by overcoming the chances of recurrence of failures in the manufacturing processes.

Quite a number of researchers have brought out improved and modified models of PFMEA. But from the literature review it is observed out
that no research work has been done exclusively on the study of issues that discourage manufacturers from effectively implementing PFMEA for manufacturing excellence. This has been zeroed in as a significant research gap and the scope of this research work has been drawn around this core objective.

The development of automotive industry has given rise to significant impact in developing countries like India with many global level automotive manufacturers setting up their manufacturing hub in India. Recognizing this development, the study is focused on PFMEA research in automotive industry in India.

Researchers within the PFMEA fraternity have identified the following reasons as prominent hurdles for implementation of PFMEA in automotive industry (Literature source has been provided in chapter 3, methodology).

1. Lack of Clear Objectives in practicing and implementing PFMEA in industry.
2. Inadequate organizational structure and management involvement in the implementation of PFMEA.
3. Improper PFMEA process management in PFMEA implementation.
4. Lack of Team development strategy while implementing PFMEA.
5. Lack of understanding on the technical aspects of PFMEA in the practice and implementation of PFMEA.
6. Inadequate Training given on PFMEA to employees.
7. Lack of resources required for PFMEA implementation.
8. Lack of measurements of PFMEA benefits and effectiveness.
10. Other major concerns as challenges and difficulties for PFMEA implementation.
In the light of the literature review and extensive discussions with PFMEA practitioners a comprehensive questionnaire was exclusively structured (Appendix-1) to study the implementation issues of PFMEA in Indian automotive industry.

Validity and reliability (internal consistency) of the measurement instruments are important to ensure that the outcomes from a study are reliable. Validity generally determines whether the measuring instrument is indeed measuring what it purports to measure and reliability refers to consistency (Hair et al. 1998). Content validity often requires judgment from experts on the extent to which a question truly measures the concept it was intended to measure. Content validity can be determined by experts and by reference to the literature (Gable, 1994). Several academic and industry experts vigorously tested the questionnaire and the content validity of the questionnaire was thus established and ascertained.

Reliability (or) internal consistency can be estimated using a reliability coefficient such as Cronbach’s alpha, as proposed by Cronbach (1951). An internal consistency analysis was performed separately for the characteristics of each dimension of PFMEA. Reliability coefficients (i.e. alpha values) range from 0.62 to 0.98. Generally, an alpha value of 0.6 or higher is considered adequate in descriptive research, Black and Porter (1996). The alpha values found for each scale in this study indicate that each factor is a reliable measure.

A total of 200 questionnaires were sent to major automotive suppliers in India and 124 responses were received. According to Mercer (1996) response rates may be poor, however, figure as low as 20% is quoted as being typical. But the response rate achieved in this survey is 62%, which is deemed to be fairly high in this type of research.
The questionnaire comprised in all the 12 sections, with the response types falling into five categories of responses like numerical percentage, dichotomous questions (yes/no), importance rating (0-5), rank order and open-choice questions. The number of questions (111), the nature of questions, the number of possible answers (175) and types of statistical analysis required the use of a software package, Statistical Package for Social Sciences (SPSS).

The list of tools deployed for data analysis in this research include, t-test, Anova, Kolmogorov-Smirnov test, Chi-Square test, Kruskel-Wallis test, Cluster analysis, Mann-Whitney U test, Proximity matrix analysis, Correlation analysis, Multiple regression analysis, and descriptive statistics.

The study identified the root concerns of PFMEA implementation and the extent of relationship existing between various factors. Team and Teamwork emerged as the most important concern for the successful implementation of PFMEA. Best team building practices at all levels, and strong cross-functional teams constitute the success in the implementation of PFMEA.

From the analysis it is interesting to find that strong relationship is established between key technical characteristics and team characteristics, which calls for a robust team to handle effectively technical issues associated with PFMEA. Next the PFMEA process management and organizational characteristics were found to be important and need constant improvement and focus. Among the organizational characteristics the percentage of managers actively participating in PFMEA process is having a direct effect on motivation, team aspects, training aspects, benefits and effectiveness, among other aspects of PFMEA. In the overall PFMEA implementation challenges “the management’s understanding of PFMEA and its commitment to
implement the same” is found to be the prime concern. Technical issues such as ranking severity, linking control plan and instruction, availability of training; resources, customer manual software and regular reviewing are the other challenges in PFMEA implementation. The Correlation coefficient at significant level of 0.01 (2 – tailed) reveals the following relationships existing between different PFMEA characteristics. Team Characteristics are highly correlated with technical characteristics (r=0.921), Managing the process is highly correlated with team characteristics (r=0.896), Organizational characteristics are highly correlated with technical characteristics (r=0.886) and training process is highly correlated with technical characteristics (r=0.770).

The study identified the need to develop a failure mode directory connected to problem directory coupled with a knowledge base for easy understanding of product and process in the implementation of PFMEA. Hence, a web based software model, PFMEA-online, has been developed to facilitate easy implementation of PFMEA, and supported by a knowledge base using the spot welding process of car front body pillar sub assembly as a case study.

1.5 LIMITATIONS OF THE STUDY

1. The study has been restricted to the geographical limits of India. The boundaries are as that of political India.
2. The study is focused only to automotive industry.
3. The study is limited to Process Failure and Mode Effect Analysis
1.6 ORGANIZATION OF THE THESIS

The presentation of the research work carried out is organized in the following chapters.

Chapter 2 reviews the literature in the areas of PFMEA implementation issues and improved FMEA techniques, standards and applications.

Chapter 3 presents the research methodology, questionnaire design used in the survey and brief description about the statistical tools used.

Chapter 4 presents the various statistical analysis and tests carried out on the survey data using statistical package for social scientists (SPSS) tool to find out the PFMEA implementation issues in the Indian Automotive industry.

Chapter 5 description of the Knowledge based process Failure Mode and Effect Analysis software tool developed to assist the implementation of PFMEA in Indian automotive Industry.

Chapter 6 summarizes the findings from the analysis results obtained through the various statistical analysis and tests.

Chapter 7 outlines the conclusions obtained from the investigation towards PFMEA implementation issues in Indian Automotive industry.