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Implementation Study Analysis Of Ftfmea Model In Indian Foundry Industry

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ABSTRACT

Failure prevention is recognised as one of the major enablers of attaining continuous quality improvement. In the recent past, researchers and practitioners are tying to infuse high degree of quality to face global market by implementing continuous quality improvement techniques which results in improved productivity by eliminating failures, defects and reworks. For this Foundry Total Failure Mode and Effect Analysis model (FTFMEA) is developed and adopted to reduce the probability of process failure and to achieve higher product quality through failure identification and rectification. This FTFMEA model has been successfully implemented in two different types of foundries considered for case study. FTFMEA model facilitates a holistic approach in preventing failures by formation of a team to recommend actions for eliminating the occurrence of failures within the foundry. This paper reports about the model implementation methodology along with the roadmap to be followed and the results obtained in terms of qualitative and quantitative measurements along with the cost of money saved by the implementation of FTFMEA model. The model enabled the team to prevent expensive failures and hence facilitates decisions, which make better use of resources and processes to obtain quality products.

Key words: Failure Prevention, Continuous Quality Improvement, Foundry Total Failure Mode and Effect Analysis Model, Methodology, Roadmap.

Introduction

Metal casting has been one of the most ancient and primary manufacturing process since the stone age. 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; Yang et al 2011). Since the cost of the product being casted is directly influenced by the rework and rejection, foundries have to implement a continuous quality improvement management system in order to keep themselves in the foray (Chapman 2011; Das., 2008). 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 to implement, the FTFMEA model in two foundries as the bench mark.

The main contribution of this paper is discussion of the implementation study and the practical viability of FTFMEA model was investigated by implementing it in two different types of foundries. The implementation study being reported here was carried out at foundries situated in Coimbatore city, Tamil Nadu State, India. As the management of these foundries prefers to maintain anonymity, the foundries are referred to in this paper as foundry 1 and foundry 2. These studies were done based on the literature survey (Hassan et al., 2010; Ginn et al., 1988; Estorillo and Posso., 2010; Upadhye et al., 2010). The results also revealed that foundry area was not being considered holistically for any continuous process and quality improvement techniques. To bridge this gap FTFMEA model was developed and implemented successfully.

The experience of the practical implementation of FTFMEA model in these foundries, revealed the practical compatibility and viability of FTFMEA model. The practical results are expressed in qualitative,
quantitative terms and the calculation of loss is in terms of money value. The qualitative and quantitative measurements are expressed by keeping the roadmap as benchmark. In case of qualitative appraisal the implementation experience are benchmarked by using the statement like complete, partial and little. In the case of quantitative analysis, the implementation experience are analysed by using a numerical percentage of implementation by keeping roadmap as the benchmark. The issues and the implementation results are presented and discussed in this paper along with the financial gain obtained by the foundries by implementing the FTFMEA model.

Literature Review And Methodology:

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). Though many type of quality management models like FTA, FMEA are available, the advantages and the pitfalls of these models along with their case studies were studied (Baghdasaran et al., 2010; Tapia et al., 2011). 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 reliable, takes shorter time period to implement, holistic and has eliminated all the pitfalls in the FMEA model which was widely used. The interaction of the different department with in the organisation is the major advantage of the TFMEA model. The researchers have been using TFMEA in many fields. However they are not widely applied and are of product specific.

Fitfmea Model Development, Implementation Methodology And Roadmap:

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 TFMEA has two significants.

- 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 1. As shown, the entire FTFMEA process involves the development of FTFMEA tables pertaining to all the associated departments and their interrelationships. Table 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. 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. With the increase in the rating, the necessity to pay attention to the failure concerned enhances. Another important feature of the table is that a column titled as “interactive functions” have been 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 and it is suggested to use FTFMEA cards. 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. 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 shown in the Table below, a column for entering the value of rating by using a Likert’s scale of range 0-10 is used to simplify the process of indicating the seriousness of the failure and the ease with which it can be corrected. Thus the formation of FTFMEA table facilitates team building, rating of failures using simple Likert’s scale, evolution and sharing of knowledge impregnated into the organisation to overcome the failures (Uit Beijerse 2000). This process implementation would increase the organizations global competitiveness and core competence. Besides, the organization would also be encouraged to evolve its own portal (Sivakumar et al., 2008) to enable both local and global knowledge workers to participate in FTFMEA process.
S – Sand Preparation Department
M - Moulding Department
C – Casting Department
SO – Shakeout Department
F - Fettling Department
FI – Finishing Department
Q – Quality, Assurance Department

Fig. 1: FTFMEA Model

Table 1: FTFMEA – Sand Mill

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

Process Name : Sand Mill
TMFEA Number : 1
Members Present : Updated by :
M - Maintenance Department, C – Casting Department

The process of implementing the FTFMEA model is based on the methodology shown in Figure 2. The failure modes which are easy to implement are implemented first and the failure which are very difficult to implement are implemented latter. After the implementation of each failure the financial benefits and the effectiveness of the implementation process have to be verified and if need arises, the implementation process will be corrected by the FTFMEA team members. The team members select the coordinator who foresees all the implementation process. In this paper the author is the coordinator for the model implementation in both foundry 1 and foundry2.

The roadmap that has been followed in the implementation process of FTFMEA model in both foundry 1 and foundry 2 are given in the Figure 3. The coordinator instructed the team members strictly adhered to the roadmap while implementing the FTFMEA model.

Implementation Results:

The results of investigating the implementation of FTFMEA model through 8 steps as given in the roadmap are briefly described in the following subsections.

Ftfmea Awareness Creation:

For the implementation process it is vital to get the permission from the management to conduct the case study. The task was carried out by explaining the advantages and the solutions that can be derived to reduce the failure and increase the quality of product. In both the foundry 1 and foundry 2 this task was successfully carried out by the author of this paper. In both foundry 1 and foundry 2 the author of this paper was recognised as the coordinator of the FTFMEA implementation programme. This enabled the coordinator to coordinate the entire
proceeding of the FTFMEA model implementation. The model was then presented to the managerial personals and supervisors to create awareness. On the whole the performance of the awareness creation programme was complete in all aspects both in foundry 1 and foundry 2. The qualitative assessment is that, the conduct of awareness programme on FTFMEA model was complete in all respects. The quantitative assessment in both foundry 1 and foundry 2 was 100% in comparison to that envisaged in the roadmap.

Fig. 2: Methodology for implementing FTFMEA in Foundry1 and Foundry 2

Fig. 3: Roadmap for implementing FTFMEA model
Ftmea Team Formation:

After the completion of the awareness creation programme, the FTFMEA team formation is the major and most important aspect in the FTFMEA model. In foundry 1, the members are selected by the coordinator with discussion with the management from the list of interested employees who have more than five year of experience. In the foundry 2, even though the list of interested employees was collected and shortlisted by the coordinator before submitting it to the management, the management gave their list of FTFMEA team members to the coordinator and asked to work with them. The members of both team were intensively trained by exposing them to the FTFMEA model. They were given a set of rules, to which they are strictly advised to follow. It is estimated by the coordinator, that the second stage of model could be implemented to 100% at both foundry 1 and foundry 2. The qualitative assessment was that the implementation was complete at both foundry 1 and foundry 2 with respect to the task specified in the roadmap.

Listing Out The Source Of Failure Data:

According to the roadmap, the coordinator was required to initiate the identification of the source data of failures. By conducting meeting in both foundry 1 and foundry 2, the coordinator along with the team, devised a mechanism of collecting various defects in their respective departments. A methodology was also devised to identify the interrelationship between the departments for a particular defect. It was decided to identify the defects in consultation with the workers.

At the end, the various departments under which the defects and process failures are to be collected and tabulated are decided. In the estimation of the coordinator the implementation of FTFMEA model was 100% in both foundry 1 and foundry 2. The qualitative assessment was that the coordinator could implement the third step to a complete extend with respect to the task specified in the roadmap.

Ftmea Data Collection:

As decided in the earlier process and with respect to the activities specified under the step four in the roadmap, the defects according to the departments were collected from the workers and supervisors. Each defect, along with the association of that defect to the other interrelated departments were also collected. The entire process took a week to complete and the help of the quality department played an important role in collecting these data. In the foundry 1 and foundry 2 this process was not able to be implemented to a greater extend. In the estimation of the coordinator the implementation of FTFMEA was around 95% in foundry1 and it was 90% in foundry 2. The quantitative assessment was that the coordinator could implement this fourth step to the little less than complete with respect to these tasks specified in the roadmap.

Ftmea Table Consolidation:

The coordinator along with team members sat for a brainstorming session in order to consolidate various defects, failures causing these defects and the failure which effect the different interacting departments. The coordinator also trained the members in the preparation of the tables. They were also asked to enter these informations in the FTFMEA tables along with the present control mechanism which is used to eliminate or reduce these failures. After consulting with the management the tables were formed. In both the foundry 1 and foundry 2 this activity was carried out to the extent of 100%. The qualitative assessment is that the implementation of this fifth step of FTFMEA model was complete in both the foundry 1 and foundry 2 with respect to the activities specified under the same step of roadmap.

Ftmea Analysis:

After consolidating the tables in the above step the members and coordinator sat for another brainstorming discussion. The coordinator introduced and trained the members in why – why analysis and in cause and effect analysis. After which the members in both the foundry 1 and foundry 2 decided to use the why – why analysis. By, using the why – why analysis the cause of the failures are decided. The coordinator induced the Linkert’s scale for rating the various failures. After deliberating the members rated these failures. The ratings of the inter department are done after a thorough consolidation within members and the coordinator. In both the foundry 1 and foundry 2, these exercise could be carried out only to a partial extend, as the exercise needed time and multiple sessions for discussion. This happened so as the coordinator could not be in regular contact with the FTFMEA team members because the members were preoccupied with their work. In the estimation of the coordinator, the sixth stage of FTFMEA model could be implemented to the extent of 75% at foundry 1 and it was 70% at foundry 2 with reference to these stipulated in the same step of the roadmap. The qualitative
assessment was that the step was implemented partially in both the foundry 1 and foundry 2 with reference to the roadmap.

**Recommended Actions Implementation:**

In this step of FTFMEA model, implementation based on the recommendations of the FTFMEA table developed by the team members is to be started in a full-fledged manner. The recommended actions which have higher ratings can be implemented very easily than the failures with lower rating values. So the management was requested to implement these recommended actions to reduce or eliminate failures based on the ratings. The management was also requested to implement those actions as a group of 4 or 5 recommendations to eliminate failures. After studying the result of those implementation processes, the management could implement other recommendation to eliminate failures. In case of foundry 1, a partial implementation of a few recommended actions were taken and implemented, but a full-fledged implementation of the recommended actions was yet to commence. So the result of the FTFMEA model can only be observed by using questionnaires to get the respond of these personals and were quantified. In case of foundry 2, the recommended actions were implemented to a greater extend. The recommendations of failures with higher ratings are implemented and the failures with lower ratings are only partially implemented. In the opinion of the coordinator the seventh step of the FTFMEA model has been carried out at the extent of 30% at the foundry 1 and it is carried out to the extend of 85% at foundry 2. The qualitative assessment is that the seventh steps of the FTFMEA model can be implemented to the little extend at foundry 1 and it is partial in foundry 2.

**Evaluate The Performance Of Implementation Process:**

The last step of FTFMEA model is used to evaluate the implemented FTFMEA model in the foundry. As the FTFMEA model, is a closed loop system, where the deviations in the results obtained can be rectified to increase the effectiveness of the model being implemented. In the foundry 1 and foundry 2 recommended actions which were implemented to eliminate failures were evaluated at constant intervals to find the effectiveness of the implemented actions. If the results are not satisfactory the team members sit together and do the corrective actions to rectify the failure. In both the foundry 1 and foundry 2, the coordinator noted that the activity carried out to the extent of 100%. The foundry 2 implemented this step of the recommended actions to the FTFMEA model, which they have implemented. The qualitative assessment of the FTFMEA model could be implemented to the complete extent at foundry 1 and foundry 2 as specified under the roadmap.

As mentioned in the above eight sub sections, most of the steps of FTFMEA model implementation could be carried out to the extent of 100% in both the foundry 1 and foundry 2. However, in the case of implementing a few critical steps of FTFMEA model, the implementation could not be carried out to the complete extend. These deficient steps of FTFMEA model implementation is discussed in the next session.

**Result and Discussions**

The implementation of FTFMEA model at foundry 1 and foundry 2 is discussed in this section by drawing the experience described in the previous section. In order to aid this discussion, the quantitative and qualitative assessment of the FTFMEA implementation at foundry 1 and foundry 2 with respect to roadmap are summarised in Table 2.

<table>
<thead>
<tr>
<th>Step No</th>
<th>Title of the step of FTFMEA implementation</th>
<th>Quantitative</th>
<th>Qualitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.1</td>
<td>100%</td>
<td>Complete</td>
</tr>
<tr>
<td>2</td>
<td>4.2</td>
<td>100%</td>
<td>Complete</td>
</tr>
<tr>
<td>3</td>
<td>4.3</td>
<td>100%</td>
<td>Complete</td>
</tr>
<tr>
<td>4*</td>
<td>4.4</td>
<td>95%</td>
<td>Less than complete</td>
</tr>
<tr>
<td>5</td>
<td>4.5</td>
<td>100%</td>
<td>Complete</td>
</tr>
<tr>
<td>6*</td>
<td>4.6</td>
<td>75%</td>
<td>Partial</td>
</tr>
<tr>
<td>7*</td>
<td>4.7</td>
<td>30%</td>
<td>Partial</td>
</tr>
<tr>
<td>8</td>
<td>4.8</td>
<td>100%</td>
<td>Complete</td>
</tr>
</tbody>
</table>

After presenting the information, the steps in which the implementation of FTFMEA model is incomplete in either foundry 1 or foundry 2 or in both is indicated by using asterisk (*) mark.

In the case of the fourth step of implementation of FTFMEA model, the identification of the source data was evasive. This task could not be carried out to the complete extend because the workers couldn’t be involved
in the process. The workers who were working in most of the department were daily labourers from northern states are mostly illiterates and don’t have the understanding and dedication of doing a work. There was also communication barrier between the workers and the team members. These workers do not work at a work place for long duration as they keep changing their place of work. This was the case in both foundry 1 and foundry 2, with the effort of the coordinator and some of the team members, this step of FTFMEA model could be implemented very close to the extent of 100%. This kind of hurdles can be eliminated by making these workers permanent and by training and educating them in the each and every step of the foundry process and FTFMEA model implementation in order to overcome these hurdles to a greater extend.

In the sixth step of FTFMEA model, implementing the FTFMEA analysis can be exercised only to the extent of 75% in foundry 1 and 70% in foundry 2. This is due to the fact that the time and cost involved in making the team members dedicate their time during their working hours. The members were not interested to work after hours due to their personal reasons. Some of the team members were afraid and evasive in suggesting the recommended action against a failure thinking that they were suggesting recommendation against the management. The foundry 1 and foundry 2 management were not ready to allocate time for the team members to go for a meeting during the working hours as they considered it as waste of time, money and they also consider that any production problems in the foundry floor will go unnoticed and the productivity will be lost due to unproductive man hours. This could not be rectified by the coordinator.

In the seventh step of FTFMEA model, implementation of the section 4.7, could be exercised only to the extent of 30% in foundry 1 and 85% in foundry 2. In foundry 1, the management is yet to implement the recommended actions of FTFMEA model during the doctoral work being reported in this paper to reduce or eliminate failures and improve the quality. They implemented only six recommended actions which are very easily implementable. Hence, these personal were requested to assume that these recommended actions were implemented to reduce failure and respond to the questionnaire. In foundry 2 the management implemented all the recommended actions which have very high rating of reducing the failures. It implemented 85% of the recommended actions. The need of financial implication may have made the management to evade the rest of the recommended actions to reduce failure.

Another important characteristic of FTFMEA model is, it facilitates the calculation of loss in terms of money value. Since money is the language of business, this aspect will be useful for the top management to view the loss that could be saved from the financial point of view. In the case of foundry 1 and foundry 2, the loss incurred was found to reduce after the implementation of FTFMEA model which is summarised in Table 3

Table 3: Results of Implementing FTFMEA Model

<table>
<thead>
<tr>
<th>S.No</th>
<th>Details</th>
<th>Foundry 1</th>
<th>Foundry 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Money saved</td>
<td>Rs.12,98,490 / month</td>
<td>Rs. 8,25,005 / month</td>
</tr>
<tr>
<td>2</td>
<td>Percentage of failure reduction</td>
<td>8%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Though FTFMEA model was not implemented completely in foundry 1, the management allowed the coordinator to implement the Knowledge based FTFMEA (KBFTFMEA) in the foundry with the help of the data collected for FTFMEA model implementation as shown in Figure 4. The working of the KBFTFMEA was found to be smooth when the data and information gathered by conducting the FTFMEA investigations were entered. This KBFTEMEA system was extensively used by the foundry 1 to enter and modify FTFMEA table, to take the print out of the FTFMEA table and FTFMEA drawings and to deliberate about the various failures and defects that occur during the production process along with their corrective actions. The FTFMEA drawing and tables are displayed at each processing stage of foundry casting production for creating awareness to reduce or eliminate failure.

On the whole, the experience of implementing FTFMEA model at foundry 1 and foundry 2 indicated that it is a practically compatible model. This claim is made as the quantitative and qualitative assessment indicates that nearly 90% can be implemented quantitatively and qualitatively. All the assessment is above the region of partial and complete, to enhance the quality and reduce the failures in the foundry industry.

Conclusion:

The application of FTFMEA model in the foundry 1 and foundry 2 revealed its practicality to reduce failures, improve quality in process and product continuously and reduces the loss of the foundry due to failure. In reality, the organisations find the need of expertise and time as the hindrance factor in implementing FTFMEA model. In order to overcome this hindrance and meet the needs of the organisations, the KBFTFMEA was developed. The application of KBFTFMEA will facilitate the foundry industries to carry out streamlined implementation of FTFMEA model. The speed at which the stages of FTFMEA model, is implemented depends on the management interest in infusing continuous improvement in the industry. As the FTFMEA model and KBFTFMEA is not developed for a particular foundry, it can be used by any type of foundry producing any type
or size of castings. The FTFMEA model can still be improved and refined by incorporating the case studies results conducting in many foundries, to examining its implementation aspects. This will make FTFMEA model more powerful in enabling the modern manufacturing organisations to implement, and reduce failures thus improve quality to achieve their business goals. The KBFTFMEA could be used as a supporting tool for successfully implementing FTFMEA in manufacturing organisations.

Fig. 4: KBFTFMEA Portal

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