MFPT 62 (2008) – Paper Abstracts Listing

Ser: 14

Session: 1A Data/Knowledge Management

Author: Mark Warren

Organization: MTC Technologies

Country: USA

Paper Title: Legacy Platform Data Validity

Co Authors:

Abstract:

Data analysis capabilities have increased exponentially; following the same progression as micro processing in general. This paper addresses the critical disconnect between modern data analysis programs and the current data gathering/management processes used for legacy DOD platforms. The central thesis is unless current data collection and management processes are improved, prognostics and diagnostics programs will fail in their designed purpose and actually decrease reliability while increasing platform operating costs. Within the body, data collection and repair practices that defeat a modern analysis effort are discussed in detail. The cited statistics and case examples demonstrate how current practices, coupled with human factors such as educational levels and serial distortion work in concert to invalidate collected data. The discussion concludes with the specific effects the different data collection processes used within the DOD have on analysis. How modern analysis systems with “learning” capabilities would increase operating costs and reduce platform reliability is demonstrated using historical cases and scenarios based on existing practices. The impacts on safety, mission completion rates, availability, platform management efforts and operating costs are detailed to demonstrate how a combination of a modern analysis system and faulty data would have the opposite effects than those predicted or desired. The final section outlines how current data validity problems can be corrected using solutions that are neither costly nor complex. The paper goes on to discuss methods of harvesting and using diagnostic data from legacy platforms without adding sensors and modern methods of raw data management that are easily implemented and cost effective. A comparative analysis follows that uses an actual case where bad data and current practices severely impacted maintenance and management efforts. The comparison shows the outcome of using invalid platform data and current data management methods versus the outcome if these problems are addressed. This analysis clearly supports the need to correct existing data validity and management problems before implementing modern analysis programs.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 12

Session: **1A Data/Knowledge Management**

Author: Richard C Millar

Organization: NAVAIR Propulsion & Power, AIR 4.4.2

Country: USA

Paper Title: The Use of Non-Parametric Statistical Tools to Assess Reliability and Availability Drivers

Co Authors:

Abstract:

A propulsion system reliability data base covering eight years of service of the F/A-18 E/F aircraft was used to trial application of statistical tools for lifetime analysis of naval aviation propulsion systems. The focus of this analysis was the records of engine removal & replacement, specifically unplanned removals, as a major limitation to aircraft availability and a driver for maintanence cost. It was established that classical non-parametric tools were most appropriate and useful for analysis and presentation of actionable information. This information was seen to be useful to guide "O"-Level maintenance and logistics, and as a supplement to the chronological trending of rates and time on wing presently used to monitor propulsion system reliability and availability. The results illuminated the impact of the Navy's active management of aircraft engine reliability through maintenance process improvement and configuration change to achieve acceptable levels of aircraft availability.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 19

Session: **1A Data/Knowledge Management**

Author: Simon Jessop

Organization: Impact Technologies, LLC

Country: USA

Paper Title: Condition Based Maintenance Optimized Scheduling Decision Support Tool

Co Authors: Phillip Gurbacki, Johan Reimann

Abstract:

Condition Based Maintenance (CBM) is a key technology enabling facility maintenance cost reduction. The CBM approach to maintenance replaces rigid time-based maintenance schedules with the “right maintenance at the right time” identified by real-time equipment health monitoring. This approach creates a new requirement for determining the best time to schedule newly identified critical maintenance actions in light of the real world constraints of available labor and resources. One of the major challenges encountered when attempting to optimize a maintenance schedule is related to the resolution of the many and often complex interdependencies or constraints present throughout the maintenance process. This paper presents a CBM decision support software tool that leverages real-time current and future health condition information to optimize maintenance resources, tasking, and planning in order to maximize the system readiness. Benefits of performing maintenance tasks have been quantified in risk, which can be defined in terms of readiness or financial. An evolutionary algorithm is used to identify the optimal maintenance schedule and novel post processing steps provide information regarding the active constraints. Implementation of the model and technical details are presented in the paper.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 66

Session: **1A Data/Knowledge Management**

Author: Matt Sedlak

Organization: RJ LeeGroup

Country:

Paper Title: Evolving from Data Management to Knowledge Management

Co Authors:

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 68

Session: **1A Data/Knowledge Management**

Author: Jim Carter

Organization: US Army Aviation and Missile Command (AMCOM Huntsville)

Country:

Paper Title: Managing Army Aviation Condition Based Maintenance Data in Support of the Fight

Co Authors:

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 69

Session: **1A Data/Knowledge Management**

Author: Bob Lawton

Organization: General Dynamics Information Technology

Country:

Paper Title: Operational and Data Challenges in Integrated Health Management of Complex Systems

Co Authors:

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 17

Session: 1B PHM Techniques

Author: Nick Frankle

Organization: Frontier Technology, Inc

Country: USA

Paper Title: Pattern Recognition of Health-Data Derived Prognostic Health Management

Co Authors: Ron Shroder

Abstract:

Prognostic health management provides the ability for system operators and maintenance personnel to anticipate system problems and to address them in a planned, rather than unscheduled, manner. Accurate forecasting of system health states can answer the questions: • Are the monitored systems operating as expected or are they in a degraded or abnormal condition? • What is the cause of the degraded or abnormal condition, what is its impact on system performance and what information should be provided to the system stakeholders to modify operations or take corrective action? Predictive analysis of system performance is often based on physical models. While idealized models of system performance can be developed, actual observation of system degradation indicates that systems do not always degrade as the models predict. Physical models can be augmented by data-derived technology that can monitor system health states and identify precursors and sources of system failure. The data-derived models described in this paper are based on the concept of “Pattern Recognition of Health (PRoH™)”. PRoH™ is based on the premise that system health can be determined from available system sensors and sources by detecting and measuring variances from normal or expected system behavior. It is a data-derived solution combining pattern recognition algorithms with basic principles from statistics and signal-processing to create models of the expected system performance and then using the model to understand system health. In the presence of degrading or unexpected conditions, PRoH provides the data relationships required to identify failure modes and recommended corrective action. Using data from existing sources, PRoH creates a set of multivariate transfer function models of the system being monitored under a variety of expected environmental and operating conditions. The process automatically discovers the relationships among system components derived from measurable data. PRoH then applies processes to monitor system health states and detect the presence of abnormalities that are small in absolute value, but statistically significant departures from expected performance. Using the information that determined the presence of an abnormality, PRoH creates failure mode signatures and identifies the degrading or failing source from of the causal relationships among the data. PRoH has been designed to overcome obstacles to application of PHM technology. It is independent of detailed system knowledge, makes accurate decisions using data that is available from existing sensors and sources, and interfaces with existing logistics systems. PRoH has been tested with a variety of extremely challenging environments including aircraft engines, rotorcraft, wheeled vehicles, communications and navigation equipment, oil production platforms, power plants provided by existing sources. In all cases the algorithms have been able to detect problems prior to detection by current methodologies and early enough to permit corrective action to be taken prior to actual system failure.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 29

Session: **1B PHM Techniques**

Author: Jay Lee

Organization: University of Cincinnati

Country: USA

Paper Title: A Toolbox Approach for Prognostic Development and Deployment, Part 1: Watchdog Agent and Tool Selection

Co Authors: Lei Yang

Abstract:

Condition Based Maintenance (CBM) methods and practices have been continuously improved for the last two decades; however, the developed prognostics approaches are mostly application or equipment specific. This paper introduces a systematic approach, namely the Watchdog AgentÂ® toolbox approach, in developing and deploying advanced prognostics tools for machine health assessment and prediction. Consisting of embedded computational prognostic algorithms and a software toolbox for predicting degradation of devices and systems, the Watchdog AgentÂ® toolbox is represented in the form of a modular architecture, including signal processing and feature extraction, performance assessment, diagnostics and prognostics modules. Characteristics of algorithms are discussed and compared. A decision making technique, Analytic Hierarchy Process (AHP), is applied for the automatic selection of algorithms from the Watchdog AgentÂ® toolbox using multiple criteria. Industrial case studies are presented to illustrate the capabilities of the proposed methodology.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 65

Session: **1B PHM Techniques**

Author: Jay Lee

Organization: University of Cincinnati

Country: USA

Paper Title: A Toolbox Approach for Prognostic Development and Deployment, Part 2: Case Studies

Co Authors: Lei Yang

Abstract:

Condition Based Maintenance (CBM) methods and practices have been continuously improved for the last two decades; however, the developed prognostics approaches are mostly application or equipment specific. This paper introduces a systematic approach, namely the Watchdog AgentÂ® toolbox approach, in developing and deploying advanced prognostics tools for machine health assessment and prediction. Consisting of embedded computational prognostic algorithms and a software toolbox for predicting degradation of devices and systems, the Watchdog AgentÂ® toolbox is represented in the form of a modular architecture, including signal processing and feature extraction, performance assessment, diagnostics and prognostics modules. Characteristics of algorithms are discussed and compared. A decision making technique, Analytic Hierarchy Process (AHP), is applied for the automatic selection of algorithms from the Watchdog AgentÂ® toolbox using multiple criteria. Industrial case studies are presented to illustrate the capabilities of the proposed methodology.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 32

Session: **1B PHM Techniques**

Author: Tianyi Wang

Organization: University of Cincinnati

Country: USA

Paper Title: The Operating Regime Approach for Precision Health Prognosis

Co Authors: J Lee

Abstract:

Data-driven multi-model prognosis is a viable approach for solving prognostic problems in complex non-linear systems, where analytic models that can cover the entire system's operating space are not available or not easy to obtain. Traditionally, the operating regime (multiple models) approach is used for non-linear system modeling and control. Following the same principle as for control purposes, many multi-model fault detection and diagnosis approaches have been derived over years. However, the applications of those methods are mostly limited to components that are under control, e.g. engines, pumps, etc. In this paper, we present the concept of a new operating-regime-based health prognosis approach, which employs the design-of-experiment thinking for the uncontrolled, online health monitoring situation. Unlike the traditional approaches that pursue real-time performance for close-loop control, the new approach aims for precision health assessment, diagnosis and prognosis, especially for those components in a complex system that exhibit tractable degradation symptoms. In this paper, several key procedures of the new approach will be discussed, including the regime partitioning strategies, regime partitioning techniques, prognosis model development, model identification and multi-model information fusion. An example of vehicle health prognosis will be used to demonstrate the concept.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 40

Session: 1B PHM Techniques

Author: Sudarshan Bharadwaj

Organization: Impact Technologies, LLC

Country: USA

Paper Title: Automated Health Management for Gas Turbine Engine Accessory System Components

Co Authors: Matthew Watson, Sudarshan Bharadwaj

Abstract:

Traditional engine health management development has focused on major gas turbine engine turbomachinery components, such as disks, blades, and main bearings, because these components are expensive to maintain and their failures frequently have safety implications. However, the majority of the events that compromise mission success and equipment availability in military aircraft arise from the degradation, faults, or failures of gas turbine engine accessory system components, such as valves, pumps, and actuators. Unanticipated and extreme operating conditions are a major cause of unscheduled maintenance events, and failure or statistical-based maintenance of these components fails to account for these scenarios. US military systems are thus moving towards condition-based maintenance, wherein maintenance is performed as and when required, thus improving asset availability and contributing significantly to mission success. In the current work, the authors have developed low-overhead diagnostics and prognostics techniques, which would enable a shift towards condition-based maintenance (CBM) of engine accessory components. The focus of the current work was on aircraft fuel and lubrication systems. A physical model of an aircraft fuel/lubrication system was created using the SIMULINK package in MATLAB. The model consisted of blocks representing the various components of the system. Model parameters were derived to indicate faults in the pump and valve components. Data-driven routines were also developed to analyze the dynamic pressure signals in order to detect faults such as pump cavitation, which would be difficult to incorporate into physical models. The features derived from these routines were fed to fault classifiers, which identified specific faults based on known fault regions in feature space. The authors also developed evolutionary prognostics methods to track the faults across feature space and thus indicate the time to failure for each component. An experimental setup representative of aircraft fuel and lubrication systems was used to successfully demonstrate this approach. Faults such as pump leakage, pump gear damage, and valve blockage were then seeded on the setup, and the developed routines were trained with high-bandwidth experimental data. Additional validation data were also collected. The pump and valve parameters derived from the developed model-based routines were found to uniquely correlate to a particular pump or valve fault. The data-driven routines yielded additional features from the pressure data, which served as indicators of pump cavitation. The derived parameters allowed wide separation between the baseline and faulted cases, yielding negligible missed detection rates for moderate faults, and a reasonable missed detection rate of 6.2% (for a false alarm rate of 5%) for an incipient valve blockage fault. The approach was thus successfully demonstrated, and its adaptable nature invites further investigation to address the availability and mission success concerns previously described.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 44

Session: **1B PHM Techniques**

Author: Kai Goebel

Organization: NASA Ames Research Center

Country: USA

Paper Title: A Comparison of Three Data-Driven Techniques for Prognostics

Co Authors: Bhaskar Saha and Abhinav Saxena

Abstract:

Traditional damage propagation algorithms rely on physics-based failure mechanisms. Alternatively one can employ data-driven approaches when sufficient test data are present that map out the damage space. In this investigation, we evaluate different algorithms for their suitability in these situations. We are interested in assessing the trade-off that arises from the amount of data needed, the computational speed exhibited, the robustness of the algorithm to input space perturbations, the ability to support uncertainty management, and the accuracy of the predictions. To start, we compare here a Relevance Vector Machine (RVM) and a Neural Network-based approach. This choice was motivated by the elegance to deal with uncertainties of the Bayesian treatment of kernel-based methods in the form of RVM and by the relative simplicity by which neural nets can approximates coefficients of an exponential damage propagation function in response to different operational stimuli. Although SVM is a state-of-the-art technique for classification and regression, it suffers from a number of disadvantages, one of which is the lack of probabilistic outputs that make more sense in health monitoring applications. The RVM attempts to address these very issues in a Bayesian framework. Besides the probabilistic interpretation of its output, it uses a lot fewer kernel functions for comparable generalization performance. RVM regression is performed on a subset of data sets (because it was found that there was inconsistent behavior between data sets) to predict remaining useful life (RUL) for the last data set. For the NN-based approach, we first transformed the data into the log space, where damage propagation was linear. Then, the rate of change for operational settings could be learned such that the states for which there were no supporting experimental data were covered by a smooth curve, employing a network with low complexity (to avoid overfitting). Future states could then be easily retrieved from this curve and RUL could be calculated by summing up the future damage. The results of the NN-based algorithm and the RVM were comparable when measured early after damage initiation. Both had an error of between 137 and 150 time units which is equivalent to about 10% prediction error. However, the error got worse for the NN-based technique the closer the RUL estimate got to actual end of life. This is due to the inconsistent data that the built-in state estimation received during operation. Future work should investigate methods for dealing with sparse time series data sets, research formal methods for validation of data-driven approaches, and investigate fusion of prognostic estimates.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 13

Session: **1D Signal Analysis, Sensors and Distributed Systems Architecture**

Author: Stanley Bognatz

Organization: M&B Engineered Solutions, Inc.

Country: USA

Paper Title: Transient Speed Vibration Analysis - Insights into Machinery Behavior

Co Authors:

Abstract:

This paper discusses the need for and benefits of analyzing machinery vibration data taken during startup and shut down to help more fully understand machinery dynamics and to resolve vibration and operational problems that are not readily solved using only steady state / spectral data. Many analysts focus on acquiring steady state vibration data, often as part of 'Predictive Maintenance' or PdM programs. Such programs have proven their worth and are often a plant's first-step in identifying and resolving reliability problems. PdM programs focus on using portable data collectors to acquire and analyze spectral data and to a lesser degree the time waveform data. This data is usually taken during constant speed operation, and is generally not phase-referenced. It achieves its intended goal of providing trended data to identify arising problems, while also providing data that can be analyzed for frequency content and severity. And it is the frequency content that allows us to begin our analysis process and identify possible fault mechanisms. However, steady state spectral analysis remains just a single tool – the identification of frequency versus amplitude. We may or may not be able to accurately identify a root cause to a vibration problem from the spectral data. This is often the case with journal bearings, whose vibration signatures usually show just a predominant one-times rotational speed frequency component, and the analyst is left with several fault possibilities to choose from. Our paper will review the equipment and techniques we use to acquire additional vibration data during startup and shut down. This 'transient' speed data provides exceptional insight into machinery dynamics, and allows us to accurately sort out most machinery problems that are not readily solvable using only steady state data. We will discuss how to properly set up for and sample transient data, discussing vibration transducers, band width filters, sample times, and required data resolution. We will review the types of transient data plots typically used in analysis, including: polar; bode; waterfall; cascade; orbit / timebase; and shaft centerline. We will discuss how to identify the major classes of machine faults within the transient data: mass unbalance; shaft misalignment; rotor resonances; structural resonances; shaft centerline movement; rotor to seal rubbing; and oil whirl / whip. And we will conclude with case histories highlighting the identification and resolution of specific problems.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 41

Session: **1D Signal Analysis, Sensors and Distributed Systems Architecture**

Author: Arun Menon

Organization: Data Physics Corporation

Country: USA

Paper Title: Paper Machine Supercalender Vibration Analysis with a DSPcentric, Multichannel Dynamic Signal Analyzer

Co Authors:

Abstract:

Paper machines structures and components are notorious for being susceptible to vibration problems. Supercalender sections are perhaps some of the most glaring examples of these issues. These sections are used to impart very high quality surface characteristics to finished paper for optimal printing results. Denim and poly-covered rolls used in supercalender operation are designed to deform in the nip, leading to very difficult to troubleshoot vibration problems. While a variety of condition monitoring strategies have been adopted by the industry in general, they have typically fallen woefully short in the complete diagnostics of supercalender vibration issues. This paper discusses a realtime, DSPcentric dynamic signal analyzer, capable of a unique blend of rotating machinery and structural analysis measurements with simultaneous raw data recording and several dynamic test strategies that were employed to deliver dramatically superior results in the successful characterization and resolution of vibration issues that have long plagued such machinery.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 58

Session: **1D Signal Analysis, Sensors and Distributed Systems Architecture**

Author: Craig Neslen

Organization: Air Force Research Lab

Country: USA

Paper Title: Advanced Sensor Development for Propulsion Health Monitoring

Co Authors: Dr. Kumar Jata, Dr. Shashi Sharma (Air Force Research Lab); Dr. Jeffrey Brogan (Mesoscribe Technologies, Inc.); Dr. Otto Gregory (University of Rhode Island); Mr. Vince Wnuk (HPI); Dr. Mauricio Pereira da Cunha (University of Maine); Dr. Behzad Moslehi (I

Abstract:

The Air Force Research Laboratory (AFRL) has established the framework for a collaborative effort to develop a strategy and technology development plan that will result in Integrated System Health Monitoring (ISHM) capabilities for Air Force (AF) systems. Legacy and modern turbine engines are one of several AF systems that are currently being envisioned for advanced instrumentation with ISHM capabilities. There are several key elements of an ISHM capability including: real time state sensing and diagnostics, real time life prediction and physics based probabilistic models. The Non-Destructive Evaluation Branch (AFRL/RXLP), Materials and Manufacturing Directorate plays a key role in developing sensing technologies that will allow realization of a real time material state sensing capability. Last year, AFRL/RXLP presented an overview of the various sensing technologies that we are pursuing for turbine engine and thermal protection system applications, which included: integrated bearing sensors, metallic and ceramic thick film sensors for strain measurements on turbine engine components, surface acoustic wave devices for temperature and pressure measurements in compressor sections and high temperature fiber optics. During the past year, significant progress has been made in the advancement of these technologies. This presentation will review the primary sensor development programs AFRL/RXLP is pursuing and will summarize the progress that has been made during the past year. Specific emphasis will be placed on sensor validation tests which have been conducted for several of these sensing systems during the past year, sensor survivability and performance results as well as future research plans for the upcoming year.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 26

Session: **1D Signal Analysis, Sensors and Distributed Systems Architecture**

Author: Fred Discenzo

Organization: Rockwell Automation

Country: USA

Paper Title: An Information Entropy Approach to Self-Powered Sensor Node Operation

Co Authors: Dukki Chung, Kenneth A. Loparo (Case Western Reserve University); Farhad Kaffashi (Case Western Reserve University)

Abstract:

Wireless sensor nodes promise to significantly change the economics of continually monitoring critical machines to prevent failure. The ability to effectively scavenge energy from the environment provides new opportunities for maintenance free embedded sensor nodes. Scavenging energy reliably from a dynamic environment requires a robust system. An adaptive energy harvesting system has been developed that is capable of re-directing available energy to change the mechanical characteristics of the power generating module. While this is a valuable capability for reliable power generation in changing and unpredictable environments, it presents additional challenges for effective power utilization. An information theoretic approach may be employed to direct the operation of the self-powered sensor node. Power generation strategies and power consumption elements are prescribed in order to maximize the amount of useful information gained for a unit of energy with the constraint on insuring adequate power for sensor node survival. Sensor node operation is translated into a problem of minimizing the entropy of the systems states of interest subject to time and power constraints. An information-theoretic approach to optimize sensor node operation subject to power constraints promises to provide maximum relevant information while operating in dynamic, unexpected environments. Techniques that integrate information value with energy utilization promise to provide an effective framework for future wireless sensor nodes.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 18

Session: **1D Signal Analysis, Sensors and Distributed Systems Architecture**

Author: Preston Johnson

Organization: National Instruments

Country: USA

Paper Title: Distributed Monitoring Systems, Architectures, Technologies, and Use Cases

Co Authors: Hunter Cloud (BRG Machinery)

Abstract:

Machinery monitoring systems, as well as the systems developed for testing and controlling machines, are becoming more distributed. Local machinery monitoring systems incorporate FGPA and DSP processors to internally distribute signal processing tasks. Wired and Wireless communications allow local monitoring systems to communicate with plant wide or internet wide data storage and analysis systems. Technical data management systems allow machinery analysts to sort and organize data from a wide network of machinery. This paper describes the technologies used for distributed data acquisition and signal processing as well as the technologies available for communications and data networking. Both a technology perspective and a machinery vibration analyst's perspective are included.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 73

Session: **1D Signal Analysis, Sensors and Distributed Systems Architecture**

Author: Mark Hinders

Organization: The College of William and Mary

Country:

Paper Title: Intelligent Structural Health Monitoring with Guided Ultrasonic Wave Sensors

Co Authors: Jill Bingham

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 5

Session: **2C Failure Analysis 1: Engineering Solutions for Failure Prevention**

Author: Marc Pepi

Organization: US Army Research Laboratory - WMRD

Country: USA

Paper Title: Army Metallurgy – A Glimpse into the Past

Co Authors:

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 27

Session: **2C Failure Analysis 1: Engineering Solutions for Failure Prevention**

Author: LiJie Yu

Organization: Computing and Decision Science Technology

Country: USA

Paper Title: A Method for Machine Failure Detection and Isolation Using Personalized Diagnostic Model

Co Authors: Mark Osborn, Daniel J. Cleary

Abstract:

Diagnostic models are often designed based on first principle physics or expert knowledge derived from set of similar machinery -- and may be termed as "fleet-based" models. Diagnostic models measure and compare common, sensor change patterns with known machinery "failure signatures." By analyzing the similarities among various failure signatures and the actual data trends of a specific machine, an application can detect, characterize and diagnose the root causes of anomalous behavior. These so-called, fleet-based diagnostic models behave adequately when the analyzed machine performs close to the overall set average. However, when individual machines vary substantially from the average, a fleet-based diagnostic model behaves increasingly poorly, providing inaccurate results, and driving up both false positives and false negatives. This paper presents an approach to dynamically personalize a diagnostic model based on individual machine data characteristics, and then demonstrates the effectiveness of this technique for false alarm reduction in an aircraft engine diagnostic application.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 51

Session: **2C Failure Analysis 1: Engineering Solutions for Failure Prevention**

Author: Michael Lister

Organization: US Army Research Laboratory

Country: USA

Paper Title: Repair of Apache Mast Support on AH64 Helicopter Using Cold Spray

Co Authors: Phillip Leyman, Vic Champagne

Abstract:

This paper is a summary of the work associated with the dimensional restoration of 7075-T6 aluminum aircraft forgings by an emerging technology called, 'Cold Spray'. Emphasis will be placed on process development and materials characterization. Corrosion, adhesion, hardness and fatigue test results will be presented and the microstructural features of the cold spray deposit will be discussed in detail, as well as the role of cold spray in regards to failure prevention.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 50

Session: **2C Failure Analysis 1: Engineering Solutions for Failure Prevention**

Author: Pete Harrell

Organization: Consulting Mechanical Engineer

Country: USA

Paper Title: Causes and Prevention of Bolted Joint Failures

Co Authors:

Abstract:

Bolted joints are perhaps one of the most common, yet least understood mechanical contrivances found in almost every aspect of engineering endeavor. This lack of understanding leads to large numbers of bolted joint failures every year; failures that are for the most part preventable. This paper will explore the causes of bolted joint failures and how to avoid them by proper design and assembly of the joint. The causes and failure mechanisms behind bolted joint failures ranging from the common to the obscure will be discussed and explained including improper loading, insufficient preload, vibration loosening, fatigue, shear, corrosion, stress corrosion cracking and creep, among others. Brief case histories will be offered to illustrate some of the more common failures.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 67

Session: **3A Electronics and Power Systems Health Management**

Author: Tommy Baudendistel

Organization: PC Krause & Associates

Country:

Paper Title: Noninvasive Approach to Health Management of Aircraft Power Systems Using Torque Ripple

Co Authors:

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 9

Session: **3A Electronics and Power Systems Health Management**

Author: Herbert Hecht

Organization: SoHaR Incorporated

Country: USA

Paper Title: Prognostics for Electronic Components

Co Authors:

Abstract:

An increasing fraction of essential functions is being allocated to electronic components so that the health status of these becomes an important concern. Even the health management system is largely implemented in electronics. And since prognostic techniques based on the concept of life consumption have become established as an important element in the health management of mechanical components there is much interest in applying similar techniques to electronics. Yet the failure modes of electronic components differ in very significant areas from those of mechanical parts: • Very small size of components (relative to candidate degradation sensors) • Large number of potential failure sites and failure modes • Low failure rates of individual parts • High rate of part innovation and reliability improvement These differences suggest that rather than concentrating on specific failure modes (bearing wear or gear tooth cracks) prognostics for electronics must focus on broader indicators of degradation. Also, because the failure predictions will be less specific than in the mechanical domain, cost trade-offs will become more important. Prognostics implies that a component is being replaced before it actually fails, and that this sacrifice in component utilization is justified by the savings due to performing the replacement at a convenient time and place rather than at a potentially very inconvenient time and place. Creditable data to support such trade-offs are very difficult to obtain but the range of cost and benefits can be bounded under some reasonable assumptions. An algorithm to support the trade-off is introduced, and applications for power supplies or converters and for memory structures are presented. These require no or very minimal changes in the items for which prognostics are being generated or in the health management architecture. In the future, specific prognostic features may be incorporated in semiconductors that will extend the range of economically sound prognostics for electronic components.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 39

Session: **3A Electronics and Power Systems Health Management**

Author: Aaron Hussey

Organization: Electric Power Research Institute

Country: USA

Paper Title: Improving Power Plant Availability Through Equipment Health Monitoring

Co Authors: Stephen Hesler

Abstract:

As reserve generating margins decrease, availability of exising power generation assets must improve. Effective application of Condition-Based Maintenance and risk-informed approaches to maintenance planning requires accurate assessment of the current condition of key plant equipment. On-line monitoring and anomaly detection is now being used by some generating plants, and has been successful in preventing costly unplanned outages. Greater value can be obtained from on-line monitoring if integrated with diagnostics and risk-informed decisions. Several gaps must be addressed to successfully realize this greater value. Among the known gaps are identification of sensor needs, performing failure signature analysis, and addressing the known challenges of wireless sensor networking to achieve cost-effective sensor additions. This paper will highlight a vision for addressing these identified gaps for the power generation industry.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 46

Session: **3A Electronics and Power Systems Health Management**

Author: Jie Gu

Organization: CALCE

Country: USA

Paper Title: Prognostics of Electronics under Vibration Using Acceleration Sensors

Co Authors: Donald Barker, Michael Pecht

Abstract:

Prognostics and health management (PHM) is a method that permits the assessment of the extent of deviation or degradation from an expected operating condition (i.e., health). During the process of health monitoring, sensors may be used to record the environmental and operational loading, such as strain gauges, and accelerometers. It is important to make sure that sensors do not fail before the failure of the monitored product; or at least we need to know which sensor has gone bad and that it has not mislead the prediction result. The multi-sensor cooperation method (sensor network) for prognostics of electronics is presented in this paper to enhance the prediction capability and accuracy, as well as the detection of bad sensors. Traditionally, sensor is put nearby the component to monitor the loading condition of that component, however what really needs are multi sensors which can be used to monitor more components by capturing the global circuit board bending behavior. In addition, a sensor network can be used to identify bad sensors and decrease the chance of false alarm. A case study is presented in which a prognostics approach using multi sensors is applied to an electronic circuit board subject to random vibration. First, modal analysis is performed to identify the relationship between sensors; then, the failure prediction results from the sensor network are compared with the result from experiment. Last, fault tree analysis and hypothesis testing are performed to evaluate the health of the whole sensor network.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 60

Session: **3A Electronics and Power Systems Health Management**

Author: Lynn Petersen

Organization: ONR

Country: USA

Paper Title: The Science and Technology Focus of the Electric Navy

Co Authors:

Abstract:

Electricity as a driving function for naval surface ships or submarines is not a new concept. History is replete with examples of electric drives dating back nearly 100 years. However, recent quantum advances in both power generation as well as electric propulsion and distribution have opened the gates for a fully electric Navy. Such advances include high power solid state switches, advanced rare earth magnet materials and processes and second generation high temperature superconducting technology have enabled system power conversion efficiencies approaching 95%.

This presentation outlines the key technologies leading the advancement towards 1) an electric navy as well and 2) areas where remaining science and technology (S&T) efforts are needed. Among these are: materials needed to improve power density, universal controller schemes and electronic prognostics and diagnostics tools to provide the right power to the right place at the right time. Fault protection and advanced controls are needed to foster a medium voltage direct current (MVDC) distribution system. The Office of Naval Research has released a Broad Agency Announcement (BAA) for compact power conversion technologies Future Naval Capabilities (FNC). Additionally, hybrid breaker technologies coupled with integrated energy storage opportunities are envisioned in the FY10 timeframe supporting the MVDC open architecture distribution system.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 61

Session: **3A Electronics and Power Systems Health Management**

Author: Terry Ericsen

Organization: ONR

Country:

Paper Title: History, Present Applications and Future Needs of Power Electronic Building Blocks

Co Authors:

Abstract:

Power Electronic Building Blocks enable dramatic improvements in marine platforms and ships – increased power, greater automation, with enhanced capabilities and missions. Systems are emerging with many power electronic components, driven by the need for security, and efficiency. Mechanical ship propulsion systems are being replaced by electric propulsion. Variable speed motor drives are replacing across-the-line motor starters to save energy and decrease system instabilities. Uninterruptible power supplies are used everywhere to maintain power continuity and quality. Offshore and deep ocean platforms use many electrical motors for sea keeping and maneuvering. Marine based renewable energy concepts such as tidal and wave power generation and offshore wind farms are emerging.

The detail and complexity of these “system-of-systems” exceeds the capability of today’s rule-based design methods. Tomorrow, there will be a “relational” design process, enabled by physics-based modeling and simulation. Similar to modern IC design, vehicle design and development will use computer-based design, development, and manufacturing. Physics-based analysis, founded on the nature of the materials and their manufacturing processes, will enable engineering justification and reliability assurance.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 4

Session: **3C Failure Analysis 2: Tribology**

Author: Marc Pepi

Organization: US Army Research Laboratory - WMRD

Country: USA

Paper Title: Sample Preservation – The Key to a Successful Failure Analysis

Co Authors:

Abstract:

Probably the most important, yet least understood step in failure analysis is sample preseveration. Irreversible damage can occur if the proper steps are not taken to preserve the fractured specimen and associated components. This paper will discuss the techniques used to ensure samples are kept in the best possible condition for future analysis. Similar to a "crime scene", every effort should be made to prevent post-mortem harm to the failed component. Although not many publications reference this subject, or discuss it in detail, the author will provide methods that have proven effective in the past.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 21

Session: **3C Failure Analysis 2: Tribology**

Author: Weizhong Yan

Organization: GE Global Research Center

Country: USA

Paper Title: Feature Extraction for Bearing Prognostics and Health Management (PHM) – A Survey

Co Authors: Hai Qiu, and Naresh Iyer

Abstract:

Bearings are one of the most common and critical components in rotating machinery. Faulty bearings are the major culprit of rotating machine problems (breakdowns). Continuously monitoring and reliably diagnosing incipient faults of bearings so that unexpected breakdowns and catastrophic failures can be prevented are crucial in cost-effective maintenance of rotating machinery. In recent years, bearing fault diagnosis in general and improving accuracy of bearing fault diagnostic systems in particular have attracted tremendous research interests and continue to be an active research direction. In this paper, we explore pattern recognition techniques for bearing fault diagnosis. Specifically, we investigate different techniques in feature extraction and classification, the two essential components of diagnostic systems, with the goal of designing a diagnostic system with improved diagnosis performance (accuracy and reliability). We validate our design by applying the system to experimental data.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 43

Session: **3C Failure Analysis 2: Tribology**

Author: Cannon Neslen

Organization: ATL Launch Systems

Country: USA

Paper Title: Fault Detection and Failure Prediction for Automated Flare Tooling

Co Authors:

Abstract:

The implementation of automated tooling into the explosive flare manufacturing processes has significantly improved the ergonomics, decreased the processing time of key flare components, and significantly increased the number of safeguards benefiting operators. Automated flare tooling sets the standard for improvement in operator performance, efficiency, and exceeding customer product expectations. This study reports the results of several quantitative and qualitative risk analyses that were designed for fault detection and failure prediction. A series of hazards analyses for each automated tooling have assessed the level of risk quantitatively and qualitatively for each potential failure mode in order to determine an appropriate hazard classification. The use of a Failure Modes and Effects Analysis (FMEA) for each of the automated tooling in the design and qualification phases analyzes all component failure modes and the impact upon personnel safety and equipment integrity. The report highlights critical failure modes from the hazards analysis' FMEA that assessed the most critical initiation hazards. Each potential failure mode was successful in predicting failures and ensuring that the designed process control systems adequately detected and safeguarded the tooling for all potential faults involved with the process. The primary purpose of the FMEA is to identify scenarios involved with each process that generates potential energy sources required for initiation of the flare explosives. The development of recommendations and additional safeguards from unacceptable hazards identified in the FMEA lower the hazard severity and frequency of all potential failure modes. This report demonstrates the success of automated tooling in increasing flare production, decreasing the number of ergonomic injuries, reducing the amount of down-time for each tooling, and reducing the number of product quality escapements.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 48

Session: **3C Failure Analysis 2: Tribology**

Author: Jack Kelley

Organization: US Army Research Laboratory

Country: USA

Paper Title: Investigation of Chemical Vapor Deposited (CVD) Aluminum as a Replacement for Cadmium on High Strength Steel

Co Authors: B Placzankis, T Considine

Abstract:

The objective of this effort was to evaluate the use of atmospheric pressure chemical vapor depositioned (CVD) aluminum coatings on high strength steel substrates. The Al CVD offers a more environmentally friendly alternative to cadmium plating for corrosion prevention on steel fasteners. The process promises to provide high production throughput, at a relatively low cost. Accelerated corrosion methods were used to evaluate the corrosion performance. These results show that after a 27 day-exposure, red rust on the coatings was observed. A post treatment of the CVD coating with a trivalent chromium conversion coating did not improve the corrosion resistance of the coatings. Coefficient of fiction, susceptibility to hydrogen embrittlement, and the lubricity of the corrosion products were measured.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 52

Session: **3C Failure Analysis 2: Tribology**

Author: Diana Lados

Organization: Worcester Polytechnic Institute (WPI)

Country:

Paper Title: Integrative Materials-Process-Component Design: Present Achievements and Future Opportunities

Co Authors:

Abstract:

The challenges in modern materials-process-component design revolve around the successful integration of several important and sometimes-competing concepts such as High-Performance & Reliability, Societal Impact, and Economics. The first is perhaps the most familiar to engineers and involves basic design requirements including strength; fatigue, impact, corrosion, wear, and creep resistance; and high-temperature properties. Then, an important consideration in an increasingly environmentally conscious (green) world is the societal impact/acceptance of the end product. These “Fit-Function-Green” attributes are finally tempered by economics, as the best material for a given application may not be economically feasible in terms of either materials/processing or recyclability. Green engineering design and reduced energy consumption throughout the life-cycle require an increased use of recycled materials as well as recyclability of the end product and necessitate simultaneous/compatible materials selection for various components. Integration further continues within each of these main areas via consistent and connective multi-disciplinary and multi-scale approaches. This context generates a fertile future of opportunities for the clever designer to develop a holistic approach based on a fundamental understanding in tandem with a suitable “application-driven-design” strategy. To specifically demonstrate the significance of these concepts an example of materials/process design integration for fatigue failure prevention in high-integrity cast aluminum components will be presented.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 2

Session: **4A Health Management Strategies**

Author: James (Jim) Kidd

Organization: US Army Research Laboratory

Country: USA

Paper Title: Cost and Time Model of a Simulated Painting Facility for Tactical Vehicles

Co Authors: Sandra Young

Abstract:

The purpose of this report is to provide a reference framework for economic and manufacturing process models. It illustrates the effect of several input variables on the cost and time required for repainting two widely deployed US Army tactical vehicles. This evaluation quantifies the time required and the expense of each processing segment for refurbishment of two different vehicles and the respective totals. This evaluation was performed with calculations using deterministic (fixed or averaged) input. Specialized process modeling software is generally amenable to both deterministic or stochastic (allows for probability distributions) input. The effect of overhead rate and a solvent waste stream are considered. A cost-sensitivity analysis is included.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 8

Session: **4A Health Management Strategies**

Author: Richard Greenough

Organization: Cranfield University

Country: UK

Paper Title: State-Of-The-Art in Integrated Vehicle Health Management

Co Authors: T.S. Baines, O. Benedettini, R.M. Greenough, and H.W. Lightfoot

Abstract:

Cranfield University in collaboration with The Boeing Company have set up a Centre of Excellence in IVHM on the University's technology park. Sponsored by the East of England Development Agency (EEDA), the Centre carries out pre-competitive research and development of IVHM technologies for the benefit of industrial partners. In addition, the dedicated facilities and university staff provide an unparalleled educational environment for learning and applying IVHM technologies. Boeing is actively involved in the creation and work of the Centre through its enterprise-wide Phantom Works technology organization. This paper will describe the organisation and operation of the Centre and will illustrate its activities by describing a research project being carried out in the Centre. This project is a demonstration of an end to end IVHM system beginning with cost/benefit analysis and extending to maintenance, logistics and operations decision support.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 16

Session: **4A Health Management Strategies**

Author: Ron Shroder

Organization: Frontier Technology, Inc

Country: USA

Paper Title: Economic Modeling for Prognostic Health Management

Co Authors: Nick Frankle, Sam Boykin

Abstract:

Prognostic Health Management (PHM) provides the opportunity for system operators to monitor performance, detect abnormal or degrading conditions and identify precursors of future failures before they experience a service interruption or catastrophic failure resulting in loss of mission, system, or life. The benefits of effective PHM technology include increased system availability, improved system reliability and reduced cost of operations. One challenge to the use of PHM has been the lack of an economic model that shows these projected benefits in traditional business terms, such as Return on Investment. A recent NASA study identified one of the challenges to utilization of new health management technologies as the “need for the technology to ‘buy’ its way on board [an aircraft]. This paper describes an approach to developing an economic benefit model for the introduction and use of PHM. It is designed to be independent of the specific equipment or systems being monitored or the industry for which PHM is used. An accurate economic benefit analysis requires identification and quantification of each element of cost associated with the equipment or systems being monitored and the potential savings that can be derived from the use of PHM technology. These elements of savings can be categorized into primary savings and secondary savings. Typical elements of primary savings are those that result directly from the use of PHM and include such elements as reduction in unscheduled equipment failures, decrease in equipment downtime, lower requirements for in-place spares, and potential reduction in catastrophic failures. Secondary elements of savings are more difficult to identify and are often overlooked in an economic analysis. However, they are just as important to an economic analysis as the primary elements. Examples of secondary elements include improvement of operational effectiveness, better use of personnel resources and lengthening of scheduled maintenance intervals. The paper describes a economic modeling principles for investigation of PHM and shows how these principles can be applied to PHM application in any business sector.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 30

Session: **4A Health Management Strategies**

Author: Thomas Cook

Organization: Impact Technologies, LLC

Country: USA

Paper Title: Shipboard Mission Readiness Assessment

Co Authors: Scott G. Valentine

Abstract:

As the US military moves toward a reduced manning environment there exists a need to provide commanding officers greater visibility to operational readiness of shipboard systems, manning, and materials to assess current and future projected mission capabilities. Development of a software information system to correlate and predict high level system health from low level system health indicators enables this capability. This paper summarizes the work associated with development of a decision support tool to provide real-time mission readiness assessment for US Navy ships. The information system developed under this program utilizes predefined mission requirements, operational constraints, system performance measures, and component health state predictions to determine overall platform, system level, subsystem, and component readiness. The development effort included creation of a robust, scalable, system modeling environment to model system operating states, subsystem interactions, and correlate independent subsystem health indicators to overall system readiness. The decision support tool employs a common hierarchical format to portray the physical system, sub-system interactions and operational dependencies. Predefined functions enable multiple independent low level health state indicators to be combined to capture the effects of complex interactions between interconnected subsystems for each independent system operating state. The software utilizes Open System Architecture (OSA) to facilitate seamless interface with Navy Maintenance Data and Information Systems. Although designed for Navy ship applications the software is generic in nature and can be adapted for other complex military systems and commercial industries including aviation, shipping and power generation. Keywords: Mission Readiness, Maintenance Reasoning, Condition-based Maintenance,

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 31

Session: **4A Health Management Strategies**

Author: David Baglee

Organization: University of Sunderland

Country: UK

Paper Title: Towards True Dynamic Decision Making in Maintenance

Co Authors: Erkki Jantunen (VTT Manufacturing Technolgy, Finland), Aitor Arnaiz (Fundación Tekniker, Spain)

Abstract:

The maintenance of machinery and assets in European industry has been shown to account for a significant proportion of operating costs, however it is a particular area where substantial savings are possible through the use of more technologically advanced approaches. Modern industrial production systems are experiencing ever increasing demands for improved machinery reliability, efficiency, safety and environmental performance. Maintenance system technology have progressed to some extent but complete solutions with the flexibility to satisfy the demands of a wide range of users are still not widely utilised. One current research project, DYNAMITE (Dynamic Decisions in Maintenance) intends to address this problem by developing and applying a blend of leading-edge communications and sensor technology, combined with state-of-the-art diagnostic and prognostic techniques. The objective of the project is to deliver a prototype maintenance system to enable the monitoring of machines and processes for predictive maintenance and control. An infrastructure for mobile monitoring technology is to be developed along with devices incorporating sensors and algorithms to support enhanced capability for decision support systems. Some key features include wireless sensors and communications, intelligent data analysis, smart tags, and semantic web technology. A key strategy of this project involves the extensive use of stored and transmitted electronic data in order to ensure that users have access to up-to-date, accurate and detailed information. This strategy provides great advantages for both human and machine-based decision making capability. For instance the system aims to assist in the inspection and maintenance process by identifying priority cases, collating and delivering detailed documentation on maintenance procedures and also to plan and schedule these activities. Several key aspects of the project will be identified and the methods and technologies used to develop the maintenance infrastructures that allow such rapid, efficient, and cost-effective decisions to be made will be discussed.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 42

Session: **4A Health Management Strategies**

Author: Wolfgang Ziemer

Organization: ePS & RTS Automation Software GmbH

Country: Germany

Paper Title: Controlled Condition Monitoring

Co Authors:

Abstract:

Condition Monitoring

Unplanned downtimes must be avoided to ensure smooth operation of machines. Critical machine components such as axes, spindles and even motors, chip conveyors, valves and cylinders are particularly important, for example, in machine tools.

With Condition Monitoring, service and maintenance technicians are provided with in-process measurement procedures and testing routines which enable continuous evaluation of the state of their machines. Furthermore, individual machine components can be monitored cyclically on time and on event.

SetUp condition monitoring is worldwide available on internet PCs for any machine. The cycle exact real time test procedures, which can contain process like logic, can be implemented remote by the technicians any time without changes on the OEMs application in hardware and software. The machines actuate them automatically with the latest procedures.

Results of condition monitoring is worldwide available on any internet PC. The monitoring and specific machine results of the procedures are sent to the ePS servers. With customizable functions the technicians get notice from ePS server via reports or individual messaging when deviations to the normal condition on a machine come.

Predictive maintenance – with Condition Monitoring

The results in detail can be evaluated for the entire life cycle of a machine using the trend analysis, enabling advanced and targeted planning of servicing measures and optimization of inspection and maintenance. Technicians can identify critical states in advance, leaving enough time to plan a course of action and minimize unplanned machine downtimes. Regardless of processes or use patterns, service personnel can identify which spare parts need to be available when and where, enabling them to optimize ordering of spare parts and, consequently, reduce servicing costs.

Just the right support in maintenance

When you need service or maintenance, you want fast and uncomplicated assistance. The results from Condition Monitoring will react immediately, before you know that you will need assistance and with addressing the upcoming problem direct to the responsible machine downtimes is kept to the minimum you need for the physical service.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 71

Session: **4B PHM Applications**

Author: JB Schroeder

Organization: US Air Force Research Laboratory

Country:

Paper Title: Introduction to Session: Lessons Learned from 15 Years of PHM Pursuits

Co Authors:

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 20

Session: **4B PHM Applications**

Author: Michael Roemer

Organization: Impact Technologies, LLC

Country: USA

Paper Title: Selected Artificial Intelligence Methods Applied within an Integrated Vehicle Health Management System

Co Authors: Carl S. Byington, Michael S. Schoeller

Abstract:

The work presented herein will highlight selected vehicle subsystem Prognostic and Health Management (PHM) technical approaches as applied within an Integrated Vehicle Health Management (IVHM) system. The selected vehicle subsystem areas to be discussed include electro-mechanical actuators (EMAs), propulsion system performance, vehicle structural integrity and general signal anomaly detection. Artificial intelligence methods including neural networks, fuzzy logic and trained probabilistic classifiers are described within the context of the selected subsystem applications. In addition, discussion on individual subsystem health condition indicators as applied within an intelligent, model-based reasoning approach is presented that examines health state and functional availability of individual components, subsystems, and the overall vehicle. The PHM approaches described herein illustrate the integration of detection, diagnostic, and prognostic reasoning capabilities from across critical subsystems on a vehicle platform. The examples provided illustrate how the selected AI technologies can be implemented throughout an end–to–end application, from data signal quality checks to off-board prognostic assessments.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 15

Session: **4B PHM Applications**

Author: Hassan Al Atat

Organization: NSF Center for Intelligent Maintenance Systems (IMS), University of Cincinnati, Cincinnati, U.S.A;

Department of Industrial Engineering & Management, School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, China

Country: USA

Paper Title: Prognostics of Automotive Sensors: Tools and Case Study

Co Authors: (1) Hassan Al Atat, Masoud Ghaffari, Jay Lee (NSF Center for Intelligent Maintenance Systems (IMS), University of Cincinnati, Cincinnati, USA); (2) Li-feng Xi (Department of Industrial Engineering & Management, School of Mechanical Engineering, Shanghai J

Abstract:

Many safety critical subsystems of a vehicle, including antilock brake system (ABS) and traction control system (TCS) depend on a reliable and precise speed signal, which is captured by wheel speed sensors (WSSs). A degrading wheel speed sensor may cause decline in ABS performance, shut down, or even a fatal accident. A comprehensive patent search and literature review reveal that existing systems (including on-board diagnosis, OBDs) can only detect faulty wheel speed sensors. To predict the degradation of wheel speed sensor before failure, a confidence value (CV) based wheel speed sensor prognostic decision model is proposed, which is built on the output signals of wheel speed sensors. Features are extracted from the signals and artificial intelligent algorithms are used to get the confidence value and identify the degradation level. Simulation is conducted to illustrate the feasibility and efficiency of the decision model.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 24

Session: **4B PHM Applications**

Author: David Siegel

Organization: NSF Center for Intelligent Maintenance Systems (IMS), University of Cincinnati

Country: USA

Paper Title: Failure Prediction of Critical Components in Military Vehicles

Co Authors: Jay Lee, Masoud Ghaffari

Abstract:

Military vehicles are subjected to harsh environments such that improved reliability of critical components are needed to achieve lower fleet cost and satisfy mission objectives. This study investigates the High Mobility Multipurpose Wheeled Vehicle (HMMWV), which is a widely used tactical vehicle. Currently there is no system on the vehicle to measure the level of degradation or the remaining useful life of its critical components. After a comprehensive literature review and discussion with the U.S Army Tank-Automotive Research, Development and Engineering Center (TARDEC), it was determined that the HMMWV alternator is not only crucial to the vehicles reliability but also very suitable for implementation of prognostic tools. A test-bed was constructed to simulate the alternator's use on the vehicle and both a new and faulty alternator were used to collect data for training purposes. Features were extracted from both the electrical and vibratory data of the alternator. They were utilized by artificial intelligent algorithms to measure the level of degradation indicated by a confidence value (CV). Preliminary results of this feasibility study indicate that this method can be extended by monitoring the alternator's performance continuously on the vehicle. This methodology can also be applied to other critical components of military vehicles.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 25

Session: **4B PHM Applications**

Author: Mickey Harp

Organization: Commtest

Country: USA

Paper Title: Preventing Machinery Failures with Online Surveillance

Co Authors:

Abstract:

Rotating equipment in production facilities offers optimal performance and reliability when properly installed, maintained, and operated. Condition monitoring devices and systems are utilized to keep tabs on the operational performance of key production equipment. All types of tools and technologies exist today in the predictive maintenance field to allow monitoring and assessment of such equipment. In many cases, a structured portable, walk-around program will suffice. In other situations, where equipment is hard to reach, inaccessible, or located in a dangerous or hazardous area, a permanent installation of sensors and surveillance hardware is necessary. Key objectives for such a maintenance program are to minimize failures, reduce downtime, and to reduce costs.

Condition monitoring tools can improve production uptime, efficiency, and profitability. Candidates for monitoring include motors, pumps, compressors, fans, gearboxes, bearings, and other critical machine elements. As components become worn, dirty, contaminated, loose, misaligned, unbalanced, and improperly lubricated, machines may experience increased vibration levels and higher temperatures, thereby leading to failures and production outages.

The tools for predictive maintenance and condition monitoring must be chosen with consideration given to planned return on investment. Production personnel should classify machines as “critical”, “essential”, or “balance of plant”, and then decide the right mix in terms of required maintenance expertise and tools.

Careful review of needs and expectations can lead a potential user for these tools down several paths. Popular choices in this area of technology include route-based portable instruments, online continuous monitoring hardware, and predictive analysis software systems. Online systems include options for wireless or hard-wired connectivity. It is important to clearly understand the pros and cons of each offering.

Recent advances in electronics technology have allowed online predictive maintenance systems to be more affordable, reliable, flexible, and modular. These systems have proven to be quite effective in providing early warnings and pinpointing root causes for machinery faults and failures. Online systems can measure and record many process parameters, allowing the user to trend and trigger on alarms so that machine performance and health can be monitored along with vibration-related faults. There has been a natural tendency to integrate some of these data with traditional process instrumentation and control systems.

This paper will focus on the ideal application of continuous surveillance systems, the economies of scale, and the distinct advantages relative to implementing a traditional portable, walk-around program. While previous experiences for such systems in this industry have brought out some areas for concern, these will be addressed as well. A specific case history and success story will be cited to show the advantages of increased awareness and improved reliability with online surveillance.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 74

Session: **4B PHM Applications**

Author: Andrew Hess

Organization: Consultant

Country:

Paper Title: PHM Applications: Past, Present, and Future

Co Authors:

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 49

Session: **5A Health Management Tools and Capabilities**

Author: Martin Karchnak

Organization: Epoch Engineering, Inc

Country: USA

Paper Title: The Neglected Role of Information Measurement in Failure Prevention and System Availability

Co Authors:

Abstract:

Information measurement, with an emphasis on its relationships with competent decision-making, is being investigated to seek out 'information' regarding the 'proper role of information measurement' in failure prevention and system availability. Effective and efficient disciplined paths for improvements are being sought. Concepts such as 'failure prevention' and 'system availability' are inextricably tied in with other concepts such as 'diagnostics' and 'prognostics'. All of these types of concepts are laced with a healthy dose of 'quantitative' data and 'qualitative facts' (e.g., "it's broken") ----- i.e. information used in decision-making (human, automatic, hybrid, whatever). Competent decision-making is considered in terms of its need to always ensure: i) that the 'facts' are correct; ii) that any conditional (i.e. Bayesian) matters are correctly addressed; and iii) that all quantitative information is characterized correctly. [Correct characterization of quantitative matters requires both acknowledgement of the existence of 'probability density functions' (pdfs) and ensuring 'minimum prejudice' in any pdf selections/characterizations.] Current practice is examined, with a focus on understanding the physical measurement process and understanding the information measurement process. Examples of specific approaches where the role of information measurement in failure prevention and system availability appears to have meaningful potential for making a positive difference in overall capabilities, including decision-making, are provided.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 57

Session: **5A Health Management Tools and Capabilities**

Author: Amit Deshpande

Organization: TechSolve, Inc.

Country: USA

Paper Title: Smart Machine Supervisory System: Concept, Definition and Application

Co Authors: Sri Atluru, Dr. Sam Huang (University of Cincinnati); Dr. John P. Snyder (TechSolve, Inc)

Abstract:

In today's competitive world, manufacturers have realized that they need to embrace automation as their mantra to success. However, the impact of automation primarily concerns with the effectiveness of process monitoring and control systems. Prevailing technologies do not look beyond the capacity of controlling a single process module. There is a need for a closed loop supervisory system, which integrates and coordinates individual process monitoring and control modules for real-time adjustment, conflict resolution and priority assignment. The integration of individual process modules with intelligent decision support system will result in higher productivity, better quality and advanced prognostics for near-zero breakdown performance. In this paper, we first define the smart machine supervisory system as open architecture system that integrates and coordinates individual process monitoring and control modules such that a real-time globally optimal machining solution is delivered for maximum productivity. The Smart Machine Platform Initiative (SMPI) is the brainchild of the Coalition on Manufacturing Technology Infrastructure (CMTI) represented by academia, industry and government agencies working towards the common goal of "first part correct". SMPI is the reinvention of the basic manufacturing environment, enabling dramatic improvements in the productivity and cost of designing, planning, producing, and delivering high-quality product within short cycle time. SMPI efforts at TechSolve, Inc. concentrate on six thrust areas, namely, Tool Condition Monitoring, Intelligent Machining, On-Machine Verification, Metrology, Health & Maintenance and the Supervisory System. We then proceed to explain the architectural and implementation details of the supervisory system with emphasis on the knowledge system. The proposed architecture is two tier – the communication level (monitor) and the decision level (adaptive control). Communication level facilitates seamless transfer and display of information among various process control modules, while the decision level enables creation and usage of a knowledge system. The knowledge system provides intelligent decision support functionality based on the data received from disparate sources, user defined business logic and self learning. We conclude with further insights into benefits, functional and technical requirements, issues and implications for successful realization of a smart machine supervisory system.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 75

Session: **5A Health Management Tools and Capabilities**

Author: Derek Norfield

Organization: Datastick Systems Inc.

Country:

Paper Title: Wire We Measuring Wirelessly?

Co Authors:

Abstract:

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 59

Session: **5A Health Management Tools and Capabilities**

Author: Rena Fish Durham

Organization: Tec-Masters

Country: USA

Paper Title: Component Remaining Life Estimate via Dynamic Reliability

Co Authors: John Pooley, Nat Albritton and R. Giuntini

Abstract:

Abstract Effective Fault Diagnosis and Prognosis are premised on successfully filtering the desired signal that characterizes the sub-component internal kinematical excitation from sensor response signal. This response signal is contaminated with extraneous signals/noise originating at either the internal excitation source point or the transmission path adjacent component contaminants. Once the desired signal is extracted then it is analyzed to determine if an anomaly exists. If an anomaly exists, then the desired signal is utilized to diagnose, isolate and identify, the underlying cause of faulty sub-component operational conditions, such as misalignment, deviant eccentricity, loose coupling, modulations or internal rubbing, which cause variants in the desired signal from nominal to anomalous to faulty. This Diagnostic analysis' of the desired signal results in dimensionless statistical scores (DSS). DSSs' derived from faulty operational conditions are statistically separability scored against DSS's derived from ideal nominal signals, resulting in a Fault Classification statistical metric. This Fault Classification is accomplished by synthesizing these DSS discriminants into an Operational Health Statistical Score (OHSS). OHSS effects fault diagnosis by tracking machinery operational condition from nominal, to nascent, then critical. Therefore, fault detection and diagnosis are sufficient to achieve Condition Based Maintenance (CBM). However, dynamic failure state tracking from incipient to functional failure is required to achieve Prognosis, which entails tracking the effect of faults and utilization stressors effect on "Remaining Life" estimates throughout the components useful life. Prognosis is the ability to track the "Remaining Life" estimate throughout a dynamic component's useful life, e.g. from current utilization time to projected utilization of next mission time. The Prognostic challenge is how to weight the OHSS with stressors and fault severity effects in order to adjust a component's "Remaining Life" estimate. Consequently, "Remaining Life" estimation is sufficient to achieve Prognostic Health Management (PHM).

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 47

Session: **5A Health Management Tools and Capabilities**

Author: Shunfeng Cheng

Organization: CALCE, University of Maryland College Park

Country: USA

Paper Title: Autonomous Prognostic Monitoring Device

Co Authors: Myra Torres, Larry Thomas and Michael Pecht

Abstract:

Prognostics is a process of assessing the extent of deviation or degradation of a product from its expected normal operating condition, and then, based on continuous monitoring, predicting the future reliability of the product. This process can provide advanced warning of failures, optimize maintenance, and improve the design, qualification and reliability of the system. Life-cycle loads can, either individually or in various combinations, cause performance or physical degradation of the product or reduce its service life. If one can continuously monitor the loads, in-situ, this data can be used in conjunction with precursor reasoning algorithms and stress and damage models to enable prognostics. In this paper, a new health monitoring device, CALCE-ePrognostic system sensor tag, is introduced firstly. This device can monitor, record and transmit the data of life-cycle loads, such as environmental and operational stress, of electronics. It has multiple sensing elements, for example the temperature, humidity and the vibration, that can monitor multiple parameters. The on-board memory enables it record the monitored data in real time and allows for later transmissions. Using the radio frequency identification (RFID) technology, this tag can transmit the data wirelessly. The device is the size of a credit card and has an imbedded battery to provide the power. It is flexible and easy to attach on the surface of the monitored product non-intrusively. Then, this paper focuses on the algorithms to analyze the monitored data for prognostic and fault diagnostics purposed. The approach taken will be sequential probability ratio test (SPRT) to find out the precursor of the failure.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 64

Session: **5A Health Management Tools and Capabilities**

Author: Tim Marvin

Organization: Impact Technologies, LLC

Country:

Paper Title: A Modeling and Analysis Environment for Solid Propellant Life Prediction

Co Authors: Jeff Steele, and Carl Byington

Abstract:

Impact Technologies has developed a modeling and analysis environment for solid rocket motor propellant life prediction. The objective of this software is to provide engineers with a tool to assess the effects of storage time, temperature and humidity on solid rocket motors and to predict their probability of successful operation when called upon. In addition to applications to rocket motor storage, this technology is applicable to single-shot devices like vehicle airbags, ejection seats, emergency shutoff valves, and torpedo squibs that must work even after long periods of storage under varied environmental conditions.

This tool not only integrates the legacy methods of damage analysis such as thermal stress-induced creep, but adds additional modules to incorporate finite element stress and strain analysis, nonlinear damage accumulation, chemical process effects, and probability theory. To allow flexibility in development, deployment, and future expansion, the software was designed with a three tier architecture. These three levels are the interface, application layer, and database layer. The GUI front end layer allows easy interface changes and remote operation. This intuitive graphical user interface additionally combines the tools for managing data (both inputs and outputs), input and results visualization, and report generation. To manage the wide variety of analysis methods and models, the middle application layer utilizes a modular architecture. This allows updated modules (lifing models, fusion algorithms, etc) to be easily integrated with existing prediction modules. The database backend provides for a distributed computing environment, sharing of knowledge resources, and easy management of large data sets. Progress forward has been directed towards the fusion algorithms and estimation of confidences associated with life predictions by feeding back empirical test results.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 7

Session: **5B Gear and Bearing PHM**

Author: John Judd

Organization: DMC CT, Dynamic Measurement Consultants. LLC

Country: USA

Paper Title: A Simplified Metrics Based Approach to Bearing Life Extension, Fault Analysis and Failure Prediction (An Update on the BearingLifeGuard (c) Project)

Co Authors:

Abstract:

A brief review/update of the Multiple Discriminant Analysis technique and how it is applied to assess rolling element bearing condition, measure life reduction and estimate probability of failure. It will include a review of the derivation of metrics used and resulting user's interface designed for maintenance managers. The presentation will include some application examples as well as a review of practical problems encountered in applying the technology in the field and how they were solved..

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 72

Session: **5B Gear and Bearing PHM**

Author: Ahmed Onsy

Organization: Newcastle University

Country: UK

Paper Title: Early Detection of the Progression of Micro-Pitting in Helical Gears Using Health Monitoring Techniques

Co Authors: Dr. Robert Bicker (Mechatronics Group, Newcastle University), Dr. Brian Shaw (Design Unit, Newcastle University), T Kent

Abstract:

Micro-pitting is a fatigue effect that occurs in gears due to high contact stress. Monitoring the progression of micro-pitting is vital to prevent the complete failure of the tooth flank. Parameter signature analysis has been successfully used to monitor the advanced phases of gear surface fatigue failures and bending fatigue failures. Due to the improvement in modern steel production, the main cause of gear contact fatigue failures is attributed to surface micro-pitting failures rather than sub-surface failures; this increases the demand for the monitoring of micro-pitting progression. This study will evaluate the detection and progression of micro-pitting in helical gears using Acoustic Emission (AE), vibration, and Oil Debris Analysis (ODA) monitoring. The paper will present an automated Health Monitoring System which has recently been developed for use with a 75mm back to back gear test rig. The results will validate the system capabilities in detecting early defects, and can be used in maintenance strategies.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 11

Session: **5B Gear and Bearing PHM**

Author: Stanley Bognatz

Organization: M&B Engineered Solutions, Inc.

Country: USA

Paper Title: Increasing Machine Reliability through Precision Alignment - The Benefits of Optical Alignment Techniques

Co Authors:

Abstract:

This paper discusses high-precision optical measurement techniques and their use in optimizing rotating machinery alignment to improve long-term reliability. All machinery experiences extraneous, uncontrollable movement. These are due to a combination of thermal growth and static deflection. Thermal growth arises due to heat in the various process fluids, while static deflection results from the effect of torque on the supporting foundations plus pipe strain. On critical rotating machinery (large motors, steam turbines, generators, boiler feed pumps, high-speed compressors, gearboxes, etc.) these movements are often large relative to the allowable shaft misalignment, and significantly degrade the quality of the shaft alignment performed when the machinery was off-line and cold. This additional misalignment causes many reliability problems, including: worn or damaged bearings and couplings; shaft / seal rubbing – leading to steam and oil leakage; and high shaft and structural vibration, to name a few. And, while OEMs sometimes provide thermal growth ‘estimates’ for offsetting cold alignment, they rarely provide data specific to that individual machine. Nor can they accurately account for static deflection, which is installation-specific. We have many cases of ‘identical’ machines, often immediately adjacent to each other, requiring significantly different cold alignment offsets, all due to a dissimilar combination of thermal growth and static deflection. Our paper will discuss our criteria for precision shaft alignment, providing a chart and calculation techniques that take into account factors such as shaft speed, bearing design and coupling design. We will review optical measurement equipment and techniques, the specific equipment needed in various applications, and the advantages that optical alignment has over other techniques. We will present a summary of data from various machines for illustration, and will conclude with several case histories detailing the efforts and results of our work, including changes incorporated by customer that improved their short and long-term reliability.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 22

Session: **5B Gear and Bearing PHM**

Author: Linxia Liao

Organization: NSF I/UCR Center for Intelligent Maintenance Systems

Country: USA

Paper Title: A Reconfigurable Embedded Prognostics Platform for Machinery Performance Management

Co Authors: Jay Lee

Abstract:

Bearings are critical components in a rotating machine since their failures could lead to a chain of serious damages in the machine. An avalanche of research activities on bearing fault diagnostics have been conducted with good successes but challenges remain on how to effectively predict bearing health degradation to prevent and eliminate potential failures.

This paper presents a new methodology that assesses bearing health degradation condition and predicts potential futures.

The presented methodology is based on the following three steps:

(I) Generate feature vector: The feature vector is a signature describing a state of bearing health, which is formed from features that are considered to be correlated to those that indicate machine health condition. Features are extracted using an algorithm such as Fast Fourier Transform (FFT) or wavelet transform depending on the characteristics of the sensory signals.

(II) Evaluate bearing health: Patterns of the feature vectors that describe up-to-now states of bearing health are grouped into a health map, using a clustering algorithm such as the method of self-organizing map, k-means algorithm, neural networks-based algorithm, and others, depending on available information about patterns of the feature vectors.

(III) Predict bearing health degradation: The evolution/dynamics of those feature vectors over time is essentially the defining characteristic of the bearing deterioration process. A multivariate ARMA model is used to obtain the possible future distributions of the feature vector. The injection of the predicted feature vector in the bearing health map indicates the future bearing health condition.

Two industrial case studies are used to illustrate the effectiveness of the presented methodology: (1) a series of roller bearing run-to-failure tests are conducted on a specially designed test rig; and (2) a spindle bearing is on-line monitored without interrupting production. The presented methodology shows a high accuracy of prediction of bearing health condition based on the experimental and validation results.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 36

Session: **5B Gear and Bearing PHM**

Author: Yi Liu

Organization: University of Illnois at Chicago

Country: USA

Paper Title: Damage Mechanics Based Bearing Prognosis Using HUMS Condition Indicators

Co Authors: David He

Abstract:

Health and usage monitoring systems (HUMS) use condition indicators (CIs) for health monitoring of flight critical components such as bearings. CIs from healthy components are normally used to set threshold such that there is a small probability of the CIs of nominal components exceeding the threshold. If a CI exceeds the threshold, the component is declared bad. The limitation of these CI thresholds is that they don't quantitatively correlate to the health condition of the components and therefore cannot be used for accurate diagnosis and prognosis in the implementation of condition-based maintenance. In this paper, our experience in using HUMS condition indicators and damage mechanics to develop bearing prognostic capabilities is reported. The HUMS condition indicators are generated by several methods: bearing passing frequencies at the base frequency, RMS of the vibration in some frequency windows, envelop analysis of the bearing passing frequencies, RMS of the envelope analysis, and cepstrum analysis of the bearing passing frequencies. We consider the bearing system as a single-degree-of-freedom vibratory system. In such a system, the natural frequency and the acceleration amplitude at the natural frequency can be related to the system stiffness. Therefore, the natural frequency and the CI at the natural frequency can also be related to the system stiffness. As the relationship between failure time and stiffness variation can be established from the damage mechanics, the HUMS CIs can be related to failure time. Finally, these bearing prognostic algorithms are validated using real rolling element bearing test data with intermediate inspection and the performance of these bearing prognostic algorithms are evaluated.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 37

Session: **5B Gear and Bearing PHM**

Author: Ruoyu Li

Organization: University of Illnois at Chicago

Country: USA

Paper Title: Hilbert-Huang Transform Based Gearbox Fault Diagnosis

Co Authors: David He

Abstract:

Demodulation and non-stationary modulating signals are two important issues in gearbox fault detection. Hilbert transform in combination with other methods provides an effective way to address these issues. This paper reports an investigation on gearbox fault diagnosis using Hilbert transform based methods. In particular, it focuses on two Hilbert transform based gearbox fault diagnosis methods: Hilbert-Huang transform and Hilbert transform in combination with wavelet packet analysis. Hilbert-Huang transform decomposes a signal using empirical mode decomposition into intrinsic mode functions and applies Hilbert transform to these functions to obtain the Hilbert spectrum. As the envelope obtained by Hilbert transform represents an estimate of the modulation existing in the non-stationary vibration signals, combining Hilbert transform with wavelet analysis would allow non-stationary analysis for effective fault detection. In this paper, both simulated signals and real vibration signals collected from a gearbox dynamics simulator are used to evaluate the effectiveness and robustness of the methods for different types of gearbox faults. Discussion and demonstration cases on improving Hilbert transformed based gearbox fault diagnosis are provided.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 3

Session: **5C Failure Prevention for Materials and Structures**

Author: James (Jim) Kidd

Organization: US Army Research Laboratory

Country: USA

Paper Title: Evaluation of Chemical Agent Resistant Coatings that are Exposed to Ultraviolet Radiation

Co Authors: James Kidd

Abstract:

The US Army Research Laboratory (ARL) has the lead research and development responsibility for chemical agent resistant coatings (CARC) and manages the relevant specifications that govern the topcoats, primers, and pretreatments for CARC systems. In striving to optimize coating durability and to extend the life cycle of vehicles and weapon systems that use CARC materials, ARL evaluated several CARC topcoats for Ultraviolet (UV) resistance. After samples were subjected to ultraviolet irradiance in laboratory weathering chambers several instruments were used to quantify four parameters that indicate the degradation of a material.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 33

Session: **5C Failure Prevention for Materials and Structures**

Author: Brandon Zwink

Organization: Purdue University

Country: USA

Paper Title: Health Monitoring of Military Composite Helicopter Structures Using Minimal Dynamic Sensing

Co Authors: Douglas Adams, Emily Prewett

Abstract:

Composite helicopter rotor blades experience multi-axial loading and foreign object impacts in flight, which can introduce delamination and other forms of material damage. Composite fuselage and frame structures can also experience ballistic damage and damage caused by shock loading during liftoff and touch down. The United States Marine Corps is interested in developing health monitoring technologies for (1) identifying loads that act on rotor blades, (2) detecting damage in the field using hand-held equipment, and (3) characterizing (locating and quantifying) damage at the depot level. These health monitoring technologies will enable condition-based maintenance of composite blades and structures. This work focuses on areas (1) and (2). First, impact loads are identified using a model based on frequency response functions obtained through modal impact testing. An overdetermined least-squares approach to force estimation is used along with a calculation of the variance in the estimated force as a function of frequency to locate and quantify impacts on a 5 m blade. Second, multiple damage detection methods are applied to detect damage in the form of stiffness loss in the 45 degree direction with respect to the chord direction on the surface of the blade with composite properties at various locations along the blade. Step relaxation (1 sensor channel), frequency response coherence (2 sensor channels), and active vibration (2 sensor channels) measurement techniques are considered. Each method compares the healthy (baseline) response of the blade with the damaged response of the blade to detect damage. Experiments are conducted to determine (a) an ideal sensor arrangement for detecting damage, (b) the sensitivity of each method to environmental changes compared with damage, and (c) the sensitivity of each method to boundary conditions and gravitational preload on the blade. A finite element model is also developed to validate the changes in measurements caused by simulated experimental damage.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 34

Session: **5C Failure Prevention for Materials and Structures**

Author: Robert Kurth

Organization: Battelle Memorial Institute

Country: USA

Paper Title: The Development and Use of Probabilistic Mechanics Models in Condition Based Maintenance

Co Authors: Kevin Boyd

Abstract:

Condition Based Maintenance (CBM) strategies are being employed to achieve high availability, lower costs, to reduce unscheduled maintenance, and to prevent failure. A successful CBM program involves detection, prediction and sensors. One of the primary drivers for inspections and downtimes is structures. Historically fatigue and fracture have dominated these inspections but there is great uncertainty in the material properties, loading, initiations times, defect sizes and so forth. As the structure ages corrosion can also begin with a corresponding high reduction on the structural life. This paper will describe the current status of the probabilistic mechanics analysis that integrates, fatigue, corrosion, fracture, and residual strength analysis. The probabilistic mechanics model has combined a wide range of probabilistic methodologies with state-of-the-art deterministic structural mechanics models, fatigue models, corrosion models, crack initiation models, residual strength models, and finite element analysis. For specific analyses of aluminum structures we have been able to demonstrate the reduction in life that occurs in the presence of corrosion. These predictions compare very favorably to the USAF/OSD corrosion monitoring program results. These comparisons will be presented. We will also discus the interaction of the risk of structural failure and inspections and how this tool is used to shorten maintenance times, reduce unscheduled maintenance, and could be used to improve inspection intervals.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 35

Session: **5C Failure Prevention for Materials and Structures**

Author: Robert Kurth

Organization: Battelle Memorial Institute

Country: USA

Paper Title: Probabilistic Mechanics Analysis of the Impact of Stress Corrosion Cracking on Pipeline Leak Before Break

Co Authors: Paul Scott, Kevin Boyd

Abstract:

Stress corrosion cracking has developed into a serious concern among nuclear and gas pipeline operators as well as in the aircraft and aerospace industries. One of the risk mitigation strategies employed in the pipeline industry is the Leak Before Break (LBB) concept. In this situation one must be able to demonstrate that a defect will grow in such a manner as to break through the wall and leak in a stable fashion for a long enough period of time that it can be detected before it causes a catastrophic failure of the piping system. There are many uncertainties associated with these analyses including the material properties, the weld, the weld stresses, the location of the defect, and so forth. This requires that a probabilistic analysis of the piping system be performed in order to demonstrate the LBB characteristics with confidence. Historically the damage in the pipe was assumed to be due to fatigue crack growth. Recently it has been found that there is a significant impact to the LBB concept from Stress Corrosion Cracking (SCC). While fatigue damage will only increase with load cycles, SCC is time dependent and will continue to grow even when there is no, or minimal, loading. This paper presents the results of a model development effort which combines fatigue crack growth and SCC damage over the service life of a pipeline system. The various leak rates are calculated and compared to the probability of detection. Conclusions about the impact of SCC on the LBB concept are then made.

MFPT 62 (2008) – Paper Abstracts Listing

Ser: 70

Session: **5C Failure Prevention for Materials and Structures**

Author: Jeff Calcaterra

Organization: US Air Force Research Laboratory

Country:

Paper Title: F-15 Structural Failure: Report on Accident Investigation and Remedial Actions

Co Authors:

Abstract: