

“Synergy between FMEA and TRIZ – Inventive Problem Solving”

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ABSTRACT :

Failure Mode and Effect Analysis (FMEA) is a systematic method to investigate and evaluate potential failure of a product, process and its effect on the system's performance. It proceeds on a cause-and-effect analysis that is similar to a fault-tree analysis. The effects of a component failure are analyzed by considering the sequence of effects of that failure on neighboring components and then propagating them up to system level. The criticality of a certain component or certain failure modes can therefore be assessed and steps taken to amend the design so that critical failure modes become sufficiently improbable.

TRIZ is a Russian acronym for inventive problem solving. The Anticipatory Failure Determination feature of TRIZ is best applicable for determining potential failure modes. The approach to determine failures is opposite to that used in conventional failure analysis. The power of the technique comes from deliberately inventing the failures. It identifies an exhaustive list of potential failure scenarios as well as any negative, harmful or undesirable effects or phenomena.

This paper brings out the essential differences as well as synergy between the two methods by taking a case-study of “Hammer Mill Failure”.

Keywords : FMEA, Failure modes, TRIZ, AFD

1. FMEA INTRODUCTION:

Failure Mode and Effect Analysis (FMEA) is a systematic method to investigate and evaluate potential failure of a product, process and its effect on the system's performance. The effects of a component failure are analyzed by considering the sequence of effects of that failure on neighboring components and then propagating them upto system level. The criticality of the components and certain failure modes can therefore be assessed and steps taken to amend the design so that critical failure modes become sufficiently improbable.

FMEA PROCESS:

The FMEA process consists of following steps,

- 1) Identifying the scope
- 2) Define the system
- 3) Identifying the failure modes
- 4) Identify effects of each failure mode
- 5) Identify possible causes of the Failure modes
- 6) Calculate criticality
- 7) Identify design or process control
- 8) Determine detection
- 9) Take actions to reduce risk

An analysis of current FMEA practice has shown that the greatest criticism is the inability of FMEA to influence design because time scale of analysis often exceeds the design-development phase.

Another serious drawback is that FMEA only comes into action when failure has already occurred.

2. TRIZ INTRODUCTION:

TRIZ is a Russian acronym for inventive problem solving. Inventive problems are those which contains conflicting requirements or contradictions. Contradiction appears while trying to improve one desirable property another desirable property deteriorates, sometimes leading even to failure. TRIZ consists of several inventive tools that help improve the desirable feature and/or simultaneously eliminate the undesirable feature.

The Anticipatory Failure Determination (AFD) tool of TRIZ is applicable for determining potential failure modes. The AFD approach to determine failures is opposite to that used in a conventional approach. The power of the technique comes from

deliberately inventing the failures. It changes the question from “What is the root or main cause of failure?” to “How can we make the system fail or create harm?” This way it identifies an exhaustive list of potential failure scenarios as well as any negative, harmful or undesirable effects or phenomena. The idea is to invent, cause and create the most catastrophic failures that result in maximum harm or damage conceivable.

STEPS IN AFD (TRIZ):

1) Problem definition:

2) Formulation of inverted problem:

3) Define function:

4) Identify failure modes:

5) Describe effect:

6) Determine cause:

7) Identify failure hypothesis:

8) Search for solution:

3. HAMMER MILL FAILURE:

The effectiveness of both FMEA and TRIZ can be understood by analyzing the failure of a Hammer Mill.

Hammer mills are often used in the food industries to crush grain. A typical hammer mill consists of a set of discs mounted on a rotating shaft, which

rests on two bearing supports. Discs are connected by rods which serve as pivots for hammers mounted in a staggered manner between the discs.

Hammers are rectangular shaped and separated by spacer-rings. Peripheral edges of the hammers are covered with hard-wearing materials. The shaft with rods is perfectly balanced before hammers are installed. The direction of rotation of hammer mill is periodically reversed to provide even wear of the hammer edges.

The problem is that cracks are developing in the vicinity of holes where rods are connected to the discs. Holes become elliptically shaped and grooves appear on the rods, which is an indication of excessive contact pressure. Careful inspections also showed the indication of excessive contact pressure on the side surface of spacer rings and hammers, which cannot be caused by working loads. All of this forces the mill to run at much lower speed than recommended by the manufacturer, which reduces productivity

The analysis by FMEA is recorded in a tabular form (in table 1) and the analysis using AFD is given after the FMEA table.

4. FMEA WORK SHEET FOR HAMMER MILL PROBLEM

ITEM	FUNCTION	FAILURE MODES	FAILURE CAUSE	FAILURE EFFECT			TARGET	RISK ASSESSMENT	ACTION TAKEN
				LOCAL	NEXT	END			
SHAFT	Transmits rotation to the discs	Break	Load fluctuation	Drum breaks	Casing breaks	Mill shut down	Production person equipment	Low	
KEY	Couples discs with the shaft	shear	Over loading	Discs slips on shaft			Productivity	low	Change keys
DISCES	Supports rods for hammers	Break	Resonance due to oscillation of hammer	Rods and hammer comes out	Shaft is damaged	Casing damaged	Equipment Production person	Medium	
		Cracks at joining holes with rods	Excessive contact pressure	Disc vibration	Rods wearing out and vibration	Hammer moving out of the plane of rotation	Equipment production	High	
Rods	Supports hammers	breaking	Resonance vibration of hammer	Rods break	Drum vibrates	Excessive noise	Equipment Production	medium	
		Grooves on rod	Hammer running out of plane of rotation	Spacer ring break	Hammer strike with each other	Casing damaged	Equipment Production	high	
Spacer rings	Separates hammer from each other	cracks	Hammer striking it	Hammer strike with each other	Grooves on rod	Rod breaks	Equipment Production	medium	
Hammers	Crashes grains	Bore of hammer widens	Hammer running out of plane of rotation	Hammer cracks	Rod wears out	Hammer strike with each other	Equipment Production	high	
Sieve	Sieves out required size grain	Wearing out and thinning	Contact with hard materials	Improper grain size			Production	low	

5. AFD SOLUTION FOR HAMMER MILL FAILURE:

Step 1. Formulation of the original problem:

The hammer mill comprising a set of discs installed on a shaft and connected by rods serving as pivots for rectangular hammers used for crushing grain.

Several undesired effects are observed, **cracks** developing in the vicinity of holes bearing rods; **grooves** are developing on rods; **excessive wear** on side surface of space rings and side surface of discs containing the rings.

Original problem: It is necessary to find the cause for the cracks, grooves and excessive wear.

Step 2: formulation of the inverted problem:

Inverted Problem : It is required to produce cracks in disks, grooves on the rods and excessive wears on the side surfaces of spacer ring and disks, under the condition of existing production process

Step3: Amplification of the inverted problem:

It is required to **break away** the rods with hammers, produce deep grooves on rods, squash spacer rings, under the condition of existing production process.

Step 4: Search for solution

It is useful to analyze the readily available resources:

a) Readily available energy sources:

b) Readily available clearances:

c) Time resources:

5. Formulation of the hypothesis:

The hypothesis is

“unbalanced centrifugal forces and hammer swinging about pivoting rods cause drum rocking. As a consequence, the hammer oscillates out of plane of rotation, causing impact loading of the rods. Hammer oscillation reduces the contact area between hammers and the rods and induces substantial contact stresses. As a result cracks develop in discs and grooves in rods. As well as occurrence of excessive wear of the side surfaces of the spacer rings and disks. Here effect of one failure intensifies the

failure of next level component and this component causes failure of next and so on till the system fails catastrophically.

6. Correcting the failure:

Now when the root cause of the failure is clear, the way to prevent is to prevent the drum rocking. Hammer layout is made symmetric by providing same number of hammers at opposite sides of the drum between the disks keeping the staggered layout.

SYNERGY:

From the analysis of the problem by both technique we saw that FMEA only gives various possibilities in which a failure can occur its effect on the system, failure modes severity which can be used for assessing the risk involved with it, but it does not tell anything about how to correct these problem.

TRIZ not only points out the root cause of the critical failure but also suggests ways of solving the problem by using the resources which are readily available within the system, in an inventive way. The methodology can be used in either a post-failure analysis mode or in a pre-operating design mode.

The proactive nature of the analysis distinguishes this from FMEA. TRIZ looks for failure mechanism that feeds into itself and generates faster and total failures. FMEA is best suited when there are some known component or sub-system level failures as it has a cause-effect branching tree structure. In absence of any known failures, AFD gives better results as it invents failures that may cause highest damage.

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