Modeling and Simulation (M&S) Impact on Reliability

Basic Thoughts

Briefing for:

Ground Vehicle Reliability

Panel

DoD Maintenance Symposium

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Current State of Reliability

Top Level Managements Assessment

6 Dec 07 – Assistant Secretary of the Army (Acquisition, Logistics and Technology) --- Reliability MEMO to Army PEOs/PMs

Emerging data shows that a significant number of US Army systems are failing to demonstrate established reliability requirements during operational testing and many of these are falling well short of their established requirement.

21 Jul 08 – Under Secretary of Defense (Acquisition, Logistics and Technology RAM MEMO to Acquisition Executives

In recent years, there has been an increasing trend within the Department of weapon systems not achieving the required reliability during development testing and subsequently being found unsuitable during Initial Operational Test and Evaluation. Also, higher than anticipated ownership cost points to insufficient reliability engineering activities and logistics planning during the program acquisition phase. This trend indicates that RAM was not adequately designed into systems.

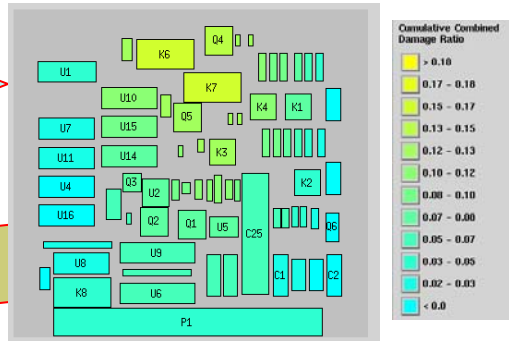
Reliability Improvement Needed Now

Consider the Use Physics of Failure (PoF) in Materiel Design

The ultimate long term goal is for DoD system developers to consistently predict & design-in reliability at the system and component levels

Proven successful with high Return on Investment

Electronic PoF



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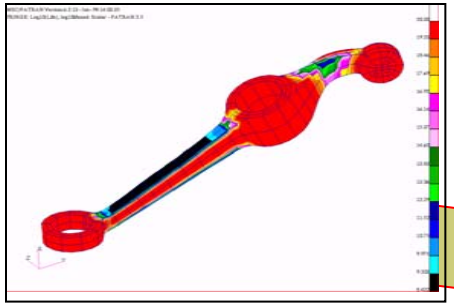
Mechanical PoF



Required for Ultra-reliability required in AAN

Ultra-Reliable System

Increase Reliability

Reduce O&S Costs

Focus Testing

Increase Readiness

Supports RCM

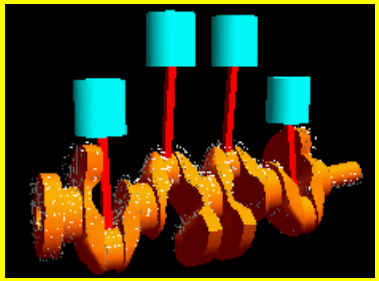
Support CBM+

PoF-Based M&S Analysis Focuses on Fatigue

Analytical Elements of Mechanical PoF

<u>PoF Design Objective:</u> Identify the fatigue spots on critical components, iteratively modify the design of the those components to assure Ultra High Reliability

Solid Modeling Tool

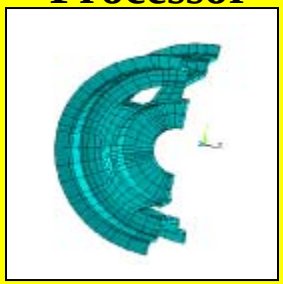


<u>Examples:</u>
- Pro/Engineer
- I-deas
- Solid Works

Dynamics Simulation Tool

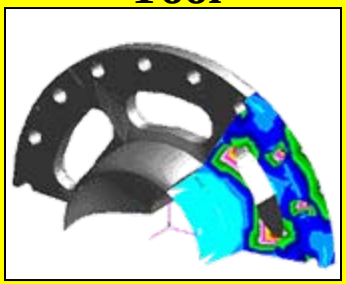
<u>Examples:</u>
- DADS
- ADAMS

FEA Tool w/Pre & Post Processor



<u>Examples:</u>
- NASTRAN
- ABAQUS
- ANSYS
- Pro/Mechanica

Fatigue Analysis Tool

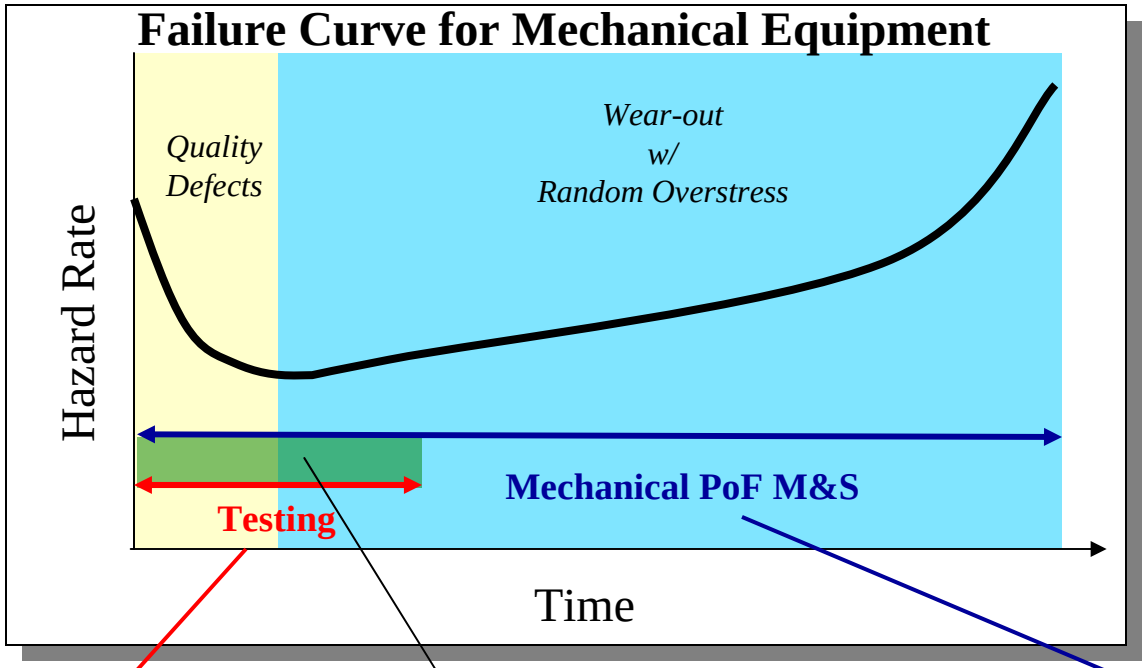


<u>Examples:</u>
- MSC/Fatigue (N-Code)
- U.of Iowa DRAW
- LMS FALANCS

An integration of these tools

The Focus of Mechanical PoF-based M&S

Predicting early in the design process what testing can not afford to reveal



Main causes of mechanical wear-out:
- **Fatigue**
- Wear
- Corrosion

Reliability testing reveals only a fraction of the failures of the total materiel life cycle

This overlap is where testing can be focused using Mechanical PoF M&S

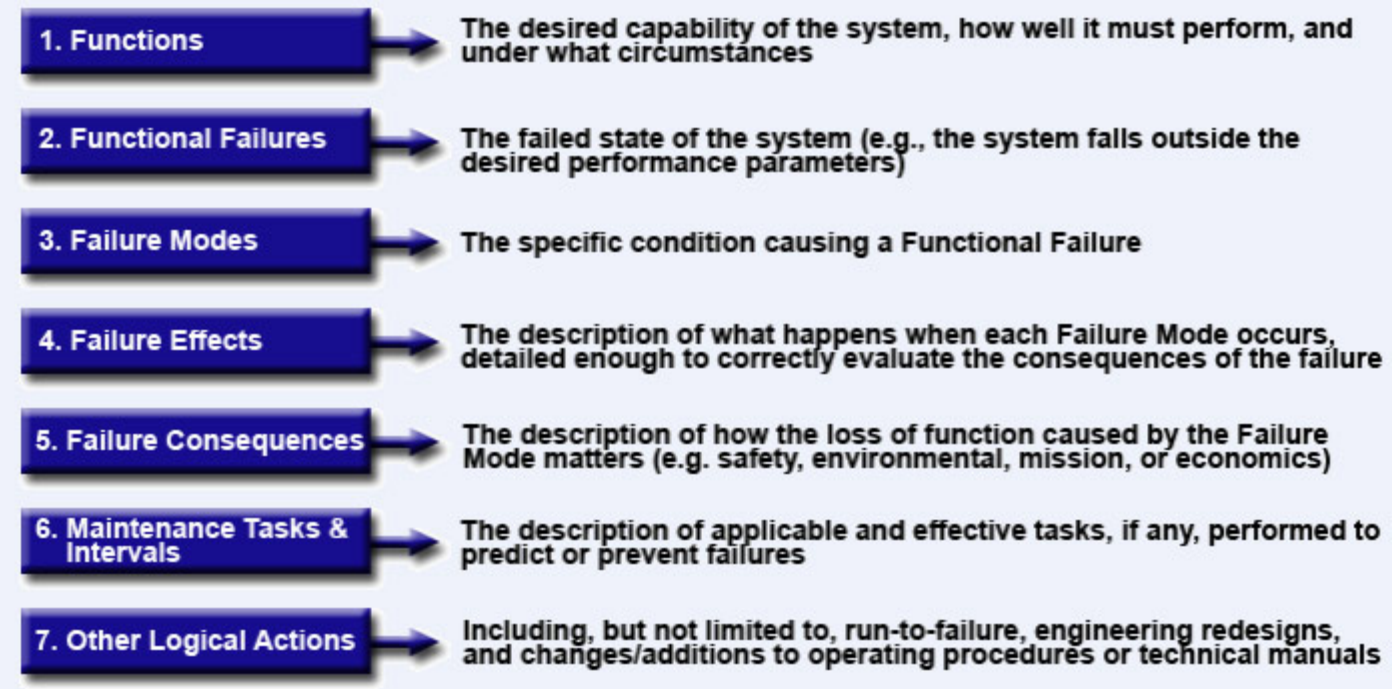
Mechanical PoF M&S:
Main focus is on understanding and predicting wear-out failures throughout the entire materiel life cycle

Mechanical PoF is required to assess life cycle reliability

Reliability Centered Maintenance (RCM)

Most Weapon's Component Can Not be Designed to Last the Life Cycle

The purpose of Reliability Centered Maintenance (RCM) is to formulate Failure Management Strategies that allow assets to continue operating at the users' **desired level of reliability performance** as opposed to what the asset was designed to do. The DoD-approved RCM process includes identifying the following items in sequence.



PoF helps in defining maintenance intervals – #6

How can PoF Help RCM

Predicting Failure: On-Condition

On-Condition tasks are performed to identify signs of impending failure and can be performed using:

- Human senses
- Sophisticated monitoring equipment; or
- Continuous monitoring by sensors being applied directly to equipment – **Condition Based Maintenance**

Examples of On-Condition tasks are:

- Performing vibration analysis: detects increased vibration signatures.
- Taking oil samples: Sample results indicate increased water content and additive depletion.
- Measuring brake pads: Identifies how much of the pad is remaining.
- Monitoring # duty cycles endured by key components

The point of an On-Condition task is to identify when action is required **based on the evidence of need** (e.g. detection of the Potential Failure Condition). How often an On-Condition task is performed depends on the P-F Interval. Following is a discussion of the P-F Curve and the P-F Interval.

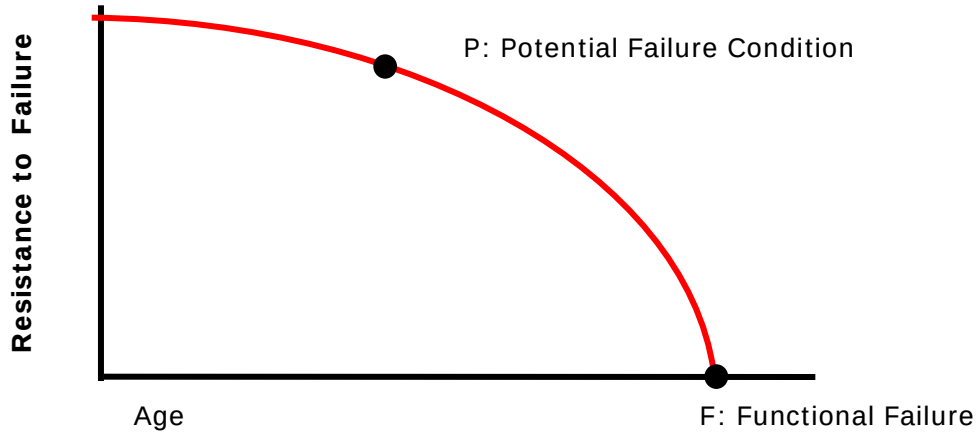
PoF can help in defining the P-F Interval

What can PoF- do for RCM

Predicting Failure: The P-F Curve

This graph depicts the P-F Curve. The graph below is a typical wear out example such as brake pads. The X axis is "**Age"**, which can be measured in any number of units such as calendar time, miles, operating hours, cycles, etc. The Y axis is "**Resistance to Failure**."

- P is the *Potential Failure Condition*, defined as evidence of an impending failure.
- F is the **Functional Failure**, as defined by the user.



Use PoF to define the P-F Curve for Critical Components

Condition Monitoring's Basic Problem

Not All Duty Cycles are not Created Equal

"Because of the limitation of sensor sample rates and data storage on in-service vehicles, algorithms and metrics need to be developed that would use simplified counting schemes to compare actual damage cycles on in-service vehicles to pre-calculated damage from various environmental conditions as calculated by PoF failure mechanism models."

Approach:

- **Categorize mission scenarios (primary, secondary, etc) and run PoF for each**
- **Initialize damage accumulation model with mission scenario results**
- **On-board sensors used to determine duration of each scenario**
- **Transfer sensor data to damage accumulation models**
- **Damage accumulation models keeps running total % of life is used**
- **Spare parts ordered and maintenance performed before component failure**

Accurately Account for Wear to Check Against the P-F Curve

Use M&S Driven Mechanical PoF
A Helper in Achieving High Reliability

Use M&S driven PoF Design Analysis to:

1) **Initially Find the High Reliability Configuration**
2) **Define RCM P-F Curve to Ascertain When a Critical Component Need to be Replaced**
3) **Develop Damage Accounting Algorithms for Condition Monitoring of Critical Components**

Comments/Questions??