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Maintenance Optimization for Critical Equipments in process industries based on FMECA Method

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Abstract:-In present era of automation and modernization, setting up of production plants involves huge capital investment especially for the process industry. The deterioration and failure of these systems might incur high costs due to production losses and delays, unplanned intervention on the system and safety hazards .The causes of failure may be human error, poor maintenance, inadequate testing, inspection or improper use and the resulting effects vary from minor in convenience to lost service time and sometimes to loss of material, equipment's and even life. Several techniques have been used to determine the causes for the failure modes and what could be done to eliminate or reduce the chance of failure. The most notable methodology dealing with this issue is the Failure modes, effects and critique analysis (FMECA). Failure modes, effects and critique analysis (FMECA) is an integral part of the technical design of maintenance and it represents a strong tool to evaluate and improve system reliability and therefore reduces costs associated with maintenance that is used in a wide range of industry. This allows to optimize the components while identifying the most critical elements and helping decision makers to define maintenance service with appropriate maintenance policy.

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 (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 of evaluation of risk 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 priorities 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 16949 etc. The practical uses of the FMECA, includes design flaws and identifies potential security risks. It plans for maintenance and troubles hooting. The FMECA is composed of two separate analyses, the Failure Mode and Effects Analysis (FMEA) and the Criticality Analysis (CA). The FMEA analyses different failure modes and their effects on the system while the CA classifies or prioritizes their level of importance based on failure rate and severity of the effect of failure. The ranking process of the CA can be accomplished by utilizing existing failure data or by a subjective ranking procedure conducted by a team of people with an understanding of the system. Although the analysis can be applied to any type of system, this research will focus on applying the analysis to an equipment of power distribution system facility. The FMECA should be initiated as soon as preliminary design information is available. The FMECA is a living document that is not only beneficial when used during the design phase but also during the system use. As more information on the system is available; the analysis should be updated in order to provide the maximum of benefit. Analysis of the Failure Modes, Effects and Criticality Analysis (FMECA) is a qualitative approach to safety studies in different fields. Indeed this technique provides a thorough knowledge of the functioning and interactions of a system, by the systematic analysis of cause-effect relationships. The information obtained is used as part of risk management, with primary concern obtaining a

-Good level of dependability of operational system.

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It allows to:
- Know the most important elements (functions and components);
- Find, evaluate and rank the weaknesses, faults and malfunctions of the system;
- Manage the critical points and;
- Specify the corrective action;
- Evaluate the effects of these measures to ensure their effectiveness and to compare them and decide.

So, FMECA occupies an important position in optimization of the maintenance function. In fact it makes the system reliable while reducing the number of failures, and making it easily maintainable because it allows the control of components and their functions. It can act on the critical elements, to dominate failures, particularly critical and catastrophic ones.

II. LITERATURE REVIEW

FMEA procedure is well documented in many literatures. 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. 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.

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. PRACTICAL METHOD OF FMECA

FMECA is a useful tool when performing a Reliability Centered Maintenance analysis. FMECA is a way to evaluate potential failure modes and their effects and causes in a systematic and structured manner. Failure modes mean the ways in which something could fail. Effects analysis refers to studying the consequences. The purpose of the FMECA is to take actions to eliminate or reduce failures, starting with the highest- priority ones. By itself, an FMECA is not a problem solver; it should be used in combination with other problem solving tools. The analysis can be done either in a qualitatively or quantitatively way. The basic steps in performing a FMECA could be

1. Define the system to be analyzed. A complete system definition includes defining system boundaries, identifying internal and interface functions, expected performance, and failure definitions.
2. Identify failure modes associated with system failures. For each function, identify all the ways of failure could happen. These are potential failure modes.
3. Identify potential effects of failure modes, for each failure mode, i.e. identifying all the consequences on the system. 'What happens when the failure occurs?'
4. Determine and rank how serious each effect is. The most critical pieces of equipment, which affected the overall function of the system, need to be identified and determined.
5. For each failure mode, determine all the potential root causes.
6. For each cause, identify available detection methods.
7. Identify recommended actions for each cause that can reduce the severity of each failure.

V. CASE STUDY

In a Hydro processing plant reciprocating compressors are heart of the plant. Reciprocating compressors are highly reliable machines designed to perform in a broad range of process conditions. However , if they are not properly operated controlled and maintained , high maintenance costs and significant down time can result. Past studies within the Hydrocarbon Processing Industry (HPI) indicate that the maintenance costs for reciprocating equipment are approximately 3.5 times that of centrifugal equipment. Substantial savings in maintenance costs and an increase in run time may be achieved through basic monitoring of some of the Machine Parameters. Large reciprocating machinery users such as gas transmission and storage companies, refineries and petrochemical industries use FMECA method for risk analysis of different components and maintenance optimization. This maintenance strategy allows not only cost reduction by reducing the number of maintenance interventions to only those actually needed, but also provides efficiency improvements through dynamic analysis of the equipment as well.

Table 1. Parameters FMECA (Occurrence)

Occurrence (O)		
Possible rate of occurrence	Criterion of Occurrence	Value
Once every 12 years	Failure near zero or no	1
Once every 10 years	Very low, failure isolation, rarely	2
Once every 8 years	Low, often fail	3
Once every 6 years		4
Once every 4 years	Average, occasional failure	5
Once every 2 years		6
Once every year		7
Once every 6 months	High, frequent failure	8
Once every month		9
Once every week	Very high, very high failure	10

Table 2. Parameters FMECA (Severity)

Severity (S)		
Duration of service interruption	Criterion of Severity	Value
> 8h	Very catastrophic	8
7h	Catastrophic	7
6h	Very serious	6
5h	Serious	5
4h	Medium	4

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3h	Significant	3
2h	Minor	2
1h	Very minor	1
30 min	Small	0.6
< 30 min	Very small	0.2

Table 3. Parameters FMECA (Detectability)

DETECTABILITY (D)		
Level of Detectability	Criterion of Detectability	Value
Not detectable	Impossible	10
Difficult to detect	Very difficult	9
	Very late	8
Detecting random (Unlikely)	Not sure	7
	Occasional	6
Possible detection	Low	5
	Late	4
Reliable detection	Easy	3
	Immediat	2
Detection at all times	Immediate corrective	1

6. Possible alternative maintenance strategies

Five alternative maintenance policies are evaluated in this case study. Briefly, they are the following.

Corrective maintenance: the main feature of corrective maintenance is that actions are only Performed when a machine breakdown. There is no intervention until a failure has occurred.

Preventive maintenance: Preventive maintenance is based on component reliability characteristics. This data makes it possible to analyze the behavior of the element in question and allows the maintenance engineer to define a periodic maintenance program for the machine. The preventive maintenance policy tries to determine a series of checks, replacements and/or component revisions with a frequency related to the failure rate. In other words, preventive (periodic) maintenances are effective in overcoming the problems associated with the wearing of components. It is evident that, after a check, it is not always necessary to substitute the component: maintenance is often sufficient.

Opportunistic maintenance: The possibility of using opportunistic maintenance is determined by the nearness or concurrence of control or substitution times for different components on the same machine or plant. This type of maintenance can lead to the whole plant being shut down at set times to perform all relevant maintenance interventions at the same time.

Condition-based maintenance: A requisite for the application of condition-based maintenance is the availability of a set of measurements and data acquisition systems to monitor the machine performance in real time. The continuous survey of working conditions can easily and clearly point out an abnormal situation (e. g .the exceeding of a controlled parameter threshold level), allowing the process administrator to punctually perform the necessary controls and, if necessary, stop the machine before a failure can occur.

Predictive maintenance: Unlike the condition based maintenance policy, in predictive maintenance the Acquired controlled parameters data are analyzed to find a possible temporal trend. This makes it possible to predict when the controlled quantity value will reach or exceed the threshold values. The maintenance staff will then be able to plan when, depending on the operating conditions, the component substitution or revision is really unavoidable.

VII. OPTIMIZED METHOD OF MAINTENANCE

The concept of man-machine cooperation was born after the advent of tools for the decision support as an assistant to a human decision maker and therefore the possibility to share the tasks with them. In these circumstances, the Group uses the FMECA tool to obtain advice that it is used in decision making. It guides the group in its approach to problem solving to bring him to discover the solution. Therefore, it has the advantage of reducing maintenance costs. Although maintenance costs depend on the characteristics of the equipment that comes in three forms: characteristics that can be provided by the supplier, operator characteristics, and characteristics common to the operator and the supplier, Maintenance costs is composed, primarily, of two components: direct costs and indirect costs. The FMECA study mainly allows optimizing the direct costs (Fig.1). Indeed it is a clever method of diagnosis to the extent that it predicts a number of weaknesses, defects, anomalies and failures at all the elements that contribute to system availability.

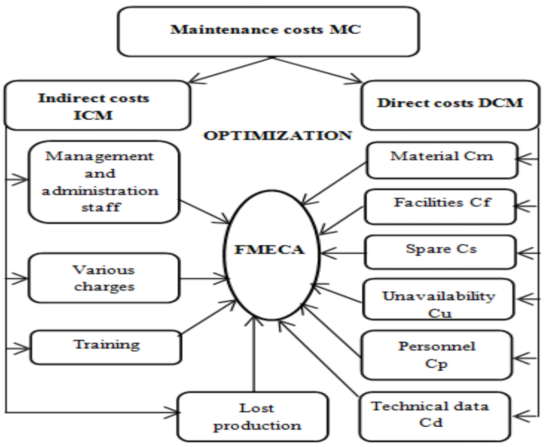

Fig1. Optimization method of maintenance costs

VIII. MAJOR FINDINGS OF THE STUDY

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. Components having RPN

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greater than 300 are critical and perform predictive maintenance. Components having RPN between 200 and 300 and hence it is semi critical, so perform preventive maintenance or modify present maintenance schedule. Rest does corrective maintenance.

IX. SELECTION CRITERIA FOR MAINTENANCE PROGRAM

Table 5. Selection of program

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

X. CONCLUSIONS

This work showed the feasibility of conducting an optimum method of maintenance. This approach is based on the analysis FMECA. The implementation of this approach shows its contribution in reducing maintenance costs. Indeed it can:

- Define the requirements of dependability in a precise manner.
- Identify critical functions for the system.
- Define the maintenance policy for the system and its components.

Here all the components of a reciprocating compressor are analyzed to find the criticality The risky components and failure modes are easily identified by incorporating the occurrence of failure mechanism. Thus as a result both the RPN and Criticality can be identified in one analysis. When such components are identified the plant manager can fix the maintenance strategies and design modifications for the improved performances.

XI. SCOPE FOR FURTHER RESEARCH

Though a number of issues of compressor systems have been investigated by the author, any study of this scale opens up new opportunities to carry out similar studies of bigger systems in future. However, based on experience and research in this area, the author identifies the following important areas, which need further research:

(a) In order to lessen the effect of subjectivity in the tools used in Criticality modeling a fuzzy-based modeling approach may be employed for enhancing the applicability and usefulness of research

(e) Risk based method for maintenance policy selection and comparative cost basis maintenance can be incorporated.

REFERENCES

[1] Arunraj., *et al* (2010), "Risk based maintenance Policy selection using AHP and Goal Programming", Safety science, vol 48 , pp (238-247) [J]

[2] Carazas et. al., (2010) "Risk-based decision making method for maintenance policy selection of thermal power plant equipment", Energy, vol 35 pp 964–975 [J]

[3] Malay Niraj, Praveen Kumar, Dr. A. Mishra, "FMECA analysis (A Heuristic approach h) for frequency and type of maintenance", International Journal of Scientific and Engineering Research, Jan 2012, Vol3, issue1

[4] Matteo Mario Savino, Alessandro Brun, Carlo Riccio, "Integrated System for maintenance and safety management through FMECA principle and Fuzzy interference engine", European Journal of Industrial Engineering 2011, Vol5, pp 132-169

[5] Dinesh Kumar, Pradeep Kumar, Amish Sachdeva, "Multi-factor Failure mode Criticality analysis using TOPSIS", Journal of Industrial Engineering International, Jan 2009, vol. 5, No.8, pp1-9.

[6] Jlong, R.A. Shenol, W. Jiang, "A reliability centered maintenance strategy based on free operating period philosophy and total life time operating cost analysis", Aerospace Engineering, March 2009, Vol 223, pp 711-719.

[7] Kovacova Monika, Janco Ronald, "Criticality Assessment for FMECA analysis using Fuzzy Logic", Journal of Applied Mathematics, 2008, Vol1, no: 1.

[8] Braglia.M, "Multi-attribute failure mode analysis", International Journal of Quality and Reliability Management, 2000, 17, pp 1017- 1033.

[9] Triantaphyllou.E, Kovalerchuk.B, Mann.L and Kannp. G, "Determining the most important criteria in maintenance decision making", International Journal of Quality and Reliability Management, 1997, 3, pp 16-24.

[10] Teng.S.H. and Ho.S.Y, "Failure modes and effect Analysis: an integrated approach for product design and process control", International Journal of Quality and Reliability Management, 1996, 13(5), pp 8-26

[11] Ben-Daya, M. and Raouf, A. (1996), ``A revised failure mode and effect analysis model", International Journal of Quality & Reliability Management, Vol.13 No.1, pp. 43-7.

[12] Garrick, B.J. (1988), ``The approach to risk analysis in three industries: nuclear power, space systems, and chemical process", Reliability Engineering & System Safety, Vol. 23 No. 3, pp. 195-205.

[13] Gilchrist, W. (1993), ``Modelling failure modes and effects analysis", International Journal of Quality & Reliability Management, Vol. 10 No. 5, pp. 16-23.

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Table 4: Maintenance Plan

Component	**Failure cause**	**Effect**	**likelihood of Occurrence P**	**Consequence-C**	Detectability D	P*C*D= Criticality	Maintenance plan
FRAME	**loose crosshead pin**	**frame knocks**	**2**	**7**	6	84	- Corrective Action: If the fault is minor. - Preventive systematic maintenance action
	loose crosshead bearing	**frame knocks**	**3**	**7**	4	84	CORRECTIVE
	low oil pressure	**frame knocks**	**3**	**4**	3	36	CORRECTIVE
	loose crank pin	**frame knocks**	**3**	**6**	7	126	CORRECTIVE
	Improper alignment	**frame knocks**	**3**	**6**	7	126	CORRECTIVE
	damaged coupling	**frame knocks**	**2**	**7**	4	56	CORRECTIVE
cylinder	liquid in cylinder	knocking noise	5	7	8	280	PREVENTIVE
	broken rider ring	knocking noise	8	7	6	336	PREDICTIVE
	loose/broken valve	knocking noise	7	6	8	336	PREDICTIVE
stuffing box and packings	**foreign matter in sealing elements**	**excessive wearof packing elements**	**8**	**6**	8	336	PREDICTIVE
	high operating temp	**wear of packing**	**8**	**6**	4	192	PREVENTIVE
	rod area scored	**wear of packing**	**4**	**4**	8	128	CORRECTIVE
	lack of lubrication	**wear of packing**	**3**	**4**	7	84	CORRECTIVE

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	high piston rod runout	**packing leakage**	**6**	**7**	4	168	CORRECTIVE
valve	impurities in gas	valve breakage	6	7	8	336	PREDICTIVE
	high condensate volume	valve breakage	6	7	8	336	PREDICTIVE
	excessive lubrication	valve breakage	7	4	8	224	PREVENTIVE
rider ring	**Dirt on liner**	**ring wear**	**4**	**7**	7	196	PREVENTIVE
	high operating temp	**ring wear**	**6**	**7**	8	336	PREDICTIVE
	insufficient lubrication	**ring wear**	**5**	**8**	6	240	PREVENTIVE
	comp. run on no load	**ring damage**	**4**	**7**	5	140	CORRECTIVE
main bearing	worn out	low oil pressure	6	7	4	168	CORRECTIVE
	worn out	misaligned	5	8	7	280	PREVENTIVE
piston rod	**not lined up with frame**	**high run out**	**6**	**8**	4	192	CORRECTIVE
intercooler	fouling	high disch temp	7	6	4	168	CORRECTIVE
unloader	**stem struck up**	**suction valve not working**	**6**	**5**	6	180	CORRECTIVE
crosshead shoe	wear	high bearing temp	6	8	8	384	PREDICTIVE