Reliability Analysis:The Mathematical Expression

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Abstract - : The reliability engineering discipline has undergone evolutionary development and breakthroughs during the last six decades. The need for reliable products was first sensed in both commercial and military sectors in early 1950s. Since then enormous progress has been made in the area of reliability engineering. Before 1950s, the focus was either on quality control or on machine maintenance problems. Literature suggests that before World War II reliability was intuitive in nature and the basic concept of reliability was born during this time period.

In this paper with the help of Mathematical simulation, the reliability analysis will be proved for particular products. The concept of reliability analysis will be more useful to check any product or physical element's durability and confidence of quality.To decide the standardization of any product, this reliability analysis will be important and key of success. The need of satisfaction related to physical products can be check by these analysis also. Some of Mathematical approaches like Boolean algebra, Logarithm equations some of the formulas and mathematical expressions will be introduced. The condition between failure and durability will be considered to check the quality & reliability.

Some of the different types of distributions like Exponential, Weibull, and Gamma & Lognormal can be express in PDF or CDF curves for reliability analysis standardizations and proof.

Finally to check the reliability of substances these analyses will be useful and easy to prove product quality and other features.

I. Introduction

Recently, due to the increased competition, complex product design and development, the use of increasingly sophisticated manufacturing processes, particularly in the area of defense and space technology, and increasing focus on customer satisfaction, the question of reliability has become a matter of great interest.

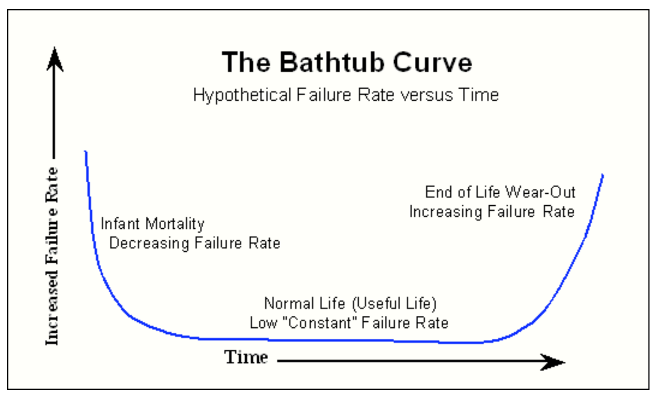
Reliability is defined the probability that a component, device, system, or process will perform its intended function without failure for a given time when operated correctly in a specified environment. Reliability deals with reducing the frequency of failures over a time interval and is a measure of the probability for failure-free operation during a given interval, i.e., it is a measure of success for a failure free operation. It is often expressed as

$$R(t) = \exp(-t/MTBF) = \exp(-\lambda t) \quad \ldots\ldots\ldots\ldots(1)$$

where λ is constant failure rate and MTBF is mean time between failure. MTBF measures the time between system failures and is easier to understand than a probability number. For exponentially distributed failure modes, MTBF is a basic figure-of-merit for reliability (failure rate λ, is the reciprocal of MTBF). Also reliability may be the product of many different reliability terms such as-

R = Rutilities * Rfeed-plant * Rprocessing * Rpackaging * Rshipping

The life of a population of units can be divided into three distinct periods. Figure 1.1 shows the reliability "bathtub curve" which models the cradle to grave instantaneous failure rates vs. time. This way wear out should never occur during the useful life of a module.



1.1 Mean Time between Failures (MTBF)

Reliability is quantified as MTBF (Mean Time Between Failures) for repairable product and MTTF (Mean Time To Failure) for non-repairable product. A correct understanding of MTBF is important.

A power supply with an MTBF of 40,000 hours does not mean that the power supply should last for an average of 40,000 hours. According to the theory behind the statistics of confidence intervals, the statistical average becomes the true average as the number of samples increase. An MTBF of 40,000 hours, or 1 year for 1module, becomes 40,000/2 for two modules and 40,000/4 for four modules.. The formula for calculating the MTBF is-

$$\theta = T/R. \quad \ldots\ldots\ldots\ldots\ldots..(2)$$

θ= MTBF (Mean time between failures)
T = Total time
R = Number of failures

MTBF calculations do not consider suspensions whereas MTTF does. MTTF is the number of total hours of service of all devices divided by the number of devices. It is only when all the parts fail with the same failure mode that MTBF converges to MTTF.Then the formula for calculating the MTTF is-

$$\gamma = T/N \quad \text{……………….. (3)}$$

γ= MTTF (Mean time to failure)
T = Total time
N = Number of units under tes

2 Diagram based model for reliability analysis.

In system reliability analysis, it is important to model the relationship between various items as well as the reliability of the individual items in order to determine the reliability of the system as a whole. Diagram-based models provide a visual representation of the system and permit a better understanding of the target system. The visual (or physical) representation of an item that belongs to a system is often used to model system reliability. Diagram-based models involve Reliability Block Diagrams (RBDs), Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Decision Tree Approach (DTA) and Root Cause Analysis (RCA) that are frequently used for reliability analysis.

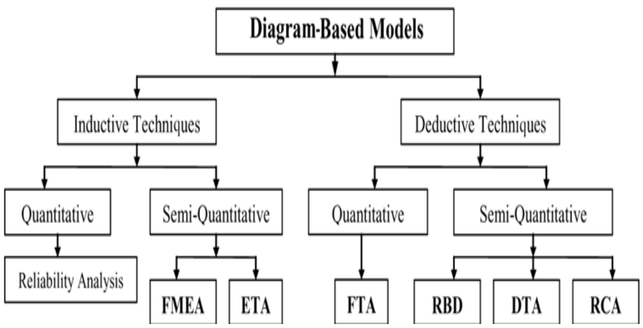


Fig. 2.1 Reliability block diagrams

System modeling tools can help you calculate the reliability, availability, and cost metrics of systems with complex interdependent component relationships. Relex OpSim provides the block diagram and phase diagram tools for system modeling combined with powerful optimization and simulation analysis techniques. Easy, intuitive graphical tools and a wide selection of maintenance-related calculations let you model complex system configurations including those with parallel, load-sharing, and standby redundancy types. Determine optimal values for spares, preventive maintenance intervals, and inspection intervals while accounting for multiple facets of component maintenance, such as spares availability, personnel requirements, and degradation factors.

2.1 Failure modes and effects analysis (FMEA)

A failure modes and effects analysis (FMEA) pronounced fah-me-ah, is a procedure in operations management for analysis of potential failure modes within a system for classification by severity or determination of the effect of failures on the system. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry. *Failure modes* are any errors or defects in a process, design, or item, especially those that affect the customer, and can be potential or actual. *Effects analysis* refers to studying the consequences of those failures.

2.2 Types of FMEA

Process: analysis of manufacturing and assembly processes
Design: analysis of products prior to production
Concept: analysis of systems or subsystems in the early design concept stages
Equipment: analysis of machinery and equipment design before purchase
Service: analysis of service industry processes before they are released to impact the customer
System: analysis of the global system functions

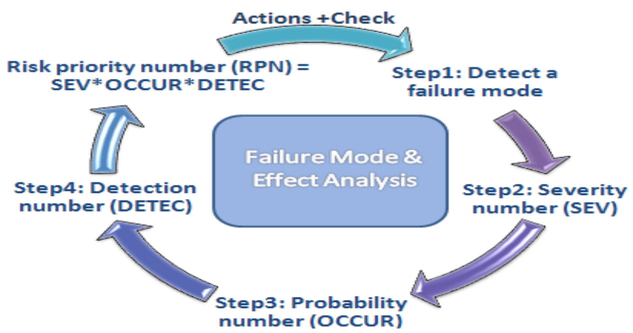


Fig. 3.2 FMEA

2.3 Element of FMEA

1. Failure mode: "The manner by which a failure is observed; it generally describes the way the failure occurs."
2. Failure effect: Immediate consequences of a failure on operation, function or functionality, or status of some item
3. Indenture levels: An identifier for item complexity. Complexity increases as levels are closer to one.
4. Local effect: The Failure effect as it applies to the item under analysis. Next higher level effect: The Failure effect as it applies at the next higher indenture level.
5. End effect: The failure effect at the highest indenture level or total system.
6. Failure cause: Defects in design, process, quality, or part application, which are the underlying cause

of the failure or which initiate a process which leads failure.

7. Severity: "The consequences of a failure mode. Severity considers the worst potential consequence of a failure, determined by the degree of injury, property damage, or system damage that could ultimately occur."

2.4 Reliability Analysis Procedures

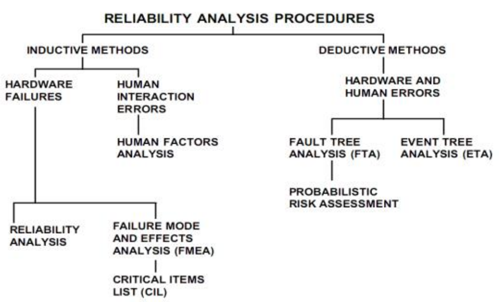


Fig.3.3 Reliability Analysis Procedures

Step 2.4.1: Severity---Determine all failure modes based on the functional requirements and their effects. Examples of failure modes are: Electrical short-circuiting, corrosion or deformation. It is important to note that a failure mode in one component can lead to a failure mode in another component. Therefore each failure mode should be listed in technical terms and for function. A failure effect is defined as the result of a failure mode on the function of the system as perceived by the user. In this way it is convenient to write these effects down in terms of what the user might see or experience. Examples of failure effects are: degraded performance, noise or even injury to a user.

Step2.4.2:Occurrence---- In this step it is necessary to look at the cause of a failure and how many times it occurs. This can be done by looking at similar products or processes and the failures that have been documented for them. A failure cause is looked upon as a design weakness. All the potential causes for a failure mode should be identified and documented.

Step 2.4.3: Detection--When appropriate actions are determined, it is necessary to test their efficiency. Also a design verification is needed. The proper inspection methods need to be chosen. First, an engineer should look at the current controls of the system, that prevent failure modes from occurring or which detect the failure before it reaches the customer.

2.5 Uses of FMEA

Development of system requirements that minimize the likelihood of failures. Development of methods to design and test systems to ensure that the failures have been eliminated. Evaluation of the requirements of the customer to ensure that those do not give rise to potential failures. Identification of certain design characteristics that contribute to failures, and minimize or eliminate those effects. Tracking and managing potential risks in the design. This helps avoid the same failures in future projects.

Example-

Table 3.5.1 FMEA Table For Ball-Pen

Part	Function	Potential Failure Mode	Potential Effect of Failure	SEVERITY	Potential Cause of Failure	OCCURRENCE	Failure Detection	DETECTION	RPN	ACTIONS
Outer Tube	Provide Grip for writer	Hole gets Blocked	Vaccum on ink Supply Stops flow	7	Debris Incress Into hole	3	Check Clearance Of hole	5	105	Make hole larger
Ink	Provide Writing medium	Incorrect Viscosity (Low)	High Flow	4	Too Much Solvent	2	QC on ink supply	4	32	Introduce More Rigid QC
Ink	Providing Writing medium	Incorrect Viscosity (High)	Low Flow	4	Too Little Solvent	2	QC on ink supply	3	24	Introduce More Rigid QC

3 Benefits

Improve the quality, reliability and safety of a product/process, Improve company image and competitiveness, Increase user satisfaction ,Reduce system development timing and cost .

Collect information to reduce future failures, capture engineering knowledge ,Reduce the potential for warranty concerns ,Early identification and elimination of potential failure modes ,Emphasize problem prevention ,Minimize late changes and associated cost ,Catalyst for teamwork and idea exchange between functions ,Reduce the possibility of same kind of failure in future ,Provides a wide range of system metrics, including Failure Rate, MTBF, MTTF, Reliability, and Availability, among others.,Model your complete operational profile using phase modeling ,Specify a calculation goal: minimize costs, maximize reliability, or maximize capacity ,Assign costs to various capacity levels ,Simulation log visually represents failures over time as each simulation is performed.

4 Limitations

Since FMEA is effectively dependent on the members of the committee which examines product failures, it is limited by their experience of previous failures. If a failure mode cannot be identified, then external help is needed from consultants who are aware of the many different types of product failure. FMEA is thus part of a larger system of quality control, where documentation is vital to implementation. General texts and detailed publications are available in forensic engineering and failure analysis. It is a general requirement of many specific national and international standards that FMEA is used in evaluating product integrity. If used as a top-down tool, FMEA may only identify major failure modes in a system. Fault tree analysis (FTA) is better suited for "top-down" analysis. When used as a "bottom-up" tool FMEA can complement FTA and identify many more causes and failure modes resulting in top-level symptoms.

5 Conclusions

Reliability engineering has come a long way over the last six decades and will go further to meet increasing global competition and customer expectations. The future thrust areas which need further research work by the researchers in the area of reliability engineering can be uncertainty quantification, failure analysis of complex systems and life testing of equipments.

5.1 Uncertainty quantification

The greatest risk (uncertainty) associated with reliability predictions is the variability or non-deterministic nature of the distribution parameters. This variability is further enhanced by three types of deviations in product design, parameters and/or characteristics. The first type of deviation occurs from permanent changes in product design or features.

5.2 Failure analysis of complex systems

The increasing efforts to improve time-to-market and enhance product functionality are throwing different challenges to reliability community. Traditional failure analysis tools (including FMEA) provide a valuable way to the incorporation of latest technological advancement into new designs resulted in more complex product designs. This increased product complexity leads to an emergence of unpredictable failure behavior. These pressures and ever increasing competition in global market are challenging reliability community to devise more efficient and effective failure analysis methods.

5.3 Reliability testing

Testing for reliability is about exercising an application so that failures are discovered and removed before the system is deployed. Because the different combinations of alternate pathways through an application are high, it is unlikely that you can find all potential failures in a complex application. However, you can test the most likely scenarios under normal usage conditions and validate that the application provides the expected service. As time permits, you can apply more complicated tests to reveal subtler defects.

6 References

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