Methods of Reliability Prediction for Heavy Earth Moving Machineries in Surface Mine: A Review

[1]Harish Kumar N S, [2]R. P. Choudhary, [3]Ch. S. N. Murthy
[1]Research scholar
[2]Assistnt Professor
[3]Professor
[1, 2, 3,] Department of Mining Engineering, National Institute of Technology Karnataka, Surathkal - 575025, India

Abstract: Now a day, achieving the good production and productivity target is one the major challenge for mining industries and also in order to remain competitive in the global market. Such as it entails proper performance measurement of huge and capital-intensive equipment completely based on reliability, availability and maintainability of the equipment through the mining industrial automation. Reliability is one of the most efficient and important to study safe operation probability and to find the failure rate of the critical part in heavy earth moving machinery. In the present paper, the aim is reviewing the basic concepts to reliability analysis of any component and methods of reliability prediction. And also the intent of this reviewed paper is to provide the understanding of Mean time between failures (MTBF), Mean time to failure (MTTF), Mean time to repair (MTTR) and also life cycle prediction of the component.

Index Terms - Reliability, availability, maintainability, probability, failure rate, heavy earth moving machineries, mean time between failures, mean time to failure.

1. INTRODUCTION

1.1. Reliability

Reliability is the probability of failure in the function of equipment and processes when they are operating correctly in a given time interval under the stated condition [1]. Product reliability is quantified as MTBT for repairable product and MTTF for the non-repairable product. Reliability analysis during the design, production, and development of critical components and the system are important to detect and eliminate reliability weakness as early possible and to perform comparative studies. Such as failure rate and failure mode of analysis, verification of the adherence to design guidelines and cooperation in design reviews. Reliability of the components has both quantitative and qualitative aspects measurement of reliability is necessary for customer requirements compliance. However measuring reliability does not make a product reliable, only by calculating the failure rate of the component and designing in reliability can component achieve its reliability target [2]. Therefore the reliability of the equation is given by Eq. (1)

$$\text{Reliability} = e^{-(Time\ /MTBF)} \qquad (1)$$

1.2. The Bathtub Curve

The lifespan of any critical part of the components can be divided into three different modes such as 1st phase, 2nd phase and 3rd phase. Figure 1.1 shows the reliability bathtub which model having an instantaneous failure rate of the components versus time taken to failure [3].

i) 1st phase (Decreasing failure rate): 1st phase of the bathtub curve are also called as infant mortality period. If we follow the slope of the line from the start to where it begins to flatten out this can be considered the first period. The first period is indicated by a decreasing failure rate of the components. In this period failure occurs in molecular and microstructural level or else production level during the early life of a population of the components.

ii) 2nd Period (constant failure rate): 2nd phase of the bathtub curve are also called as normal life period. In this period we can able to see the straight line portion of the graph. Failure occurs more in random sequence during this time. In this period difficult to predict the failure mode of the components, but the failure rate is predictable. Notice that constant slop.

iii) 3rd Period: (increasing failure rate): 3rd phase begins at the point where the slope starts to increase and extends to the end of the graph. This is what happens when becoming old and begin to fail at an increasing rate.

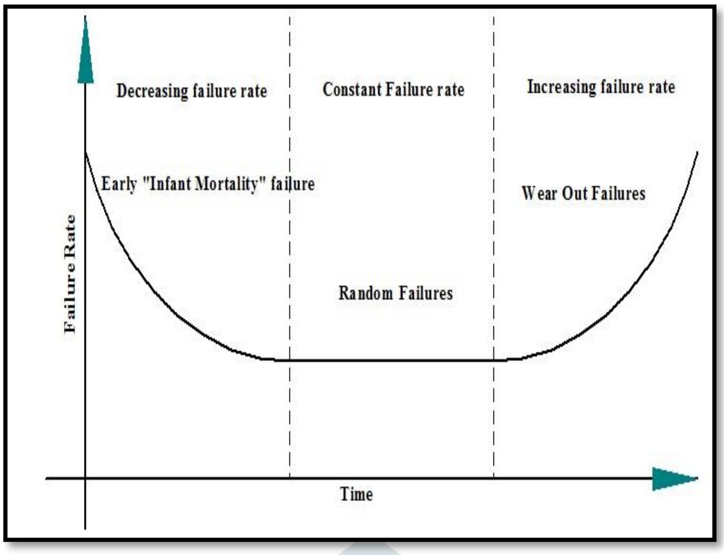

Fig 1.1Bathtub Curve

1.3. Availability, MTBF and MTTF

MTBF impacts both reliability and availability. Before MTBF explained it is important to have a foundation of this concept reliability and availability.

i) Availability: Availability of any components or system is defined as the probability that the system is operating at a time t_o, given that it was operating at time zero. Availability can be viewed as the like hood that the system or component is in a state to perform its required function under given conditions at a given instant of time. Availability is determined by system reliability, as well as its recovery time when a failure does occur. When a system has long continued operating time, failure is unpreventable. Availability is often looked at because when failure does occur. Therefore the availability of the equation is given by Eq. (2)

$$\text{Availability} = \frac{MTBF}{MTBF+MTTR} \qquad (2)$$

If MTBF goes up, availability goes up and if MTTR goes up, availability goes down.

ii) MTBF: The MTBF is the basic measure of the system reliability. It is defined as the ratio of a number of the test samples to the number of the failure of components. It is given by Eq. (3)

$$\text{MTBF} = \frac{No.\ of\ Samples}{No.of\ failures} \qquad (3)$$

iii) MTTF: It is a basic measure of the reliability for the non-repairable system. It is the meantime expected until the first failure of the subsystem of the equipment.

iv) MTTR: MTTR is impacted on availability, not on reliability. If it takes a longer time to recover the system from failure, the system is going to have lower availability.

v) Failure rate: the failure rate of a component or system is defined as the probability per unit time that the component or system experience a failure at the time [3 & 4].

2. RELIABILITY PREDICTION METHODS

2.1 Reliability Prediction Basics

Reliability prediction is one of the most common forms and plays a very important role in reliability analysis. Reliability prediction predicts the failure rate of the system and subsystem of the components and overall system reliability. The reliability prediction is also used to find the failure rate of the components, design feasibility, compare design alternatives, identify potential failure area, a design factor of the components and track reliability.

2.2 Role of reliability prediction

Reliability prediction has many roles in the reliability engineering process. The impact of the proposed design change on reliability is determined by comparing the reliability prediction of the existing and proposed design. The ability of the design to maintain an acceptable reliability level under environmental extremes can be accessed through reliability prediction.
Today there are numerous method of predicting reliability or MTBF, they are

i) Part count prediction: it is generally used to predict the reliability of a product early in the product development cycle to obtain a rough reliability estimate relative to the reliability specification. A failure rate is calculated by literally counting similar component of a product and grouping them into the various component types. the number of component in each group is then multiplied by a generic failure rate. Lastly, the failure rates of all the different part groups are added together for the final failure rate. By definition, part count assumes all components are in series and required that failure rates for non series component are calculated separately.

ii) Part stress analysis prediction: it is usually used much later in the product development cycle when the design of the actual component. It is similar to the part count in the way the failure rates are summed together. However, with part stress, the failure rate for each and every component is individually calculated based on the specific stress level of the component is subjected to the fatigue load on the components. In order to assign the proper stress level to each component, a product design and its expected environment must be well documented and understood. The part stress methods usually yield a lower failure rate than the part count method. Due to the level of analysis required, this method is extremely time-consuming compared to other methods.

iii) MIL–HDBK-217: today rarely used reliability prediction method is MIL–HDBK-217. In 1996 the U S army announced that the use of MIL–HDBK-217 should be discontinued because it has been shown to be unreliable and its use can lead to erroneous and misleading reliability prediction. MIL–HDBK-217has been cast off for many reasons, most of which have to do with the fact that component reliability has improved greatly over the year to the point where it is no longer the main drive in product failure. The failure rate is given in MIL–HDBK-217 are more conservative than the electronic component available today.

iv) Telcordia: The Telcordia reliability prediction model evolved from the telecom industry and has made its way through a series of change over the year. It was first developed by Bellcore communication research under the name Bellcore as a means to estimate telecom equipment reliability. Basically, the Bellcore was based on MIL–HDBK-217; its reliability models were changed in 1985 to reflect field experience of their telecom equipment. Today Telcordia continues to be applied as a product design tool within this industry.

v) HRD5: HRD5 is the handbook for reliability data for an electronic component used in a telecommunication system. HRD% was developed by British telecom and is used mainly in the UK. It is similar to MIL–HDBK-217 but doesn't cover as many environment variables and provides a reliability prediction model that covers a wider of an electronic component including telecom.

vi) RBD (Reliability Block Diagram): the RBD is a representative drawing and calculation tool that is used to model system availability and reliability. The structure of a reliability block diagram defines the logical interaction of failure within a system and not necessarily their logical or physical connection together. Each block can represent an individual component, subsystem or another representative failure. The diagram can represent an entire system analysis or any subset or combination of the system which requires failure, reliability or availability analysis. It also serves as an analysis tool to show how each element of a function and how each element can affect the system operation as a whole.
An RBD performs the system reliability and availability analysis in mines on the large and complex system by using the block diagram to show the connection between systems. The RBD define the logical interaction of failure analysis within the system during operation. The RBD may be developed manually or using stander software like a realist.
An RBD is a drawing and calculation tool used to model complex systems. An RBD is a series of subsystems representing portions of a system. Once the system is configured properly and complete system data is provided such as the failure rate, MTBF, reliability, and availability of the system can be calculated. As the configuration of the diagram changes, the calculation results also change.
The RBD system is connected by a parallel or series configuration is as follows

1. Series Connection
2. Parallel connection

This paper provides a survey of the RBD based reliability analysis techniques while highlighting their strengths and weaknesses of the system in mining equipment's [5].

vii) FMEA/FMECA: Failure Mode and Effect Analysis is a process used for analyzing the failure modes of a product. This information is then used to determine the impact each failure would have on the product, thereby leading to an improved product design. The analysis can go a step further by assigning a severity level to each of the failure modes in which case it would be called FMECA (Failure Mode, Effective and Criticality Analysis). FMEA uses a bottom to top approach of any components [5].

viii) Fault Tree: fault tree analysis is a technic that was developed by Bell Telephone Laboratories to perform a safety assessment of the Minuteman Launch Control system. It was later applied to reliability analysis. Fault tree method can help the detail of events, both normal and fault related, that lead down to the component level fault or undesired event that is being investigated. Reliability is calculated by converting the completed fault tree into an equivalent set of equations. This done by using the algebra of events, also referred to as Boolean algebra. Like FMEA, the probability data for the calculation can be difficult to obtain.

Fault Tree Analysis directly focuses on the modes of failure, which is a more effective method than system reliability block diagram. Symbols used in FTA are easy to understand. The tool helps identify areas of concern for new product design or for improvement of existing products and failure system in earth movers in the minis. It also helps identify corrective actions to correct or mitigate problems. Failure data analysis helps to reduce considerable LCC (Life Cycle Cost).

The methodology of Fault Tree is to analysis the reliability is as follows

As computer programming and simulation has become a very useful tool in reliability. In given data set of correlation and equation can be developed that can be used alone with the simulation to predict the failure rate of the earth movers in mines for newly designed or else underdeveloped systems. The simple methodology of the reliability by using fault tree analysis as shown in figure 2.1 [6]. If any component is assumed to be the top event then the probable causes my included the stresses on the components, pressure, road conditions, proper maintenance etc. The failure rate for this parameter can be found and the remaining may be acquired by using the fault tree analysis in computer simulation [7].

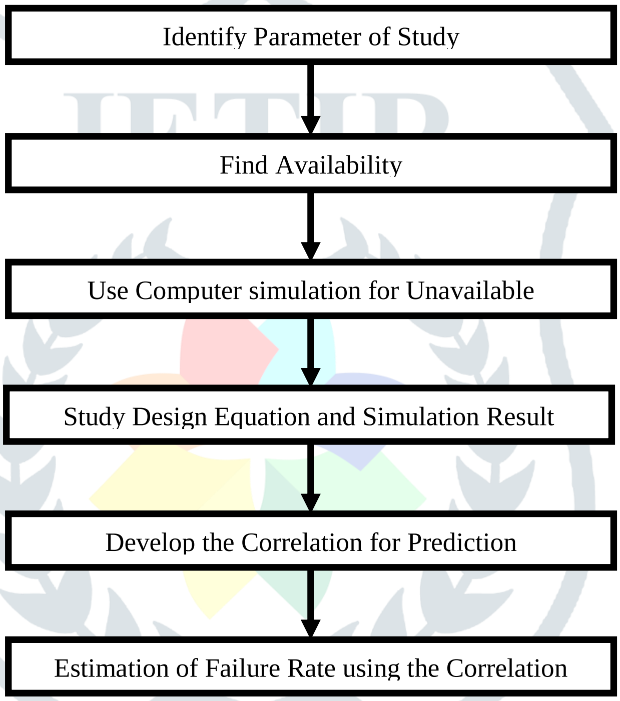

Fig. 2.1 Methodology reliability analysis by using fault tree analysis

ix) HALT: Highly Accelerated Life Testing (HALT) is a method used to increase the overall reliability of a product design. HALT is used to establish how long it takes to reach the literal breaking point of a product by subjecting it to carefully measured and controlled measured stresses such as temperate and vibration. A mathematical model is used to estimate the actual amount of time it would have taken the product to fail in the field. Although HALT can estimate MTBF, its main function is to improve product design reliability.

3. CONCLUSION

This paper explored the reliability, Availability and maintainability evaluation and analysis methods of the heavy earth machinery in surface mine to facilitate the surface mining. This paper focuses on the prediction method of the RAM to evaluate the failure rate, MTBF, MTTF and MTTR using the parametric and non-parametric analysis technics. Generally, this paper is contributed to the bunch of knowledge for heavy earth machinery maintenance and also important thing is, we can able to select the best method of Reliability prediction to analyses the reliability and failure analysis of critical systems in heavy earth machinery in mines.

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Author 1

Harish Kumar. N. S completed her B. E in 2010 and M. Tech in 2012.He is pursuing Ph. D on Reliability Engineering in Department of Mining Engineering, National Institute of Technology Karnataka, Surathkal – 575025

harishkumarns11@gmail.com

Author 2

Dr. R. P. Choudhary, Assistant Professor, Department of Mining Engineering, National Institute of Technology Karnataka, Surathkal - 575025 awarded his Ph.D. from J.N.V. University, Jodhpur, 2009.

rpkhokhar@yahoo.co.in

Author 3

Dr. Ch. S. N. Murthy, Professor, Department of Mining Engineering, National Institute of Technology Karnataka, Surathkal - 575025 awarded his Ph.D. from IIT Kharagpur, 1999.

chsn58@gmail.com