CHAPTER 3

DESIGN AND DEVELOPMENT OF FTFMEA

3.1 INTRODUCTION

Metal casting has been one of the most ancient and primary manufacturing process since the stone age (Lin et al 2010). The castings are made in foundries. This casting process still holds its position as the most commonly used manufacturing process in this 21st century (Karunaker and Dattu 2008). Due to globalization the market conditions are very rapidly changing. Along with globalization, the present economic scenario and stiff competition among the foundries at both indigenous and global markets have made the foundries to be competitive. In order to survive these tough economic conditions and competition, the foundries have to produce high quality products through the manufacturing process excellence, to reduce rejections due to failures in the parts being casted (Singh and Khanduya 2010; Motoyama et al 2012; Santos and Barbosa 2006). Also the manufacturers should be always ready for the dynamic changes in the customers demands to maintain their competitive edge (Buran and Gershwin 1996; Chhabra and Singh 2011). This has to be done without increase in price of the product being casted (Vijayaram et al 2006). Since the cost of the product being casted is directly influenced by the rework and rejection, foundries have to implement a continuous quality management system in order to keep themselves in the foray (Das 2008; Esfandyari et al 2011).
Another important factor that affects the foundry is the dependence of the industry on the machines and human labours, which play an important role in the quality of the produced product (Mohan et al 2008a, Ahuja and Khamba 2009).

In order to overcome these difficulties, FTFMEA model is required to enable foundries to reduce and even prevent failures thus improving quality of the product made along with the financial gains of the organizations. So a FTFMEA model is being developed along with the roadmap for implementing the FTFMEA model in foundries as illustrated in this chapter.

3.2 LITERATURE REVIEW ON TFMEA IN FOUNDRY

The need to improve the quality of the product being casted felt the need for implementing the globally accepted approaches like Total Quality Management (Sekhar and Mahanti 2006, Ebenezer et al 2011b). Though there are many type of quality management models are available as specified in the literature survey chapter, different models have their inherent advantages and their pitfalls which were studied and it was found that most of the models are problem specific or industry specific. The pitfalls of those techniques led to the development of TFMEA (Devadasan et al 2003). This TFMEA is more reliable, takes shorter time period to implement, and easily understandable to apply for any quality oriented issues. The researchers have slowly started to apply TFMEA in many fields. However they are of mostly product specific.

This research and practical gap indicated the need for developing and applying FTFMEA model in foundry as a process FTFMEA model to achieve continuous quality and reliability in the products being casted by conducting real time case studies. In this thesis we try to identify, understand and prevent failures to reduce or eliminate defects in the foundry processes holistically thus improving quality.
3.3 FTFMEA MODEL DEVELOPMENT

The existing TFMEA is being modified according to the requirements of the foundry. It is designed and developed as a FTFMEA model. The model is termed as FTFMEA since the term “total” in FTFMEA has two significant:

- FTFMEA prevents failure that originates not only in the design and production departments, but it also prevents failures from all other departments functioning in the organisation. This helps to identify, analyse, rectify and prevent the recurrence of failures holistically.

- FTFMEA calls for association of all the departments in the organisation to analyse and rectify each failure. This ensures that each failure is prevented from reoccurring in that organisation.

The conceptual features upon which the FTFMEA technique encompassing the above two meanings were evolved and depicted is shown in Figure 3.1. As shown, the entire FTFMEA process involves the development of FTFMEA Tables pertaining to all the associated departments and their interrelationships.

Table 3.1 shows the format of FTFMEA Table to be developed for the Sand Mill department. The table has a column for entering the “rating”. In this column, ratings are entered by using a Likert-type scale ranging from 0 to 10.
A Likert-type scale is a psychometric scale commonly involved in research that employs questionnaires. It is the most widely used approach to scaling responses in survey research. The term “rating” refers to the importance attached to the failure concerned. Rating numbers have to be assigned against specific criteria such as perception of the FTFMEA team, perception of management, employee’s willingness, seriousness of the failure etc. With the increase in the rating, the necessity to pay attention to the failure concerned enhances.

Another important feature is that a column titled as “interactive functions” is added. Under this column, the departments associated with each failure should be listed. The entry in this column indicates that the concerned failure has its impact on the departments listed along with the ratings concerning to that department. In order to ensure that the entire process, FTFMEA is monitored and managed from a centralised source, it is suggested to use FTFMEA cards and drawings. In the case of FTFMEA cards, against each process, a card containing all the failures along with the departments concerned shall be noted. A FTFMEA card may contain the collective information received from the FTFMEA tables developed by all the departments. The updated FTFMEA cards can be circulated across the organisation and displayed at strategic locations.

As an example sand lumps found in the foundry sand is shown as a failure mode in Table 3.1 with its corrective actions, its effects along with the rating given by the Team members. The Associated department which gets effected by the sand lumps is also included in the table with their respective ratings. The associated departments FTFMEA tables have to be developed for which ratings has been given.
This method of monitoring FTFMEA would ensure that the information on failure details and measures required to prevent them are disseminated across the organisation. FTFMEA model also facilitates the easy retrieval of past failure histories that can be used for preventing the recurrence of failures. Thus, the proposed FTFMEA technique is incorporated with an aim to ensure holistic failure prevention.

As FMEA, FTFMEA is also a concurrent engineering tool. The people involved in FTFMEA sessions usually come from many different disciplines. There are usually from the departments of engineering, customer service, marketing, manufacturing, as well as managers. All of these people have to work together to determine possible failure modes for parts or processes. These people determine the ratings associated with each failure modes. By bringing in a diverse group of people together, more defects can be identified and properly scored for rectification.

Thus the proposed FTFMEA tool helps industries to holistically improve all the aspects of quality like the quality development in systems and procedures followed, quality maintenance of the product produced by proper and periodic equipment maintenance and continuous quality improvement in the process being involved.
Figure 3.1 FTFMEA Model

Table 3.1 FTFMEA – Sand Mill

<table>
<thead>
<tr>
<th>Process Name</th>
<th>Sand Mill</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMFEA Number</td>
<td>1</td>
<td>Last Updated on</td>
</tr>
<tr>
<td>Members Present</td>
<td>Updated by</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Causes of Failure</th>
<th>Effects of Failure</th>
<th>Present Control</th>
<th>Rating</th>
<th>Departments</th>
<th>M</th>
<th>C</th>
<th>Recommended activities</th>
<th>Approved By</th>
</tr>
</thead>
</table>

M – Maintenance Department, C – Casting Department
3.4 FOUNDRY PROCESS AND ITS FAILURE MODES

The aim of all the foundries is to produce finished cast products of higher quality which meet the established specifications, standards and satisfy customers. This can be obtained by quality development, quality maintenance and quality improvement of the product produced. These aspects are achieved by imposing a good quality assurance system (Packer and Miller 1978; Xian Ping 2012). The International Committee of the Foundry Technical Association (ICFTA 1974) established about 110 types of defects, classified into 24 groups and subdivided into 7 classes. Most of the casting defects have their origin in the moulding process, metal preparation and handling along with another dozen parameters which influence them (Santos and Babosa 2006; Cheng et al 2008).

The foundries create a large quantity of wastes. One quarter to one ton of solid waste per one ton of casting (EPA 1981), out of which 30 to 60% is made up of core and moulding sands. The foundry sand can be recycled and reused to save raw material (Tonda et al 1997; Fiore et al 1999; Zenetti et al 2000), for production of moulds and cores. The mixing of the base sand, additives, bonding agent and water in the Muller during the sand preparation process along with the mould and core preparation operation with improper drying of the core and mould affect the quality of the cast products(Fox et al 2012).

The moulding parameters like temperature, pressure, composition of metal, pattern material, pattern plate leveling, quality of moulding box and moulding box pin will all affect the quality of the cast products. Metal melting temperature variation and improper handling contribute to non-conformities in the composition of the metal being melted. Deoxidizing, pouring and tapping temperatures of metals affect the quality of the cast products. The mishandling in the fettling and machining operation also effect the quality of the product being made.
Figure 3.2 Foundry flow processes
In order to overcome these effects on the cast product quality assurance is done. Quality assurance is been done by evaluating casting defects by visual assessment, occurrence survey, sampling, chemical analysis and metallographic examination in each and every processes of product casting stage (Hornung et al 1990). The various processes in a foundry are briefed in this section (Force and Mbohwa 2010) as shown in the Figure 3.2. Each step impacts the quality of the final product. The activities carried out in each and every step and their impacts with respect to quality are discussed in the following subsections.

3.4.1 Sand Mill

Sand mill is the process by which the sand (new / old), Bentonite and Bentakol are mixed together with 3 to 3.5% of water. This mixture is called green sand and this is the sand used for making the mould (Siddique and Noumowe 2008). In modern foundries, to make large castings the silica sand is mixed with a liquid Resin and catalyst. Resin acts as a bonding agent and the catalyst improves the permeability and induces a reaction with the silica sand and resin. This type of sand is called as Furan sand.

The major failures while carrying out this process are listed below:

- Sand lumps
- Bentonite lumps
- Sand properties not meeting specifications
- Improper mixing of sand

3.4.2 Moulding

The pattern which is made of aluminum is fixed to the pattern plate by a method called methoding. The gate, sprue, sprue basin and riser are all
set into the pattern plate as match plate pattern type. In the moulding section, by using semiautomatic machine, two half of the moulding box cope and drag are filled with green sand upon the pattern plate where the sand is compacted by the action of the vibrating table to make the cavity. In order to make the holes and contoured surfaces, core is made by using core boxes and kept into the mould cavity. Cores are machine made by core shooter and cold box or it is manually done. In modern foundries to make large casting, the moulding section is replaced by a FLL (Fast loop line) unit which is fully automated. The furan sand fills each half of the mould box and it is transferred by conveyors into a shaker which removes the mould from the box. The mould then enters into the oven for drying and hardening.

The failures encountered during this process are:

- Low mould hardness
- Improper core setting
- Improper mould setting
- Gas entrapment
- Knock out
- Improper methoding
- Colour change of core
- Shutter plate oaring failure
- Diaphragm valve failure
- Improper mixing
- Core box temperature control
- Core box failure
- Core bend and bulge
- Improper setting of Match plate.
3.4.3  Casting Process

Melting the solid metal into molten state is called casting. The material compositions, their hardness, strength and their microstructure are all controlled in this process. The metal is melt by using rotary and induction furnace. The molten metal is poured into the ladle and is transferred to the pouring area to be poured into the mould cavity.

The failures encountered in this process are:

- Improper Charging
- Improper Slag removal
- Tapping temperature low or high
- Short Pour

3.4.4  Shake Out

Breaking the casting out of the mould by using a vibrating table is called shake out. The failures encountered in the process are

- Hot knock
- Lumps.

3.4.5  Fettling

The removal of unwanted portions like the runner, riser, and spirals from the cast product is called fettling. It is done by shot blasting and by using human labour. The casting surface is smoothened and finished by manually grinding and machining the casting. By using the grinding wheels the surfaces of castings are smoothened and corrected for other small protrusions.
The failures encountered in the process are

- Over grinding
- Over blasting
- Poor surface finish

3.4.6 Cleaning

The parts which have been casted is been sent to casting cleaning area has to be cleaned to remove the moulding sand that sticks to the casting. After final cleaning, it is sent to the paint line.

3.4.7 Inspection

Inspection is an important aspect in any foundry industry and the inspection department is named as quality assurance department in foundries and it plays a significant factor in the study.

3.4.8 Finishing

The final step in the process usually involves grinding, sanding, or machining the component in order to achieve the desired dimensional accuracies, physical shape and surface finish. Removing the remaining gate material, called a gate stub, is usually done using a grinder or sanding. These processes are used because their material removal rates are slow enough to control the amount of material. These steps are done prior to any final machining. After grinding, any surfaces that require tight dimensional control are machined. Many castings are machined in CNC milling centers. The reason for this is that these processes have better dimensional capability and repeatability than many casting processes.
3.4.9 Heat Treatment

Heat treatment is a very high value method used to improve the quality of metal materials. Heat treatment can change or influence the organization and the nature of cast iron, and can get higher strength, hardness, and improve the wear resistance.

The basic principal can be divided into two categories.

- The first category, the organizational structure will not change by heat treatment or should not be changed.
- The second category, the basic organizational structure will be changed by heat treatment.

The first heat treatment process is mainly for the elimination of internal stress. The internal stress is caused in the casting process because of different cooling conditions, and the organization, strength and other mechanical properties will not change significantly due to this heat treatment. For the second heat treatment, the basic organization structure changes.

Since, in most of the foundries after the cleaning process the product is sent to the customers without heat treatment and final operations. So these factors are not considered in the study.

Along with the above known process defects, the defects that occur due to job stress (measured by job strain) have various effects on the individual as well as on the organization. Absenteeism, work related accidents, turnover and impaired decision making etc., are the factors affecting an organization along with the sufferings of the individual. It causes the worker not to match the capabilities, resources or needs of the worker. This is an important issue which causes significant economic loss to
manufacturing organizations as the strain influences on the employee’s productivity. The economic costs of job strain are difficult to estimate but very high in the foundries as the working environment is too hostile (Mohan et al 2008).

3.5 ROAD MAP

The subsection illustrates the road map to implement FTFMEA model. The roadmap of this FTFMEA is shown in Figure 3.3 and it is encompassed with eight stages. The activities envisaged under these stages are briefly described in the following eight subsections:

3.5.1 Awareness Creation and Implementing of FTFMEA Model

The FTFMEA coordinator approaches the foundry in which the FTFMEA programme has to be conducted. To begin, meetings with the management are organized. During this meeting the coordinator narrates the salient features of FTFMEA and its advantages in implementing the model in the organization. Then the coordinator narrates the importance and specific benefit of implementing FTFMEA model to the managerial persons and supervisors.

Since, in most of the foundries after the cleaning process the product is sent to the customers without heat treatment and final operations. So these factors are not considered in the study.

The contributions required from the top management, managerial persons and employees are also enumerated. The coordinator clarifies the quarries raised by both top management and employees on FTFMEA implementation. At the end of this deliberation, top management and employees are convened and are aware of the FTFMEA model.
Figure 3.3 Roadmap for implementing FTFMEA
3.5.2 FTFMEA Team Formation

The management, managerial personnel and employees are invited to join the FTFMEA team. The persons who are interested are requested to give their names. The names are collected and submitted to the management. The management is requested to select the team members from all the departments and the selected persons should have more than 5 years of experience in their respective department and the team size is restricted to a maximum of ten members for easy communication and data flow. The management selects the team members for the FTFMEA, as per the request of the coordinator. The team is trained in all the aspects and stages of FTFMEA in order to the increase quality of the castings produced.

3.5.3 Identification of the Associated Departments and Listing Out the Sources of Failure Data

The FTFMEA team which has been trained by the coordinator are requested to identify the various sources of defects and their association with the various departments in the organization. The various defects and their association with the different departments are finalized after a through deliberation within the team members and the coordinator.

3.5.4 FTFMEA Data Collection

After deciding what are the departments in which failure exits and its associated defects, the team members are asked to collect data about the specific failures and defects in each and every department of the organisation. The team members are also instructed to interact with other supervisors and workers in their department to collect the failures and defects data. They are also requested to collect the reasons of the occurrence of these defects and their possible corrective actions.
3.5.5 FTFMEA Table Consolidation

The data collected by the team members regarding defects in various departments are verified and tabulated. The details about the FTFMEA tabulation are being explained by the coordinator. The various defects and their associated departments along with the present control mechanism are being entered and prepared in the form of the FTFMEA Table.

3.5.6 FTFMEA Analysis

The team members conduct brainstorming sessions to identify the failure modes, cause of the failure and the recommended actions to be taken in order to prevent, eliminate or reduce the defects due to the effect of failure. The team members deliberate and identify the solutions to overcome these failures. During this session the team members use ‘cause and effect analysis’ and ‘why – why analysis’ to identify the cause and effects of these failures. The coordinator and the team members rate the various failure modes according to the ease of the implementation. The failures with higher rating are very easy to implement and the failure with lowest rating is very difficult to implement. The modes of failure with rating in the middle are easy to implement.

3.5.7 Implementation of FTFMEA Recommended Actions

Based on the ranking as mentioned in the above subsection the FTFMEA Team members implement the recommend actions. For this the employees and the managerial employees are called for a meeting to explain the ways and means to implementing recommended actions. FTFMEA charts, drawings and Tables are displayed wherever required to reduce the defects.
3.5.8 Evaluate the Performance of FTFMEA

The Implementation of FTFMEA model is being evaluated by the team members and the coordinator after a period of two months. The deviations in the implementation process and the corrective actions that have to be implemented to improve the model are discussed and analyzed by the team members. This methodology acts as a closed loop system to increase the effectiveness of the FTFMEA model which is being implemented.

The above eight stages streamline the execution of the FTFMEA model for achieving continuous quality improvement and loss reductions in real time foundry scenario.

3.6 CONCLUSION

Currently, the foundries are at a tough period due to the recession and increase in price of raw materials over the years. Because of poor quality, many foundries have lost their market share and some have even shut down their operations, as it become uneconomical to run. In order to overcome this situation, it is necessary to improve the quality thus reducing the failures and defects resulting in reduction in the cost of production, which ultimately improves the foundries competitiveness. Foundry is a labor intensive job and the labours involved in it are not knowledgeable as they are mostly not well educated to carry out any complex scientific analysis.

The 21st century foundries are trying to improve the quality to be competitive in the market. The scope of these efforts has been in the managerial areas and not in the areas to detect and overcome defects (Kardach et al 2011). Hence FTFMEA model is being introduced in the foundries, as
FTFMEA technique is simple, effective model and with its holistic approach it can be easily implemented in foundry without wasting much time and money (Devadasan and Muthu 2003). It not only acts as a diagnostic tool but also as a decision making tool for enabling continuous improvement through reduction and elimination of defects and improving quality of the product being made. One more advantage which signifies the implementation of FTFMEA is that, it does not include any complex scientific and engineering concept as most workers involved in foundry are not knowledgeable to implement any scientifically based concepts.

The practicality of FTFMEA was investigated by implementing FTFMEA in two separate real time case studies. A KBFTFMEA incorporating FTFMEA was developed to assist in documenting, increasing the processing speed and decision making. The working of this KBFTFMEA was examined by implementing it in one of the foundries taken for the case study. The capability of the FTFMEA in continuous quality improvement is demonstrated in the next chapter.