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Research Paper

FMEA IMPLEMENTATION IN A FOUNDRY IN BANGALORE TO IMPROVE QUALITY AND RELIABILITY

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Failure Mode and Effect Analysis (FMEA) is a technique to identify and prioritize potential failures of a process. This paper reports the description of FMEA methodology and its implementation in a foundry in reducing rejections of bushes. It is used as a tool to assure products quality and as a mean to improve operational performance of the process. The work was developed in an Indian foundry, in co-operation with part of the internal staff chosen as FMEA team members and was focused on the study of core making process. The problems identified in the various steps of core making process contributing for high rejection are studied and analyzed in terms of RPN to prioritize the attention for each of the problem. The monetary loss due to core rejection is considered as measure of risk.

Keywords: Core, FMEA, Failure mode, Risk priority number

INTRODUCTION

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, followed by the effects of failures on the product and product end users. The risks of these effects are then assessed accordingly as shown in Figure 1 (Xu *et al.*, 2002).

Basic Terms Used

Failure: The loss of an intended function of a device under stated conditions.

Failure Mode: The manner by which a failure is observed; it generally describes the way the failure occurs.

Failure Effect: Immediate consequences of a failure on operation, function or functionality, or status of some item.

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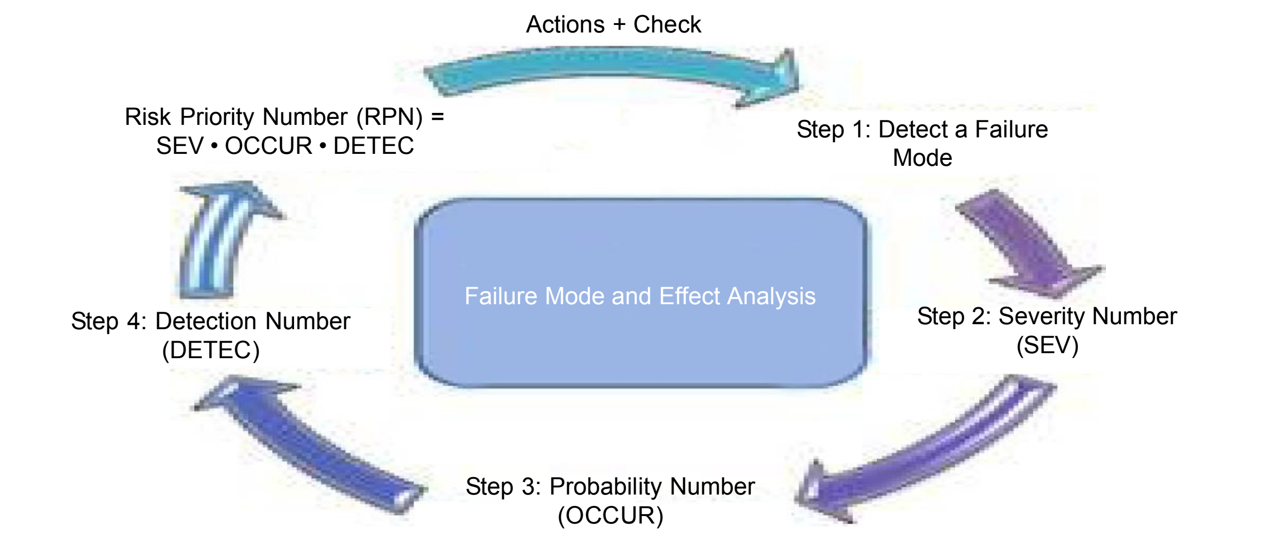
Figure 1: Failure Mode and Effect Analysis Cycle



Indenture Levels: An identifier for item is complexity. Complexity increases as levels are closer to one.

Local Effect: The failure effect as it applies to the item under analysis.

Next Higher Level Effect: The failure effect as it applies at the next higher indenture level.

End Effect: The failure effect is at the highest indenture level or total system.

Failure Cause: Defects in design, process, quality, or part application, which are the underlying cause of the failure or which initiate a process which leads to failure.

Severity: The consequences of a failure mode are severity. Severity considers the worst potential consequence of a failure, determined by the degree of injury, property damage, or system damage that could ultimately occur.

DATA COLLECTION

Before design and implementation of FMEA to core making process it is required to have careful knowledge of the process, therefore the same is studied by using process flow chart. The first phase of the work was to collect the core rejection data, information about cores, production lines and core making machines through visits to the production plant. Percent average Core rejection of three months is gathered from QC reports and the most common problems due to which cores are rejected are noted before the start of the study. Once FMEA team obtained all the information available about the problems of core rejection or potential failures of the core making process, it moved the operative phase of risk evaluation through definition of the FMEA form. The form used in this work is based on the reference manual (Chrysler/Ford/General Motors Task Force).

It has been found that shrinkage is the defect which is occuring more and needs to be eliminated as shown in Figure 2.

The first step of FMEA begins with identifying the process as shown in Table 1.

Figure 2: Defect Mapping of 0080 Bush

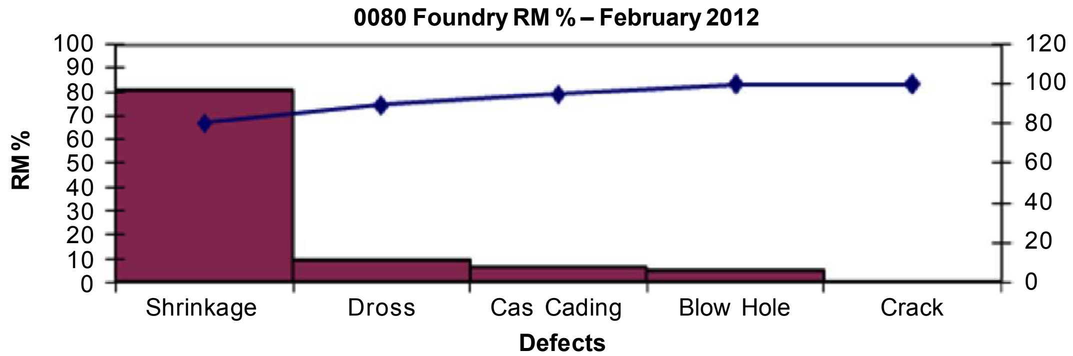


Table 1: Process Flow Chart of 0080 Bushes

Operation No.	Operation	Measure	Decision	Storage	Delay	Transport	Description of Activities	Procedure or Specification
1							Preparing Dies and Heating of Dies	As per Regular Heating with Lpg Bumer/Next to Hot Metal
2		Not OK					Charge Makeup and Melting of Charge	Work Instruction for Melting and Pouring of HTB-16
3							Metalur-gical Analysis of the Alloy	Work Instruction for Chemical Analysis for HTB-16
4			OK				Pouring of the Castings	Work Instruction for Pouring of HTB-16 SEC: 24.0 and 28.0
5							Fettling of the Castings	Chipp off Extra Projected Material with Small Hammer
6				For Disposal			Inspection of the Castings	Visual Inspection
7				OK			Movement of the ok Castings to Machines Hop	Casting ok Status "OK FOR NEXT OPERATION"

Then we founded out the potential failure modes and its effects by brainstorming with people from Production and Quality departments of the company as shown in Table 2.

Table 2: Analysing Failure Modes

Potential Failure Mode	Potential Effect(s) of Failure
1. Less die/core pins temp.	Blow holes/cracks at serration lines
2. More die/core pins temp.	Shrinkage at inner diameter
3. Sticking of casting on to the die	Die damage
4. Composition and properties of the alloy out of spec	Ingoting of melt/production plan affected
5. Low hardness	Rejection
6. High hardness	Rejection
7. Improper solidification of casting	Defective casting
8. Improper solidification and gas entrapment	Defective castings
9. Damages caused to casting	Defective casting

Occurrence

In this step it is necessary to look at the cause of a failure mode and the number of times it occurs. This can be done by looking at similar products or processes and the failure modes that have been documented for them in the past. A failure cause is looked upon as a design weakness. All the potential causes for a failure mode should be identified and documented. Again this should be in technical terms. Examples of causes are: erroneous algorithms, excessive voltage or improper operating conditions. A failure mode is given an occurrence ranking (O), again 1-10. Actions need to be determined if the occurrence is high (meaning > 4 for non-safety failure modes and > 1 when the severity-number from step 2 is 9 or 10). This step is called the detailed development section of the FMEA process. Occurrence also can be defined as %. If a non-safety issue happened less than 1%, we can give 1 to it. It is based on your product and customer specification.

Severity

Determine all failure modes based on the functional requirements and their effects. Examples of failure modes are: Electrical short-circuiting, corrosion or deformation. A failure mode in one component can lead to a failure mode in another component, therefore each failure mode should be listed in technical terms and for function. Hereafter the ultimate effect of each failure mode needs to be considered. A failure effect is defined as the result of a failure mode on the function of the system as perceived by the user. In this way it is convenient to write these effects down in terms of what the user might see or experience. Examples of failure effects are: degraded performance, noise or even injury to a user. Each effect is given a severity number (S) from 1 (no danger) to 10 (critical). These numbers help an engineer to prioritize the failure modes and their effects. If the sensitivity of an effect has a number 9 or 10, actions are considered to change the design by eliminating the failure mode, if possible, or protecting the user from the effect. A severity rating of 9 or 10 is generally reserved for those effects which would cause injury to a user or otherwise result in litigation.

Detection

When appropriate actions are determined, it is necessary to test their efficiency. In addition, design verification is needed. The proper inspection methods need to be chosen. First, an engineer should look at the current controls of the system, that prevent failure modes from occurring or which detect the failure before it reaches the customer. Hereafter one should identify testing, analysis, monitoring and other techniques that can be or have been used on similar systems to detect failures. From these controls an engineer can learn how likely it is for a failure to be identified or detected. Each combination from the previous 2 steps receives a detection number (D). This ranks the ability of planned tests and inspections to remove defects or detect failure modes in time. The assigned detection number measures the risk that the failure will escape detection. A high detection number indicates that the chances are high that the failure will escape detection, or in other words, that the chances of detection are low.

Risk Priority Number (RPN)

RPN play an important part in the choice of an action against failure modes. They are threshold values in the evaluation of these actions. After ranking the severity, occurrence and delectability the RPN can be easily calculated by multiplying these three numbers: RPN = $S \times O \times D$. This has to be done for the entire process and/or design. Once this is done it is easy to determine the areas of greatest concern. The failure modes that have the highest RPN should be given the highest priority for corrective action. This means it is not always the failure modes with the highest severity numbers that should be treated first. There could be less severe failures, but which occur more often and are less detectable. After these values are allocated, recommended actions with targets, responsibility and dates of implementation are noted. These actions can include specific inspection, testing or quality procedures, redesign (such as selection of new components), adding more redundancy and limiting environmental stresses or operating range. Once the actions have been implemented in the design/process, the new RPN should be checked, to confirm the improvements. These tests are often put in graphs, for easy visualization. Whenever a design or a process changes, an FMEA should be updated (Stamatis, 1997).

A few logical but important thoughts come in mind:

Try to eliminate the failure mode (some failures are more preventable than others).

- Minimize the severity of the failure.
- Reduce the occurrence of the failure mode.
- Improve the detection.

Then we calculated the severity, occurrence and detection of the failure modes and finally calculated the risk priority number as shown in Table 3.

Then finally actions were suggested and readings were calculated as depicted in Table 4.

Table 3: Calculation of RPN

Potential Failure Mode	Potential Effect(s) of Failure	Severity	Occurence	Detection	RPN
Less Die/Core pins temp.	Blow Holes/Cracks at serration lines	5	4	5	100
More Die/Core pins temp.	Shrinkage at inner diameter	5	3		15
Sticking of casting on to the die	Die damage	5	3	5	75
Composition and properties of the alloy out of spec	Ingoting of melt/Production plan affected	5	4	5	100
Low hardness	Rejection	5	4	5	100
High hardness	Rejection	5	4	5	100
Improper solidification of casting	Defective casting	6	3	4	72
Improper solidification and gas entrapment	Defective castings	6	3	3	54
Damages caused to casting	Defective casting	6	3	2	36

Table 4: Calculation of New RPN

Recommended Action(s)	Actions to be Taken	Severity	Occurence	Detection	RPN
Pre heat the dies and pins before casting	During Production	5	2	1	10
Check the condition of the coating before casting	During Production	4	3	1	12
Check the given charge w.r.t. charge slip	During Production	6	3	2	36
Fix control limits in spectra	During Pouring	5	3	3	45
Before pouring ensure the chemistry	During Production	5	3	3	45

RESULTS AND DISCUSSION

The design and subsequent implementation of FMEA in this foundry has permitted to detect which were the most probable and serious problems or causes in the core making process responsible for core rejection.

The criteria used to evaluate these problems or causes are the amount of damage caused to the production in terms of core rejection or lost production volume and subsequent monitory loss.

The management of the foundry wants to reduce the rejection below 5% by implementing FMEA tool. After implementation of FMEA to the core making process the rejection of cores and subsequent loss was reduced to 4.2% of the total rejection.

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