Study of Centrifugal Pump Using Failure Mode Effect and Critical Analysis Based on Fuzzy Cost Estimation: A Case Study

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Abstract: ***This paper represents the generic process of FMECA for centrifugal pump failures and a case study on centrifugal pump failure cost estimation actual and after implementation of optimum strategies of maintenance. FMECA focused on critical components and reduce them their priority level and frequency with exact analysis of maintenance requirement of centrifugal pump.***

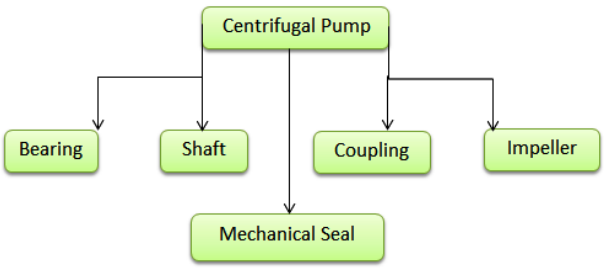
Keywords: FMECA, Centrifugal Pump, CBM, TBM and PM

1. Introduction

Centrifugal pumps have been considered as one of the most important components in any plant which have to deal with fluids as essential part of its business. The primary function of moving those fluids which are undergoing any kind of transformation through other components of the plant such as furnaces, reactors, heat exchangers, and so on, make of the pumps a special focus of attention from reliability, safety, and financial viewpoints. The assessment of the effect that the reliability and maintainability of pump systems have in the overall plant availability plays a very important role in the definition of a suitable maintenance strategy. The key issues of this strategy are not only the reduction of unplanned shutdowns and component repair times and elimination of critical components and their chronic failures and unplanned downtime.

Figure 1: Centrifugal Pump Set-up [Reputed Manufacturing Industry Source]

Sub Components of Centrifugal Pump:



2. Failure Mode Effect and Criticality Analysis

Failure Mode Effect and Criticality Analysis (FMECA) defined as that technique which is frequently used to enhance reliability of a centrifugal pump. With help of FMECA, potential failure modes as well as functional failures within a system and its equipment analyze mode of failure cause and effect, identifies potential weak links, and puts forward improvement measures. [1]

The severity and probability indices are added together to yield the criticality index. It represents a measure of the overall risk associated with each combination of severity and probability. This probability is used for failure prediction for a particular frequency and diagnoses them with optimum maintenance strategies like as condition based maintenance (CBM), time based maintenance (TBM) etc.

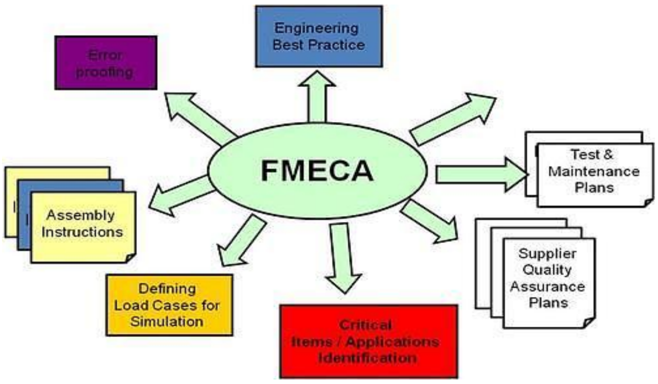
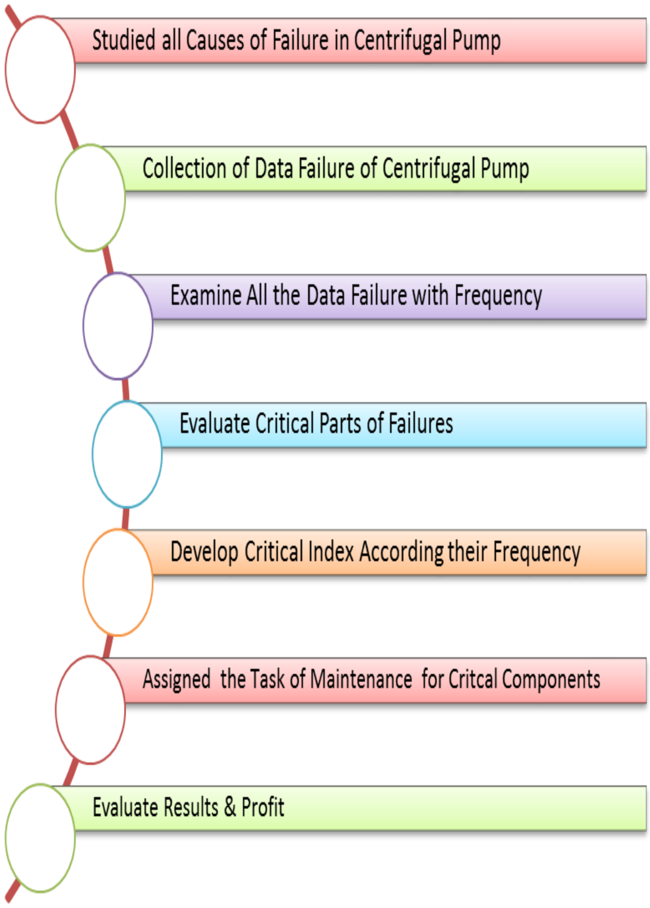


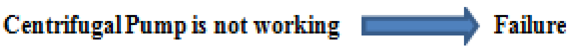
Figure 1: Basics of applied Failure Modes Effects and Criticality Analysis [2]

Information gained from FMECA includes [3]:

1. Listing of potential failure modes and failure cause which help guide the system testing and inspection techniques.
2. Criticality of potential failures that could affect overall system performance.
3. Detection and control measures for each failure mode.
4. Management information.
5. Input for further analysis.

3. Methodology Analysis of Data Failure of Centrifugal Pump





Centrifugal has two type failures:

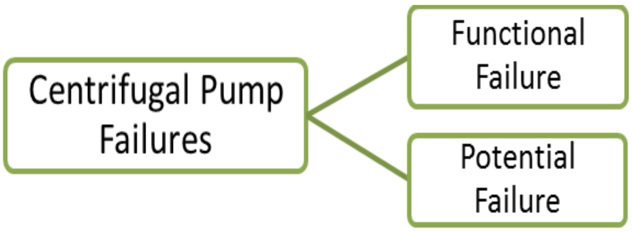


Table 1: Failure Mode Effect and Criticality Analysis [Reputed Manufacturing Company]

Type of Failures	Symptoms
Functional Failure	No liquid delivered
	Not enough liquid delivered
	Pump works for a while then quits.
	Pump takes too much power.
	Pump loses prime after starting.
	Viscosity of liquid differs from design condition.

Type of Failures	Symptoms
Potential Failure	Bearing Failure
	Seal Leakage
	Shaft Cracks
	Pitting marks on impeller
	Misalignment

Table 1 Failure Mode Effect and Criticality Analysis [Reputed Manufacturing Company]

SNo.	Components	Function	Function Failure	Description Of Failure			Failure Effect
				Failure Mode	Failure Mechanism	Detection Of Failure	Local
1	Mechanical Seal	Prevent leaking through shaft	Leaking	Leaking	Leaking through seal	Liquid dropping, noise from shaft	-Fluid leakage -Losses of pumping efficiency.
2	Bearing	To bear and hold load from shaft in order to spin	Wrong doing	Worn out	Shaft and seal will be broken	Vibration and noise on pump	-Excessive pump vibration -Increased in shaft radial movement -Eventual pump shutdown
3	Shaft	Protect shaft from corrosion and erosion on stuffing box	Eroded and corroded shaft	Corroded	Corroded	Wrong doing	-Vibration - Possible bearing damage -Eventual coupling failure
4	Impeller	Flow the liquid	Not able to flow fluid	Worn out	Decreasing pump capacity	Decreasing pressure	- Pump low efficiency - Vibration - Reduce in suction power

Table 2: Criticality Priorities Group [4]

Group	Criticality Index
I	3 - 2.5
II	2.5 - 2
III	2.1 - 5
IV	1.5 - 1

Table 3 Criticality Analysis for Centrifugal Pump [Reputed Manufacturing Company]

Failure Modes (System)	Components or Sub-system	Failure Modes (components)	Criticality Analysis			Criticality Index	Group
			Production	Safety	Cost		
Centrifugal pump not Functioning	Shaft	Worn	1	2	3	**1.4**	**IV**
		Excessive Deformation	1	2	3	**1.4**	**IV**
	Bearing	Misalignment	3	3	3	**3**	**I**
		Seizure	3	3	2	**2.8**	**I**
		Broken	3	3	2	**2.8**	**I**
	Mechanical seal	Fracture	2	2	2	**2.5**	**II**
		Leakage	2	3	1	**2.2**	**II**
	Impeller	Pitting marks	3	2	1	**2.2**	**I**
		Blade damaged	3	1	2	**2.2**	**I**

From table 3, it is clear that criticality component rank given below:

1. Bearing
2. Mechanical Seal
3. Impeller
4. Shaft

Therefore, the priority of critical components, the maintenance strategies like as – Condition Based Maintenance (CBM), Time Based Maintenance (TBM) and Planned Maintenance (PM) as per schedule would vary which is given table 4.

Table 4: Maintenance Strategies of Centrifugal Pump on the Basis of Component Criticality

System	*Failure Mode*	*Rank Group*	*Task*	*Frequency*
Centrifugal pump not Functioning	Bearing	I	CBM	Weekly
	Mechanical Seal	II	TBM	Weekly
	Impeller	III	PM	Monthly
	Shaft	IV	PM	Six Monthly

4. Profitability of Centrifugal Pump after Implementation of Optimum Maintenance Tasks

Table 4: Total Labor Required For Maintenance [Reputed Manufacturing Company]

	Frequency	Time (Hours)	No. of Workers	Man – hour per stage
Six Monthly	2	18	4	144
Monthly	9	6	3	162
Weakly	45	8.2	1	369

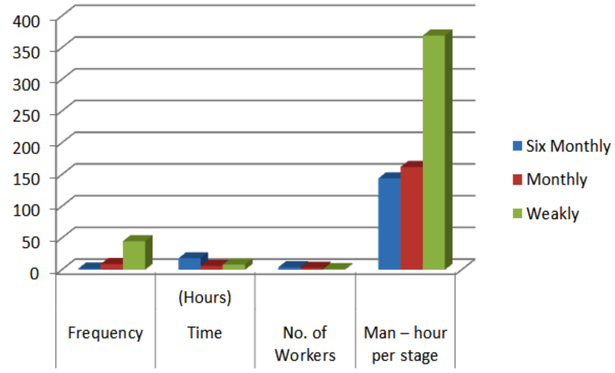


Table 5: Labor Saving Cost [Reputed Manufacturing Company]

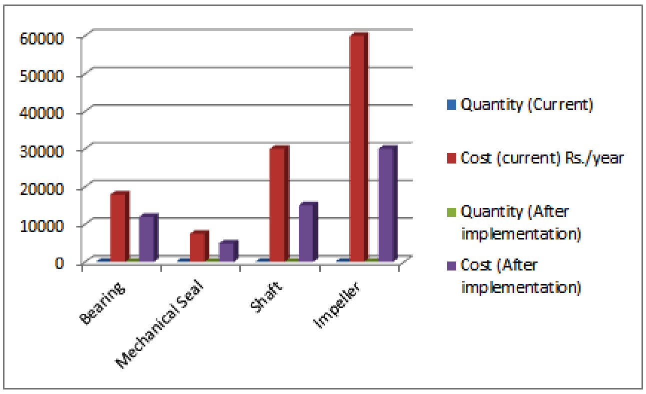
Item	Labor Type	Number of Labors Per Day (Current Maintenance)	Number of Labors Per Day (After implementation)
Engineers (45,000 ₹/Month)	Mechanical	4	3
	Electrical	3	2
	Control	4	2
Technicians (25,000 ₹/ Month)	Mechanical	6	4
	Electrical	6	4
Total Cost (₹/ Year)		**7,95,000/-**	**5,15,000/-**
Saving Cost (%) = 35.22			

Table 6: Downtime Cost [Reputed Manufacturing Company]

Average downtime cost rate = 8,500 ₹/ hour	**Actual**	**After implementation**
Average downtime of centrifugal pump	35 hr/year	22 hr/ year
Average downtime of the system auxiliaries	22 hr/year	12 hr/year
Total downtime	54 hr/year	34 hr/year
Total downtime Cost	**4,59,000 ₹/year**	**2,89,000 ₹/year**
Saving Downtime Cost (%) = 37.04		

Table 7 Spare Parts [Reputed Manufacturing Company]

Equipment	**Spare Part**	**Quantity (Current)**	**Cost (current) ₹/year**	**Quantity (After implementation)**	**Cost (After implementation)**
Centrifugal Pump	Bearing	6	18,000	4	12,000
	Mechanical Seal	6	7,500	4	5,000
	Shaft	4	30,000	2	15,000
	Impeller	2	60,000	1	30,000
Total Cost (₹/year)			**1,15,500/-**		**62,000/-**
Saving Spare Parts Cost (%) = 46.32					



5. Results

1. The labor cost decreases from ₹ 7,95,000/- to ₹ 5,15,000/-
2. The downtime cost decreases from ₹ 4,59,000/- to ₹ 2,89,000/-
3. The spare parts cost decreases from ₹ 1,15,000/- to ₹ 62,000/-
4. The net profit is 4,53,000 ₹/year.

S.No.	Parameters	Actual (₹)	After Impleme-ntation (₹)	Savings (₹)	
1	Labor saving cost	7,95,000	5,15,000	2,80,000	35.22 %
2	Downtime cost	4,59,000	2,89,000	1,17,000	37.04 %
3	Spare Parts	1,15,000	62,000	53,000	46.32 %

6. Conclusions

1) Profitability is a new parameter based on costs and potential profit to reduce the losses caused by failure occurrence, has been used in order to consider economic aspects.
2) The cost-based FMECA presents graphic representation, and provides an efficient classification of failures based on fault priority and economic profit.
3) To select the best mix of failures to be repaired and this type of problem is easily resolvable through priority of critical index of components and diagnose them appropriate maintenance strategies.

4) Enhance the profit with 36.74 % overall (including labor, downtime and spare parts cost only) per year by the proper selection of maintenance strategies with the help of FMECA.
5) Hence, in order to good maintenance system with the FMECA approach of failure cost consideration:
   a) Reduced downtime and failure rate.
   b) Enhance Profitability.
   c) Increase reliability of centrifugal pump.
   d) Increase production without any interruption due to failure.

References

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