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FAILURE MODE & EFFECT ANALYSIS OF LEAD ACID BATTERY

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ABSTRACT

Now a days Reliability of any mechanical system is the most important factor of the product design, so the need for reliability estimation & prediction of critical modes of failure for mechanical system became the talk of the town. Lead acid battery which has been in use for different applications for over 13 decades. Their areas of application have transcended the traditional areas of automotive vehicle and have spread to newly developed area such as in traction of hybrid-electric vehicles, in un-interruptible power supply units and in telecommunication system for standby duties. The objective of this paper is presents the failure mode its severity, their effects on the service life of Lead Acid Battery. The Risk Priority Number (RPN) of the automobile battery based upon the failure data from a battery . This is very useful to understand Battery faults & maintenance.

KEYWORDS: Reliability, FMEA, RPN, Battery, FTA, Lead acid & Failure data.

INTRODUCTION

In our Industrial sector, customers are placing increased demands on companies for high quality, reliable products. The increasing capabilities and functionality of many products are making it more difficult for manufacturers to maintain the quality and reliability. FMEA has become a typical tool for both engineering design and process analysis. It has proven to be of great value in the early identification of potential reliability and safety issues.

In order to increase reliability of a system, analysis of failure data is essential. In last two decades many of the researchers have worked toward reliability estimation with proper statistics & failure data and suggested some of the most efficient techniques such as FTA, FMEA & FMECA etc. In this paper we have presented the general procedure for FMEA its application in various fields and the modifications that have been made through the time to overcome the inadequacies of the method. Battery life, reliability, and life-costs has always been a most important concern where they are needed in photovoltaic systems, telephone and telecommunications, computers, Uninterruptible Power Supplies or backup and emergency power to the AC power line, electric vehicle. The life costs can make or break a products success, and false trust in a defective battery can be catastrophic. Determining battery lifetimes is beset with difficulties. Performance data are not generally available and costly to generate since large numbers of batteries must be tested to destruction. Furthermore, the required test period to verify the predictions is often greater than commercial decision lead time.

The lead acid battery consists of essentially two electrodes immersed in sulfuric acid electrolyte. The negative terminal is the electrode attached to lead containing spongy active mass, whereas the positive terminal is attached to a porous grid containing granules of metallic lead dioxide. These two materials are arranged in a matrix and are separated and immersed in concentrated sulfuric acid to provide the mobile positive and negative charges. The matrix comprises a cell, several of which are placed in series to form the battery. [1] The components of the Lead acid in the cut section are shown in fig. 01. Kadir et al. [2] paper takes the advantages of the failure modes and effects analysis (FMEA) to adapt innovative marine technologies integrated with the operational aspects in order to prevent crankcase explosion failure onboard ships. The main objectives of the study are to improve the machinery system reliability and to enhance operational safety concepts on board ship. Xiao et al. [3] introduced a useful method to simultaneously analyze multiple failures for complex systems. L. Sultan et al. [4] include a discussion about qualitative part of criticality analysis where occurrence is plotted in X-axis and severity is plotted in Y-axis.

Depending on values of severity and occurrence, the failure modes are transferred to different zones named-confirmed critical characteristics, confirmed significant characteristics and RPN- Top 20% by Pareto and annoyance region. N. Ravi et al. [5] describe a new technique for prioritizing failures for corrective actions in failure mode and effects analysis. This technique extends the risk prioritization beyond the conventional risk priority number (RPN) method. A new scale has been defined. Povolotskaya et al.[6[introduces a formulation of appropriate risk estimation methods that can be used for improving of processes in the electronics area. Two risk assessment methods have been chosen with regard to the specifics of adhesive joining based on electrically conductive adhesives. Brik et al.[7] presents an approach of reliability to analyze lead-acid battery's degradation.

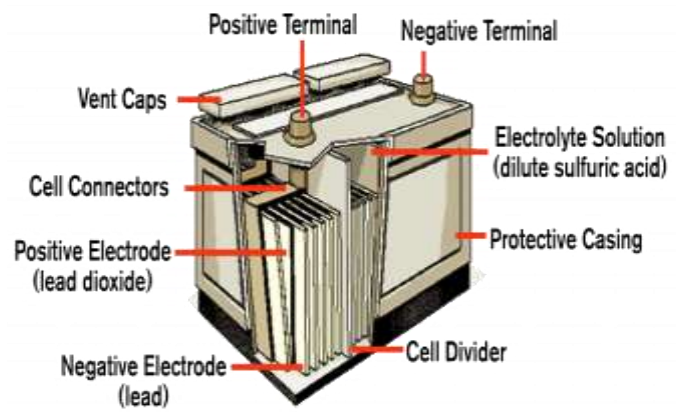

Fig. 1 Lead acid Battery

MATERIALS AND METHODS

Failure mode & effect analysis : The FMEA is a proactive analysis tool, allowing engineers to define, identify, and eliminate known and/or potential failures, problems, errors, and so on from the system, design, process, and/or service. Furthermore, FMEA is an inductive approach to support risk assessment studies and the principle of FMEA is to identify potential hazards along with the focused system and to prioritize the required corrective actions or strategies. In 1949, the FMEA methodology was developed and implemented for the first time by the United States Army and then in the 1970s, with its strength and robust characteristics, its application field extended first to aerospace and automotive industry, then to general manufacturing. Today FMEA is mainly applied in industrial production of machinery, motor cars, mechanical and electronic components. [2] Failure mode and effects analysis (FMEA) has proven to be a useful and powerful tool in assessing potential failures and preventing them from occurring. It represents a powerful and documented method for engineers to present in a structural and formalized manner their subjective thinking and experience in terms of: What might go wrong, What might cause it to go wrong & What effects would it have?

Once FMEA is completed, a critical item list is compiled enabling the analyst to pinpoint system inherent vulnerabilities, thus ensuring that safety, quality and reliability are built into the design and manufacture stages of products.

Types of FMEA'S : There are several types of FMEAs; some are used much more often than others. FMEAs should always be performed for engineered systems whenever failures would mean potential harm or injury to the user of the end item being designed. The types of FMEA are:

Process - focuses on manufacturing & assembly
Design - focuses on components and subsystems
System - focuses on global system functions
Service - focuses on service functions
Software - focuses on software functions

RPN Methodology: The risk priority number (RPN) is a mathematical product of the seriousness of a group of effects (severity), the likelihood that a cause will create the failure associated with those effects (occurrence), and an ability to detect the failure before it gets to the customer (detection). In equation form,

$$RPN = S \times O \times D$$

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Where

S = Severitynm ; O = Occurrence & D = Detection

TABLE 1 Maintenance Strategy based on RPN

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

Severity, Occurance & Detection

Severity: Severity is an assessment of the seriousness of the effect of the potential failure mode on the customer after it has occurred. The severity of the failure should be predicted and recorded on a 1 to 10 scale, which is called severity rating. Since the severity rating is based solely on the effect, and not the cause of the failure, it always remains the same, regardless of its possible causes.

Occurrence: When considering "occurrence of failure", one must evaluate the risk, that is, the probability that the failure mode will occur as a result of a specific cause. A design change is the only way a reduction in the occurrence can be affected After considering the failure mode and its possible causes, the estimate of the probability of the failure actually occurring must be recorded, using all available knowledge, and then the probability of occurrence would be ranked on a 1 to 10 scale

Detection: The probability that a potential failure will be detected before it reaches the customer should also be estimated based on a scale of 1 to 10. This is called 'detection rate'. Ranking are shown in Table 2.

TABLE 2 Severity Ranking, Occurrence Ranking & Detection Ranking

	Severity Ranking		Occurrence Ranking		Detection Ranking	
Rank	**Effect**	**Criteria**	**Effect**	**Criteria**	**Effect**	**Criteria**
1	No	No effect	Almost Never	Failures unlikely	Almost Certain	Proven detection methods available in concept stage
2	Very Slight	Customer not annoyed	Remote	Very few Nos. of failures likely	Very High	Proven computer analysis available in early design stage
3	Slight	Customer slightly annoyed	Very Slight	Few Nos of failures likely	High	Simulation and/or modeling in early stage
4	Minor	Customer experiences minor nuisance	Slight	Occasional High Nos of failures likely	Moderately High	Test on early prototype system element
5	Moderate	Customer experiences some dissatisfaction	Low	Medium Nos of failures likely	Medium	Test on preproduction system components
6	Significant	Customer experiences discomfort	Medium	Medium Nos of failures likely	Low	Test on similar system components
7	Major	Customer dissatisfied	Moderately High	Moderately High Nos of failures likely	Slight	Test on product with prototypes and system components installed
8	Extreme	Customer very dissatisfied	High	High Nos of failures likely	Very Slight	Proving durability test on Test on product with system components installed
9	Serious	Potential hazardous effect	Very High	Very high Nos of failures likely	Remote	Only unproven or unreliable techniques available

10	Hazardous	Hazardous effect	Almost Certain	Failure almost certain	Almost impossible	No known techniques available

FMEA Process

Two alternative approaches may be used when performing a FMEA, a functional approach or a hardware approach. The functional approach considers sub-systems in terms of their function within the system and is often applied when hardware components cannot be uniquely identified.
To conduct a FMEA the essential steps are carried out in order as follows:
(1) Describe the part name, number and function.
(2) List the possible modes of failure.
(3) Estimate the severity of the failure.
(4) List the potential causes of failure.
(5) Estimate the frequency of occurrence of failure.
(6) Describe failure detection.
(7) Estimate failure detection.
(8) Evaluate the RPN.
(9) Recommendation for corrective action.

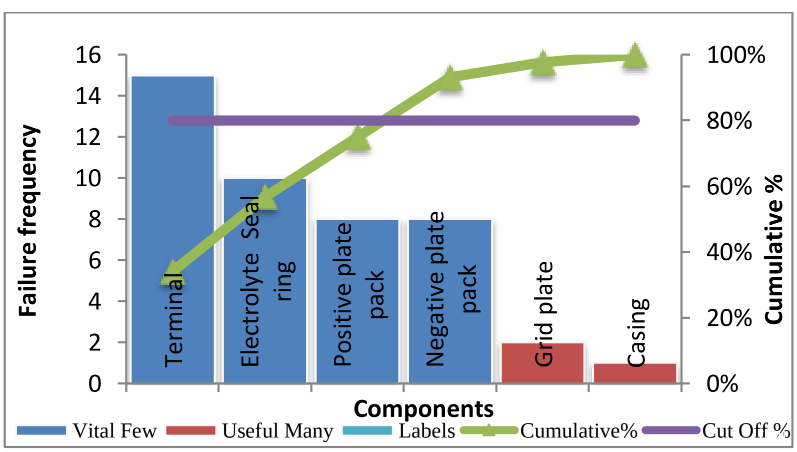
FMEA OF LEAD ACID BATTERY

To perform FMEA of Lead Acid Battery the Failure Data of Battery is very much essential. The failure data of the lead acid battery is collected from battery manufacturer from Nanded, Maharashtra. The failure data is given in Table 3

TABLE 3 Failure Data

Sr. No.	Components	Failure frequency	% of failure	Cumulative failure %
1	Terminal	15	34.09	34.1%
2	Electrolyte Seal ring	10	22.72	56.8%
3	Positive plate pack	8	18.18	75.0%
4	Negative plate pack	8	18.18	93.2%
5	Grid plate	2	0.045%	97.7%
6	Casing	1	0.022%	100.0%

The Failure Mode & Effect Analysis sheet based on the above data is shown in the table number 4. The FMEA sheet showcases the components, its failure modes, effects, causes, and recommendation for corrective actions to improve the active life of the lead acid battery.



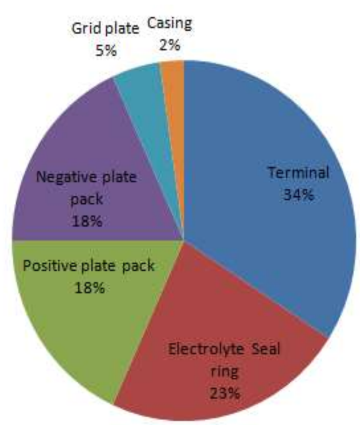


Fig. 2 Pareto analysis of Lead acid Battery

Fig.3 Percentages of failure components

TABLE 4 FMEA of Lead acid Battery

Parts	Failure Modes	Effects	Causes	S	O	D	RPN	Recommendations
Terminal	Weak Terminal	Battery Bank Fails	Excess Heat during batteries connected in Bank	4	9	7	252	In Battery Bank the links & cables should be standard
Terminal connector	Sulfating	Improper Output	Fluctuation of liquid level	5	8	8	320	Coat with Petroleum jelly to avoid sulfating
Electrode Plates	Electrodes Melts	Battery Fails	High heat & low liquid level	8	4	7	224	Check Water level regularly
Electrolyte sealing ring	Contraction of + & - cell	Lower voltage Output	Fluctuation of charging voltage	6	5	6	180	Keep constant charging current using OVCD
Output Terminal	Nut & bolt melts	No Output	Excess Heat at connections	5	7	6	210	Use petroleum jelly while joining nut at terminal

RESULTS AND DISCUSSION

Failure Mode & Effect Analysis which is very much helpful in identification & analysis of failures of the system. The result of FMEA identifies the "Terminal" of the battery as the most critical component which affects the active life of the battery. The RPN of the Terminal is high as compare to other components because the terminal material reacts to the higher temperature as well as the low liquid level adversely. By improving the thermal properties of the terminal material the active life of the battery can be increased and the Mean Time between Failures can be improved.

CONCLUSION

As the Lead acid batteries can fail prematurely during the active life due to the abusive use. The FMEA is one of the most effective tools to identify the criticalities of the system & to improve the active life and reduce the downtime. The result of FMEA shows that the critical component as terminal having higher Risk Priority number, To reduce the failures of the terminal the connections of the terminal should be done with standards and liquid level of the battery need to be check at fixed intervals.

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