



# Tutorial Abstracts

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## Tutorial Abstract and Outline

### 'Fracture Analysis for Maintenance Engineers'

Debbie Aliya, Aliya Analytical

This seminar will go over the basics of determining whether single or repeated loads caused fracture. It will also discuss how to tell what stress type (stretching, squeezing, bending or twisting) causes what shape of component fragments for basic geometries, including cylinders, plates, and solid rectangular shapes, when the material involved is ductile (such as mild steel) and when it is a brittle material (such as cast iron). The value of doing additional tests in certain circumstances will also be described. One use of this information would be to give the maintenance engineer tools to determine whether failures are normal or possibly due to poor design, in a fact based way that can be presented to equipment manufacturers. Machine designers could also benefit from this material.

1. Introduction
  - a. What is fracture?
    - i. Process of separation of atomic bonds
    - ii. Creates fragments where a single piece existed prior
    - iii. Often associated with extensive deformation
      - (1) deformation makes many materials more forgiving of both imperfections and excessive loads than they otherwise would be
    - iv. Both deformation and fracture are crystallographic processes
      - (1) they can only occur along certain directions with respect to the crystal
    - v. Many wear processes are actually "micro-fracture" events
    - vi. Corrosion influences in fracture
  - b. Once a crack starts, it will either stay the same size or get bigger
    - i. Cracks can grow in a stable manner or an unstable manner
      - (1) Stable cracks are allowed to propagate in airplanes
      - (2) Unstable cracks grow at a speed which is unstoppable EVEN IF LOAD IS REMOVED!
        - (a) speed of sound in the medium
        - (b) driven by stored energy (elastic strain, atomic bonds acting like springs)
    - ii. Once a crack starts, the initial stress analysis can get thrown out the window....
  - c. Cracks are usually undesirable in machinery
    - i. Cracks sometimes have "a cause" (such as unanticipated service condition)
    - ii. Cracks usually have multiple factors which allowed them to happen

2. Fracture analysis can often reveal or confirm the cause or some of the factors which allowed the crack to happen
  - a. If the factors which allowed the crack to happen are known, action can be taken for prevention, assignment of accountability, etc.
  - b. The appearance of the fragments can reveal a lot of information about
    - i. the type of material
    - ii. the type of loads that caused the crack
    - iii. whether there was an unusual environmental contaminant or condition (temperature)
3. To understand cracks, have to understand loading
  - a. Classification of Degree of Loading: Elastic versus Plastic
    - i. There really is no black and white cut off between elastic and plastic
      - (1) Elastic and plastic ranges for each material and PROCESS CONDITION depend on
        - (a) Loading rate
        - (b) Temperature
        - (c) Geometry!
  - b. Classification of loading types
    - i. Axial, bending, torsion and their combinations
      - (1) VERY Important to understand because each has associated characteristic fragment shape
4. There are many different types of cracks and many ways to characterize cracking events
  - a. Classification by Loading Type: Monotonic versus Cyclic
  - b. Classification by Mechanical Behavior: Ductile versus Brittle
  - c. Classification by Loading Geometry: Key to Macrofractography
  - d. KEY POINT OF FRACTURE ANALYSIS: Since most real components are either shaped or loaded in a manner to create non-uniform stresses, we can learn to PREDICT the EXPECTED CRACK LOCATION!
  - e. Another key to predicting expected fracture initiation location is that STRENGTH in addition to STRESS can vary within the part.
  - f. One more complication: Residual stresses must be added to applied stresses to really be able to predict expected crack initiation SITE
5. Environmental problems
  - a. Stress corrosion / Hydrogen Embrittlement / Corrosion Fatigue
  - b. Susceptible alloys- problem with “corrosion resistant” materials
  - c. Some of these “Damage Mechanisms” have characteristic appearances

6. Summary

- a. Fragment appearance provides information about
  - i. Material characteristics
  - ii. Loading characteristics
    - (1) rate
    - (2) geometry
  - iii. Environmental factors
- b. Additional tests are often/ usually required to determine why something broke unexpectedly with a great deal of certainty
- c. There are MANY references available which document these concepts...

## Tutorial Abstract and Outline

### Federated Architecture: Moving Beyond the Silos

Harlan Shober, RJ Lee Group Inc

The tutorial will outline the challenges with data integration between disparate systems often referred to as “data silos”. Not covered in the presentation are the reasons behind the data integration. In this respect each integration effort is different from the next. What is discussed, is how new technologies and methodologies such as federated security and Web 2.0 methods (Service Oriented Architecture or SOA) can be applied to the problem.

Within any large enterprise or amongst a group of enterprises the challenges of securely sharing data are numerous. From firewalls and VPNs to application logins there are roadblocks to sharing data. Data, in turn is virtually locked away in silos controlled and leveraged only by the data generators.

This presentation explores an enterprise architecture that helps to break down the barriers to cross domain, cross network, cross system, and cross application communication of data assets.

Federated Architecture is a term that means something different to many people. Some feel that if software is using XML it is a federated architecture. In truth, federated architecture is an implementation of a Service Oriented Architecture (SOA) centered on web services and a federation of organizational partners. It facilitates the secure communication of information assets amongst human and system members of a federation, where the terms of the information assurance and security are agreed upon when an organization joins the federation.

To see the fruits of adopting a federated architecture there are a host of technologies, philosophies, methodologies, and standards that have to be incorporated into the solution. However, value can be realized through the incremental adoption of these concepts. Throughout this presentation we will walk through a proposed path forward in the implementation of a federated architecture.

These concepts will be defined and their application demonstrated within the framework of “Moving Beyond the Silos”. We will identify and show the use of COTS, GOTS, and open source tools and how they fit into the overall process.

#### References:

- DoD. (2009) “Principles and Patterns at the U.S. Department of Defense” Published: January 19, 2009 (SOA Magazine Issue XXV: January 2009) <http://www.soamag.com/I25/0109-2.php>
- Artech House. (2003) “Role-Based Access Control” By David Ferraiolo, D. Richard Kuhn, and Ramaswamy Chandramouli

## **Tutorial Abstract and Outline**

### **Data Management Issues**

**Chris Sautter**, University of Alabama Huntsville

Data Management is appearing to become the 8,000lb gorilla that the community is needing to tame. While sophisticated tools, algorithms and capabilities have been successfully developed over the past decade for determining the health of a system and prognosing when a failure will occur in the future, the growing issues now seem to be associated with data, e.g, (a) how to handle the large volume of data from say a sizeable fleet of aircraft that can each generate Gbytes of data from each sortie, (b) what data parameters to collect and/or store (c) capably and efficiently fusing widely disparate data and (d) whether data can be artificially generated to cover missing data or gaps in datasets. This interactive discussion will elicit opinions, statements of need and offers of pertinent capabilities from participants and capture a consensus of views as well as factual information to help the community better understand the size and possible solutions to these problems.

## Tutorial Abstract and Outline

### Digitizing the Material World: Using Physics-based Computational Material Simulation to Predict Long Term Durability

Animesh Dey, Vextec

Traditional industry approaches to durability prediction have focused on gathering physical data test points and using FEA stress models. Consequently, these methods ignore the fact that not all components fail according to their FEA models, and do not take into account the material's varying response to the stresses it is subjected to. Furthermore, since these traditional methods do not differentiate for various damage mechanisms, nor do they provide a quantitative analysis in predicting the risk of failure, they make it difficult to predict the full range of performance, durability or failure. No one can afford the time or money required to physically test the complete range of in-service conditions possible; therefore engineers are forced to build in design margins or knock-down factors (often as high as 10X), which add weight, restrict operating performance, reduce efficiency, and raise operating costs.

It has now been possible to develop a more accurate, cost-effective approach to durability prediction. Simulations are built on a computational framework that utilizes physics-based material micromechanics to predict the damage state, and a probabilistic approach to variability to accurately quantify risk of failure. This approach addresses key factors that the traditional trial and error approach overlooks, namely, the variation in the material microstructure; how individual damage mechanisms combine to produce material degradation; an evaluation of stresses at the material microstructural level where damage ultimately originates rather than at the standard component level; and the variations in the manufacturing process, operating conditions and applications in use.

Simulating the microstructure — and the stress to which it is subjected — is the key to understanding how materials behave, and more importantly, predicting how they're going to behave. Using an iterative computational framework that begins with a single grain, and continues until all the millions of grains in a component are simulated and the material is calibrated — in effect, digitizing the material's behavior — it is now possible to predict, with a very high degree of accuracy, the performance, durability, failure and long-term costs of any component in a complex system, from a single part to an entire product line.

Such a system is now possible for several reasons. First, computing power has accelerated in performance and decreased in price to the point where complex simulations of this type are not only economical, but practical as well. Second, physical testing simply takes too long and costs too much, and in the end, only presents a handful of data points at best, and "what if" scenarios cannot possibly be explored without repeated testing under alternative conditions. Third, and most importantly, a patented application of a new computational framework now makes it possible to derive very quickly a whole universe of complete, accurate life cycle predictions.

## Tutorial Abstract and Outline

### Diagnostic Sensors for EHM Systems

Chris Nemarich, US Navy Military Sealift Command HQ

This tutorial presents an overview of diagnostic sensors that can be used in equipment health monitoring systems with the emphasis on sensors that can be integrated into automated machinery control systems. The tutorial will acquaint the attendee with the variety of sensor technologies available and present a methodology for selecting the 'best' sensor technology for the application. Sensor measurement basics and terminology such as range, span, resolution and hysteresis will be covered. The fundamentals of the most commonly used sensors (temperature and pressure) will be presented in detail. Other topics covered will include: sensor signal conditioning, analog vs digital sensors, smart sensor interfaces, using existing process control sensors for fault detection and diagnosis, and recent advances in sensor technology.

#### **Attendees of this tutorial should come away with an understanding of:**

- The variety of available diagnostic sensors for EHM use
- Sensor measurement basics
- Sensor interface and signal conditioning
- Methods for developing sensor requirements and selection
  - Fundamentals of temperature and pressure sensing

## Tutorial Abstract and Outline

### 'Cepstrum Analysis for Machine Diagnostics and Operational Modal Analysis'

Professor Bob Randall, University of New South Wales

The cepstrum is basically the inverse Fourier transform of a logarithmic spectrum, but has a number of variants. This gives two main application areas in machine dynamics, the first being diagnostic, and the second to do with determination of structural dynamic properties. The diagnostic application is based on the fact that many faults in machines (such as in gears and bearings) give rise to families of uniformly spaced components (harmonics and sidebands) in response spectra. These are much more evident on log amplitude than on linear amplitude scales. In the cepstrum, whole families of harmonics and sidebands are collected into a single dominant component, with a very accurate measure of the average spacing, and the ability to detect patterns not obvious to the eye. The application to operational modal analysis is based on the fact that the cepstrum of a response signal can be divided into its components from the forcing function and transfer function, thus allowing determination of the structural dynamic properties from response measurements alone. For SIMO (single input, multiple output) systems, the cepstrum of each output signal is the sum of the cepstra of the forcing function and the system properties.

Where the input log spectrum is reasonably smooth and flat (impulsive or broadband random) the input is concentrated in the low part of the cepstrum and the high part can be curve-fitted for the system poles and zeros. For minimum phase systems, the "complex cepstrum" can be derived from response autospectra only, without requiring phase information. The so-called "differential cepstrum" has the advantage that it can be calculated from a time signal directly and also that its mathematical formulation allows the poles and zeros to be obtained using methods designed for fitting impulse response functions from free response data. For excitation by a series of (say burst random) pulses, the "mean differential cepstrum" gives a more accurate result.