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A Cost-effective Approach to Reliability Prediction and Analysis of Mechanical Systems

US Department of Defense Directive-Type Memorandum 11-003 – Reliability Analysis, Planning, Tracking, and Reporting

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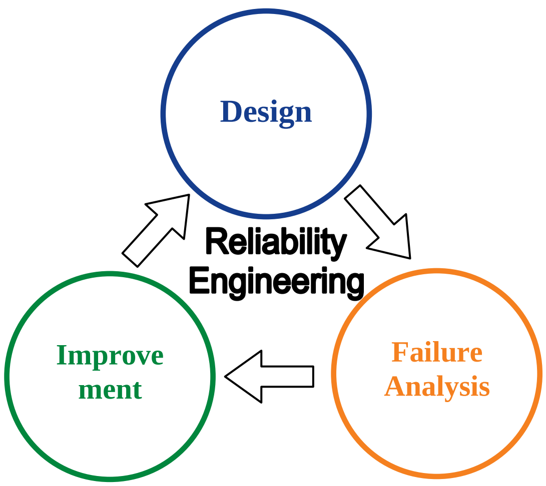
Introduction

In 2011, the US Department of Defense issued directive memorandum (DTM) 11-003 with the goal of reducing the cost of acquired military systems through improved reliability. These costs are typically incurred through routine maintenance, field failures, and replacement of systems and components. The directive requires that reliability be tracked throughout a product's lifecycle, beginning at the design/development phase and continuing through testing/demonstration, deployment, and field operation. Program managers are encouraged to perform reliability analyses early in the acquisition process (at the design phase), as changes made later in the test, analyze, and fix stage (TAAF), become more costly. In the following paper, we seek to inform the program manager of one approach to the reliability prediction and analysis process, specifically as it applies to the development phase of a mechanical system.



What is a Reliability Analysis?

A reliability analysis is a method that seeks to predict the amount of time at which a system component or assembly is likely to fail. It is a statistical approach that considers the type of loads and environmental conditions that a system will be subjected to in the field. These operating conditions may be coupled with engineering calculations that compare the level of stress experienced by the system under normal operating conditions to stress levels at which failure is likely to occur. Where stress data is unavailable or not feasible, an alternative reliability prediction method is often utilized and is referred to as the parts count method. The parts count method predicts reliability through published, field collected data from identical or similar systems. In rare cases, reliability data may be provided by the manufacturer for stock components or systems. Whether provided manufacturer reliability data, or implementing the stress-based or parts count method, the final result is typically a mean time between failure value (MTBF), which is the statistical average time in which a component or system is expected to fail.

How is a Reliability Analysis Useful?

During the design and development phase, a reliability analysis can be used to estimate the mean time between failure of a system and then be compared to performance goals. It may also be used to assess how design changes may improve or detract from the reliability of the overall system. When designing two or more similar systems, it may be used to evaluate similar designs and predict which may be the most reliable. In later phases of a product's lifecycle, reliability may be correlated with test and field data and used as a tool for tracking reliability progress, and/or used as part of a maintenance program.

Reliability Analysis Requirements

Prior to performing a reliability analysis, DTM-11-003 requires that a Design Failure Modes Effects Analysis (DFMEA) and a Failure Modes, Effects and Criticality Analysis (FMECA) be performed. A DFMEA is basically a brainstorming task used to explore and document ways that a design might fail in a real-world application. Likewise, FMECA is an extension of the DFMEA, assigning a likelihood of failure to each component/assembly and also predicting the consequential severity of failure. The two, above analyses feed into a reliability prediction analysis, allowing the engineer to determine which parts are most critical to the reliability of the system. Other data required to perform a reliability analysis may include mission profiles and environmental conditions. A mission profile is a statistical definition of environmental stresses and materiel duty cycle versus time. Information such as vibration/shock loads, duty cycle, and mission length are included in mission profiles. Likewise, environmental conditions such as temperature, humidity, and contaminant exposure may be specified.

Brief Example of a Reliability Analysis Performed on a Military Vehicle Seat

A military vehicle supplier is in the process of designing a new armored personnel carrier vehicle. The customer has provided a mission profile specifying the typical mission speed and distance. Road vibration characteristics, and shock magnitude and frequency produced during cannon fire are also provided. No test or field data is available since the seat is a new innovation. Also, the supplier would like for Proof Engineering to perform a DFMEA and FMECA prior to the reliability analysis, as well as a finite element analysis (FEA) of the seat.

After receiving details of the design, a DFMEA and FMECA analysis are performed in order to identify key failure modes and the consequential severity of each failure. These tools are helpful in determining which components and systems should be analyzed using a mechanical stress-based approach and which should be analyzed using the parts count method.

An FE analysis is performed on the seat system for various loading conditions including vibration and shock. Stress levels of components and assemblies are recorded, and using a fatigue model, reliability predictions are made.

Considering parts analyzed by the parts count method, NPRD-2011 and NSWC-98 field data are referenced and reliability results are determined.

Results from each of the methodologies are compiled to produce a mean time between failure for the entire seat system. Also, based on the average driving speed, a mean distance between failure (MDBF) value is predicted in terms of miles driven.

Based on the analysis, it is determined that the seat meets customer reliability targets, but several recommended changes may greatly improve the predicted performance. Changes such as using weld nuts in lieu of standard nuts and washers and replacing rubber components with nylon increase the MDBF by 5,000 miles.

Following the completion of the analysis, the customer is provided with a reliability report and supporting documentation to satisfy (DTM) 11-003 requirements.