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Selection of Maintenance Strategy Using Failure Mode Effect and Criticality Analysis

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Abstract: ***Equipment utilization have been major points of interest for many companies due to their direct impact on productivity. Highest possible utilization and improvement of performance of equipment will show significant increase in productivity. Machine down time effects productivity. Down time can be reduced by performing appropriate maintenance. Failure mode effect criticality analysis helps us to select suitable maintenance technique. This paper focuses on selection of suitable maintenance techniques that help to reduce downtime and increase productivity. To demonstrate the selection process a chemical industry is used as a case study. Failure Mode and Effect Analysis (FMEA) is used for selection of maintenance technique.***

Key words: **MTBF, Risk Priority Number, FMECA.**

I. INTRODUCTION

Failure Mode and Effect Criticality Analysis (FMECA) is a methodology designed to identify potential failure modes for a product or process, to assess the risk associated with those failure modes, to rank the issues in terms of importance and to identify and carry out corrective actions to address the most serious concerns. Failure Modes, Effects and Criticality Analysis (FMEA / FMECA) requires the identification of the following basic information namely Item, Failure, Effect of Failure, Cause of Failure and recommended action. A typical failure modes and effects analysis incorporates some methods to evaluate the risk associated with the potential problems identified through the analysis. The most common method is Risk Priority Number. To use the (RPN) Risk Priority Number method to assess risk, the analysis team must rate severity of each effect of the failure; rate the likelihood of occurrence for each cause of failure, rate the likelihood of prior detection for each cause of failure (likelihood of detecting the Problem before it reaches the end user or customer), calculate the RPN by obtaining the product of the three ratings. RPN is equal to Severity x Occurrence x Detection. The RPN can then be used to compare issues within the analysis and to prioritise problems for corrective action. This risk assessment method is commonly associated with Failure Mode and Effects Analysis (FMEA). The Failure Modes, Effects and Criticality Analysis (FMEA / FMECA) procedure is a tool that has been adapted in many different ways for various purposes. It can contribute to improved designs for products and processes, resulting in higher reliability, better quality, increased safety, enhanced customer satisfaction and reduced costs. The tool can also be used to establish and optimize maintenance plans for repairable systems and/or contribute to control plans and other quality assurance procedures. It provides a knowledge base of failure mode and corrective action information that can be used as a resource in future trouble shooting efforts and as a training tool for new engineers. In addition, an FMEA or FMECA is often required to comply with safety and quality requirements, such as ISO 9001, QS 9000, ISO / TS 16949etc. Maintenance can be a planned one or unplanned. Both predictive and preventive maintenance comes under planned maintenance. Corrective maintenance comes under planned or unplanned maintenance. Preventive Maintenance is planned maintenance of plants and equipments in order to prevent or minimize break downs and depreciation rates. The preventive maintenance includes routine inspection, cleaning, lubrication, adjustment, minor repair, internal cleaning of equipment and components, lubrication, oil changing, replacement of consumables like belts, bearings etc., overhauling and reconditioning. After preventive maintenance, equipment's health is restored back nearly to the equipment's original condition. The frequency of preventive maintenance is cyclic in nature. The frequency of maintenance is not the same throughout the life of the equipment. Predictive maintenance means predicting the failure before it occur, identify the root cause for those failure symptoms and eliminating those causes before they result in extensive damage to the equipments. The objective of predictive maintenance is to run the equipments in good condition for a long time between two overhauls. Predictive maintenance calls for regular or continuous inspection and monitoring of equipment's condition and health. It requires Hi-tech instruments and specialized skills to collect and analyze data and to find out the root cause of failure symptoms. Based on these inspections and monitoring several minor repairs and adjustments are planned and organized generally in cyclic manner or in fixed time interval schedules. It involves three stages namely detection, analysis and correction. Corrective maintenance means action for correcting or restoring a failed unit. Its scope is very fast and may include different types of action from small action like typical adjustments and minor repairs to redesign of equipment. It includes both scheduled and unscheduled actions and is governed by failure of the item as well as condition of the items. This type of maintenance is generally one time task (once taken up, completed fully). Some of the corrective maintenance job may call for collection of extensive data about breakdown and their causes, proper analysis of those data before coming to conclusion about actual jobs to be done. Corrective maintenance includes collection of data, identify causes, find out possible solution to eliminate

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likely causes and implement those solutions. FMECA is systematic process whereby each mode of failure of every component within the system is assessed for probability of occurrence, effect of failure and criticality in terms of successful operation, safety, maintenance etc. The Risk Priority Number (RPN) establishes priority for further investigation of different failure modes. It is calculated as the product of ratings on frequency of occurrence, severity and likelihood of detection. Failures that score high in this rating can potentially be the source of system unreliability and their causes should be corrected. FMECA results in improved reliability of an item by identifying potential areas of failure and providing required documentation on how system failure occurs.

Effect	Criteria: Severity of effect	Ranking
Hazardous without warning	Effects safe operation without warning	10
Hazardous with warning	Effects safe operation with warning	9
Very High	Major Disruption, item has to be scrapped, customer discomfort	8
High	Loss of Primary function, Customer dissatisfied	7
Moderate	Minor Disruption, item has to be scrapped, customer discomfort	6
Low	Minor Disruption, item can be reworked, reduced performance	5
Very Low	Minor Disruption, item can be reworked, Customer dissatisfied	4
Minor	Minor Disruption, defect noticed	3
Very Minor	Minor Disruption, noticed by average customer	2
None	No effect	1

Table1. Ranking of Severity

II. LITERATURE REVIEW

FMEA procedure is well documented in the literature[1,4,5,6,7,8].It emerged in the studies done by NASA in 1963 and then spread to car industry, where it was used to quantify the possible defects at the design stage of a product so these are not passed on to the customer. The method identifies the criticalities based on its risk and is considered as last point of failure investigation [2]. RPN evaluation uses linguistic terms to rank the chance of failure mode occurrence, the severity of the failure effect and chance of failure on numerical scale 1 to 10. The method is mostly preferred by manufacturing industries [3]. Reliability is expressed as the probability that a process or equipment will perform its function or task under stated conditions for a defined observation period [6]. Both corrective and preventive maintenance have direct effect on the reliability of the equipment and thus the performance of the equipment [9]. From the literature, it is evident that FMEA is a most popular tool for the analysis of the performance of a product or a process.

III. OBJECTIVE OF STUDY

The present study is aimed to

(a). Find the Reliability, Risk Priority Number, and Rank.

(b). Suggests the most suitable maintenance method.

IV. METHODOLOGY OF STUDY

In the present study, an extensive use of secondary data was made. The study was made both analytical and descriptive. Here FMECA techniques are used and ranked equipment to select appropriate maintenance strategy.

The steps involved in FMECA are:

(i) Identify equipment number and specification
(ii) Study the failure of the equipment and failureEffect.
(iii) Rank the severity
(iv) Detection of occurrence
(v) Find risk priority number (RPN)
(vi) Ranking of Failure
(vii) Prepare report for highlighting critical failures
(viii) Recommend maintenance action to reduce Critical failure.

Ranking is shown in below tables.

Table2. Ranking of Detection

Detection	Ranking
Impossible	10
Very remote	9
Remote	8
Very low	7
Low	6
Moderate	5
Moderately high	4
High	3
Very high	2
Almost certain	1

Table3. Ranking of Occurrence

Probability of Failure	Ranking
Very High	9-10
High	8-9
Moderate	4-6
Low	3
Very Low	2
Remote	1

The effect of severity is ranked in a 10 point scale based on effect as shown Table 1. The detection (D) is also ranked in a 10 point scale as given in Table 2. The occurrences (O) is ranked 9-10,8-9,4-6, 3,2 and 1 if the occurrence is very high, high, moderate, low, very low and remote respectively as shown in Table 3. The RPN

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Value lies between 1000 and 1. High RPN shows high risk and low RPN shows low risk. If RPN > 300, and then do Predictive maintenance. If RPN is between 200 and 300 then do Preventive maintenance. If RPN<200, then do corrective maintenance or follow the present

V. MAJOR FINDINGS OF THE STUDY

The fifty five equipments of the process industry under study are considered for this analysis. Only seventeen equipments namely Chlorine Blower 1, Chlorine Blower 2, Chlorine Blower 3, Hydrogen Blower 1, Hydrogen Blower 2, Chlorine Compressor 1, Chlorine Compressor 2, Chlorine Compressor 3, Air Compressor 1, Air Compressor 2, Air Compressor 3, Air Compressor 4, Screw compressor1, Screw compressor 2, Jack well Pump1, Jack well Pump2, Jack well Pump 3 are having failure under the period of study and the MTBF is tabulated. Equipments are ranked based on severity, detection and occurrence. The risk priority number (RPN) for these equipments are found out. The reliability of all the equipments is calculated. Three equipments namely Chlorine Blower 3, Hydrogen Blower 2, Screw Compressor 1 is having low reliability so life testing and replacement has to be done if present recommended maintenance strategy doesn't works. Only five equipments namely Hydrogen Blower1, Chlorine Compressor 2, Air Compressor 1, Air Compressor 2, and Air Compressor4 having RPN greater than 300. So these equipments are critical and perform predictive maintenance. Here only Air Compressor3 has RPN between 200 and 300 and hence it is semi critical, so perform preventive maintenance or modify present maintenance schedule. Rest eleven equipments namely Chlorine Blower 1, Chlorine Blower 2, Chlorine Blower 3, Hydrogen Blower 2, Chlorine Compressor 1, Chlorine Compressor 3 , Jack well Pump 1, Jack well Pump 2, Jack well Pump3, Screw Compressor 1, Screw Compressor 2 have RPN less than 200 and hence less critical, so perform corrective maintenance or continue present maintenance schedule. The details are given in Appendix, Table (A) & Table (B).

VI. INTERPRETATION

Only seventeen equipments namely Chlorine Blower 1, Chlorine Blower 2, Chlorine Blower 3, Hydrogen Blower 1, Hydrogen Blower 2, Chlorine Compressor 1, Chlorine Compressor 2, Chlorine Compressor 3, Air Compressor 1, Air Compressor 2, Air Compressor 3, Air Compressor 4, Screw compressor1, Screw compressor 2, Jack well Pump1, Jackwell Pump2, Jack well Pump 3 have failure and rest is reliable because of zero failure. Only five equipments namely Hydrogen Blower1, Chlorine Compressor 2, Air Compressor 1, Air Compressor 2, and Air Compressor4 having RPN greater than 300. So these equipments are critical and perform predictive maintenance. Only Air compressor 3 is having RPN greater than or equal to 200. So perform preventive maintenance schedule. The criteria for the selection of the maintenance program is summarized and shown in Table 4.The details of the study and its application are entered in standard FMECA form (Table B).

Table4. Selection Criteria for maintenance program

Rank	Maintenance Technique	Criteria
1	Predictive Maintenance	RPN> 300
2	Preventive Maintenance	200<RPN<300
3	Corrective Maintenance	RPN<200

maintenance for this equipment and reduce the time gap between the Preventive Maintenance. The rest eleven equipments namely Chlorine Blower 1, Chlorine Blower 2, Chlorine Blower 3, Hydrogen Blower 2, Chlorine Compressor 1, Chlorine Compressor 3 , Jack well Pump 1, Jack well Pump 2, Jack well Pump3, Screw Compressor 1, Screw Compressor 2are rated 3 since RPN is less than 200. So perform corrective maintenance or follow present maintenance strategy. More over the reliability of Chlorine Blower 2, Hydrogen Blower 2, Jack well Pump 2, and Screw Compressor 1 is less. So go for life testing and replacement if the present strategy does not work.

VII. CONCLUSION

The down time and production loss is a concern for the industries. Productivity can be increased and down time can be decreased by performing proper maintenance. Reliability, Mean time between failures, RPN are tabulated and ranked the equipments as per the criteria. Improper maintenance or lack of proper maintenance schedule is one of the main causes of increase in failure as well as down time. In the present study FMECA is used for analyzing machine failure. Panking is done for machine having down time and based on the rank proper maintenance strategy is recommended. The most suitable maintenance method was found out. The advantage of FMECA is that it improves the operating performance, improves maintenance and improves safety and protection the study can be extended to schedule the maintenance, resource allocation as well as test the life of equipment having less reliability.

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FAILURE MODE AND EFFECT CRITICALITY ANALYSIS (DESIGN FMECA)

Item…………………… FMECA Number ………………
Model No. …………..... Prepared By ……………………
Key Date ……………… FMECA Date (Org) …………....
Core Team ……………. FMECA Date (Rev) ………….. .

Item	Failure Mode	Potential effect of failure	S	Class	Potential cause of failure	O	Current Control	D	RPN	Recommend-ed action	Target Completion date	Action results				
												Action taken	S	O	D	RPN

Source: TCC Ernakulam

Table B: Ranking of equipments

47	AC 1	Air Compressor 1	10	4	16.8	0.92

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Table a: the details of down time, Failure etc

Sl.No	Eqpt No:	Eqpt Name	S	O	D	RPN	Reliability	Rank	Maintenance Technique
1	BL 03 A	Chlorine Blower 1	8	1	5	40	0.63	3	Corrective Maintenance
2	BL 03 B	Chlorine Blower 2	8	4	5	160	0.63	3	Corrective Maintenance
3	BL 03 C	Chlorine Blower 3	8	4	5	160	0.28	3	Corrective Maintenance
4	BL 05 A	Hydrogen Blower 1	8	8	5	320	0.87	1	Predictive Maintenance
5	BL 05 B	Hydrogen Blower 2	8	1	5	40	0.39	3	Corrective Maintenance
6	CC 1	Chlorine Compressor 1	8	2	5	80	1	3	Corrective Maintenance
7	CC 2	Chlorine Compressor 2	8	9	5	360	0.99	1	Predictive Maintenance
8	CC 3	Chlorine Compressor 3	8	4	5	160	0.74	3	Corrective Maintenance
9	AC 1	Air Compressor 1	8	10	5	400	0.92	1	Predictive Maintenance
10	AC 2	Air Compressor 2	8	10	5	400	0.98	1	Predictive Maintenance
11	AC 3	Air Compressor 3	8	5	5	200	0.78	2	Preventive Maintenance
12	AC 4	Air Compressor 4	8	10	5	400	0.98	1	Predictive Maintenance
13	PU 2001 A	Jackwell Pump 1	5	1	6	30	1	3	Corrective Maintenance
14	PU 2001 B	Jackwell Pump 2	5	2	6	60	0.49	3	Corrective Maintenance
15	PU 2001 C	Jackwell Pump 3	5	2	6	60	1	3	Corrective Maintenance
16	SC1401	Screw compressor1	6	2	5	60	0.39	3	Corrective Maintenance
17	SC1402	Screw compressor2	6	1	5	30	1	3	Corrective Maintenance

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Sl.No	Eqpt No:	Eqpt Name	Failures	No of Eqpt	MTBF	R
1	PU1401/A	HS Brine Pump 1	0	2	No	Reliable
2	PU1401/B	HS Brine Pump 2	0	2	No	Reliable
3	PU1308A	Barium Carbonate	0	2	No	Reliable
4	PU1308B	Barium Carbonate	0	2	No	Reliable
5	PU 1310 A	Clarified Brine Pump1	0	2	No	Reliable
6	PU 1310 B	Clarified Brine Pump2	0	2	No	Reliable
7	PU 1311 A	Filtered Brine Pump 1	0	2	No	Reliable
8	PU 1311 B	Filtered Brine Pump 2	0	2	No	Reliable
9	PU 1313 B	Secondary Purified Brine	0	2	No	Reliable
10	PU 1313 B	Secondary Purified Brine	0	2	No	Reliable
11	PU 1314 A	DM Water Pump 1	0	2	No	Reliable
12	PU 1314 B	DM Water Pump 2	0	2	No	Reliable
13	PU1301 A	Depleted Brine Pump 1	0	2	No	Reliable
14	PU1301 B	Depleted Brine Pump 2	0	2	No	Reliable
15	PU1303 A	Dechlorinated Brine	0	2	No	Reliable
16	PU1303 B	Dechlorinated Brine	0	2	No	Reliable
17	PU 1306 A	Sodium Bisulphate Pump	0	2	No	Reliable
18	PU 1306 B	Sodium Bisulphate Pump	0	2	No	Reliable
19	PU 1302 A	NaOH Pump 1	0	2	No	Reliable
20	PU 1302 B	NaOH Pump 2	0	2	No	Reliable
21	PU 1312 A	Chlorine Water Pump 1	0	2	No	Reliable
22	PU 1312 B	Chlorine Water Pump 2	0	2	No	Reliable
23	BL 03 A	Chlorine Blower 1	3	2	42	0.63
24	BL 03 B	Chlorine Blower 2	3	2	42	0.63
25	BL 03 C	Chlorine Blower 3	1	2	126	0.28
26	BL 05 A	Hydrogen Blower 1	4	2	21	0.87
27	BL 05 B	Hydrogen Blower 2	1	2	84	0.39
28	PU 1316 A	H2SO4 Feed Pump 1	0	2	No	Reliable
29	PU 1316 B	H2SO4 Feed Pump 2	0	2	No	Reliable
30	PU 1318 A	HCl Pump 1	0	3	No	Reliable
31	PU 1318 B	HCl Pump 2	0	3	No	Reliable
32	PU 1318 C	HCl Pump 3	0	3	No	Reliable
33	PU 1310 A	Condensate Pump 1	0	2	No	Reliable
34	PU 1310 B	Condensate Pump 2	0	2	No	Reliable
35	CC 1	Chlorine Compressor 1	0	3	0	1
36	CC 2	Chlorine Compressor 2	13	3	9.69	0.99
37	CC 3	Chlorine Compressor 3	4	3	31.5	0.74
38	VC 1	Chilled Water	0	3	No	Reliable
39	VC 2	Chilled Water	0	3	No	Reliable
40	VC 3	Chilled Water	0	3	No	Reliable
41	CW P1	Chilled Water Pump 1	0	2	No	Reliable
42	CW P2	Chilled Water Pump 2	0	2	No	Reliable
43	CT 1 P1	Cooling Tower Pump 1	0	4	No	Reliable
44	CT 1 P2	Cooling Tower Pump 2	0	4	No	Reliable
45	CT 1 P3	Cooling Tower Pump 3	0	4	No	Reliable
46	CT 1 P4	Cooling Tower Pump 4	0	4	No	Reliable
48	AC 2	Air Compressor 2	16	4	10.5	0.98
49	AC 3	Air Compressor 3	6	4	28	0.78

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Volume 1, Issue 6, June2012

50	AC 4	Air Compressor 4	15	4	11.2	0.98
51	PU 2001 A	Jackwell Pump 1	0	3	0	1
52	PU 2001 B	Jackwell Pump 2	2	3	63	0.49
53	PU 2001 C	Jackwell Pump 3	0	3	0	1
54	SC1401	Screw compressor1	1	2	84	0.39
55	SC1402	Screw compressor2	0	2	0	1