MFPT 2009 - Paper Abstracts Listing

Topic: 1B - Health Management for Turbomachinery

Presenting Author: Eric Olson

Organization: Mechanical Solutions Inc

Country:

Paper Title: Use of Operating Deflection Shapes for Turbomachinery Diagnostics

Co Authors: William D Marscher

Abstract:

With the advent of signal analysis by Fast Fourier Transform (FFT), the evaluation of machinery operationally-induced vibrations became particularly useful, since complicated signals in the time domain could be interpreted in terms of frequency content versus expected strength of the vibration signal at various discrete frequencies. However, evaluating vibration at many locations remained difficult or down-right impractical because of limitations on the number of analyzer channels, as well as limitations on computer storage capacity and processing power. Over thee last ten years, it has become cost-effective for even small businesses to purchase large-channel-count FFT analyzers, not to mention extremely powerful laptop computers to store and rapidly process the data. This has made practical the rapid accumulation of comprehensive spectral as well as time-frequency data on a very large number of measurement points on rotating machinery, as well as its piping and foundation. Faults such as cracks, looseness, and excessive excitation force frequencies can be visualized, and thereby precisely located and understood, though animation of the vibrations data as an “Operating Deflection Shape” (ODS). The paper explains the general workings of the procedure, and provides a case history to illustrate successful application of the procedure in accomplishing accurate machinery diagnosis.

Topic: 1B - Health Management for Turbomachinery

Presenting Author: Mike Denton

Organization: National Instruments

Country:

Paper Title: Advanced Signal Processing Algorithms and Architectures for Sound, Vibration, and Machine Condition Monitoring

Co Authors:

Abstract:

Many sound and vibration applications have adopted signal processing. FFT-based signal processing algorithms might not help in some applications. Several advanced signal processing algorithms beyond the FFT such as Time-Frequency Analysis, Order Analysis, Quefrency and Cepstrum, wavelet analysis, and AR Modeling uses are outlined. These advanced algorithms can solve sound and vibration challenges that FFT-based algorithms cannot solve. This presentation will introduce the background of these algorithms and their application examples, such as bearing fault detection, motor testing and turbomachinery monitoring.

Topic: 1B - Health Management for Turbomachinery

Presenting Author: Richard Holmes

Organization: VEXTEC Corporation

Country:

Paper Title: Scaled Turbine Engine Testing for Cost-effective Health Prognosis

Co Authors: Thomas Brooks, Robert Tryon

Abstract:

Full scale gas turbine engine testing is expensive and time consuming. An efficient alternative is the use of low cost subscale engine testing that can simulate the conditions of a full-scale engine and its failure mechanisms. VEXTEC has developed scaled turbine engine tests as a platform to gather probabilistic data on multiple material failure mechanisms such as thermal mechanical fatigue, biaxial crack growth, creep and foreign object damage. These tests are efficient in terms of cost and schedule and provide insight into full scale engine behavior. Complex multi-axial stress fields and thermal environment typically observed in gas turbine engines are naturally reproduced in the scaled engine testing. Subscale engine testing is validated by comparing the test data with full scale engine testing results. This paper discusses the capabilities of the scaled engine and its benefits compared to full scale engine testing.

Topic: 1B - Health Management for Turbomachinery

Presenting Author: Bill Marscher

Organization: Mechanical Solutions Inc

Country:

Paper Title: Turbomachinery Prognosis Based on Finite Element, Tribological, and Fatigue Analysis Calibrated by Test

Co Authors: William J. Kelly

Abstract:

The most difficult aspect of PHM is prognosis, the reliable prediction of remaining useful life. The application of a deterministic approach has been demonstrated to be successful, by developing physical representations of diagnosed issues. The basis for the approach is a combination of a computer-aided engineering numerical model created using finite element analysis, with closed form tribological and fatigue/ fracture mechanics formulations. The resulting analysis is grounded in rn realism by modifying load distributions and frequency spectra within the model until the model results reasonably match instantaneous test results as well as test result trending over time.

Topic: 1C - Health Management Tools and Capabilities 1

Presenting Author: Matt Leonard

Organization: US Air Force Research Laboratory

Country:

Paper Title: Hot Spot Monitoring of a Metallic Lug Component

Co Authors: Steven E. Olson, and Jeong-Beom Ihn

Abstract:

Aircraft structural components may have known “hot spots” where a particular type of damage is anticipated to occur or has consistently been observed in the field. Automated inspection of these areas, or hot spot monitoring, may offer significant time and cost savings for aircraft maintainers, particularly when the hot spots exist in areas that are difficult to access or where traditional non-destructive inspection methods will not work. This paper discusses the development of hot spot monitoring techniques for a metallic lug component using piezo-generated elastic waves. The development process has followed a multi-step approach progressing from simple coupon tests to the full scale component. Modeling, experimentation, and signal analysis performed at various steps of the development are discussed.

Initial testing has been performed on titanium dogbone coupons. Two different sensor configurations have been considered. Explicit finite element simulations indicate the potential to detect thru-cracks of less than 0.10 inch. However, actual crack detection has been complicated by issues of sensor system robustness and the reliability of “truth” data, as well as the complexity of the dogbone coupons utilized. Subsequent testing has been performed using titanium cantilever beam specimens. Arrays of packaged piezoelectric sensors have been utilized to improve sensor robustness and visual inspections with fluorescent dye penetrant have been used to improve the reliability of the “truth” data. Damage indices have been calculated which show the potential to detect cracks on the order of 0.10 inch. However, additional testing is required to further refine and tune this technique as only limited data is available from the cantilever beam testing. Recent experiments include fatigue testing of lug subcomponents with a geometry and material properties very similar to the full scale component. The sensor layout and packaging for the subcomponent tests has benefitted from lessons learned during the dogbone and cantilever efforts. Five subcomponent tests have been performed with waveform data collected over a range of frequencies and visual crack lengths recorded after specific numbers of cycles. Preliminary work demonstrates that damage indices can be mapped to crack length for edge sensors. However, as the crack grows beyond the field of view of the edge sensor, the usefulness of the edge sensor response decreases. Further work is required to combine the readings of all the piezoelectric sensors into a single crack length estimate. Building on the results from all of the earlier testing, SHM system development is underway for a full scale lug component to be fatigue tested under spectrum loading.

Topic: 1C - Health Management Tools and Capabilities 1

Presenting Author: Bill Marscher

Organization: Mechanical Solutions Inc

Country:

Paper Title: Applying Computational Fluid Dynamics to Predict Turbomachinery Erosion Rates

Co Authors: Dr. Edward M. Bennett, Artem Ivashchenko

Abstract:

Turbomachinery flowpaths can be damages by particulates in the primary gas. It is essential to understand the flow and erosion created by these particles in order to improve the safety and efficiency of the turbomachines. Recent advances in Computational Fluid Dynamics (CFD) permit the flowpath designer to quantify the damage caused by the particulates, as well as to judge the efficacy of design alterations with respect to erosion. This paper applies a computational erosion analysis on an FCC gas expander that has been known to experience particle erosion damage, and to quantify the change in erosion rate created by an increase in the design reaction of the expander stage.

Topic: 1C - Health Management Tools and Capabilities 1

Presenting Author: Genna Swerdon

Organization: Impact Technologies, LLC

Country:

Paper Title: A Systems Engineering Approach to Electro-Mechanical Actuator Diagnostic and Prognostic Development

Co Authors: Matthew J. Watson, Sudarshan Bharadwaj, Carl S. Byington, Matthew Smith, Kai Goebel, Edward Balaban

Abstract:

The authors have formulated a comprehensive Systems Engineering approach to Electro-Mechanical Actuator (EMA) Prognostics and Health Management (PHM) system development. The approach implements software tools to integrate simulation-based design principles and dynamic failure mode and effects analysis. It also provides automated failure mode insertion and propagation analysis, PHM algorithm design and verification, full dynamic simulations, code generation, and validation testing. This process aims to produce the appropriate fault detection and prediction algorithms needed for successful development of an EMA PHM system.

As an initial use case, the developed approach was implemented to develop and validate a model-based, virtual sensor software package for landing gear EMA PHM. This effort included creation of a dynamic, component-level system model that can be used to virtually sense parameters, detect degradation, isolate probable root cause, and assess severity. This model is also used as a virtual test bed for performing fault insertion analysis to address algorithm development and experimental prioritization. The developed model was validated using data from a test stand, which was specifically constructed for EMA PHM development. The model-based predictor was then coupled with failure mode diagnostics, advanced knowledge fusion, and failure mode progression algorithms to form a complete prototype EMA PHM solution.

Topic: 1C - Health Management Tools and Capabilities 1

Presenting Author: Tim Irwin

Organization: M&B Engineered Solutions, Inc.

Country:

Paper Title: A Comprehensive Machinery Condition Analysis of Integrally-Geared Centrifugal Air Compressors

Co Authors: Stanley R. Bognatz

Abstract:

This paper will present a methodology, various techniques, and tools to use for determining a comprehensive operating condition of an integrally-geared air compressor, its driver, and their auxiliary systems. Routine operating condition measurements are important in the data collection, but there are several advanced techniques and additional technologies that allow for a considerably more accurate and complete analysis of the machine's overall condition. A combination review of historical data, present operating parameters, visual examination of the operating equipment, vibration analysis, including high frequency response characteristics, oil analysis, and motor diagnostics will provide a comprehensive view of the machine's condition. The comprehensive condition analysis will result in recommendations for appropriate inspection and/or maintenance on the machine and its auxiliary systems. The discussion will also include the areas of the machine and auxiliaries that cannot be 'evaluated' during operation and recommended routine maintenance schedules. Examples of previous condition analysis results will be included for review and discussion.

Topic: 1C - Health Management Tools and Capabilities 1

Presenting Author: Hosen Jawan

Organization: University of Al Mergab

Country: Libya

Paper Title: Some Thoughts on Micro-Abrasion Mapping of Steels in Corrosive Environments

Co Authors: M.M.Stack M.T.Mathew

Abstract:

In studies of micro-abrasion, there has been significant recent interest in the interaction of wear with the corrosive environment. This is because there are many micro-scale-abrasion processes where the presence of the corrosive media may modify the wear on the surface. In addition, if the surface dissolves rather than preferentially corrodes changes in the mechanical properties of the surface (affecting the wear process) may result from the effects of corrosion.

In this study, the micro-abrasion of a steel/polymer couple was studied in carbonate/bicarbonate solution. The effects of applied load and potential were investigated on the wear rate and the corrosion and wear contributions were quantified. Scanning Electron and Atomic Force Microscopy were used to characterize the surfaces following micro-abrasion-corrosion.

The results were used to identify various micro-abrasion-corrosion mechanisms on the surface. These regimes were suggested on the basis of the ratio of the micro-abrasion to the corrosion rate. In addition, micro-abrasion-corrosion maps were constructed showing the transitions between the micro-abrasion-corrosion regimes as a function of load and applied potential.

Topic: 1C - Health Management Tools and Capabilities 1

Presenting Author: Matt Sedlak

Organization: RJ LeeGroup Inc

Country:

Paper Title: Federated SOA: A Solution to Support CBM+ Weapon System Health Management

Co Authors:

Abstract:

Topic: 1D - Sensors

Presenting Author: Bill Nickerson

Organization: Impact-RLW Inc

Country:

Paper Title: Wireless Power for Wireless Sensors

Co Authors:

Abstract:

The best kind of wireless sensor uses wireless power. Wireless power must be in the form of stored energy (battery, fuel cell) or it must be converted at the sensor from environmental energy sources (mechanical, thermal, solar). This article considers, compares, and contrasts the storage vs harvesting options. This paper will explore the state of practice of energy storage and power harvesting for wireless sensors through public domain literature. It will also compare the environmental energy sources available in industrial environments and the advantages and disadvantages of alternative energy sources. Fundamental limitations of the energy sources will be discussed. Non-dimensional comparisons among the available technologies will be provided as a guideline for selection among the alternatives for a given application.

Topic: 1D - Sensors

Presenting Author: Renard Klubnik

Organization: Wilcoxon Research

Country:

Paper Title: Measuring Displacement Using Accelerometers

Co Authors:

Abstract:

Displacement is the most easily understood vibration parameter, yet is the least commonly utilized in vibration analysis. Measuring displacement with a 4-20 mA sensor is now an option. With an accelerometer mounted on the machinery and no cabling oro instrumentation before it is converted to displacement, the cleanest signal is possible. Now, data screens for process control machinery can be calibrated in mils displacement in the same manner that vibration velocity signals have been recorded with previous generation sensors.

Topic: 1D - Sensors

Presenting Author: Ben Ward

Organization: Makel Engineering, Inc

Country:

Paper Title: Lubricating Fluid Wear Metal Detection for Machinery Failure Prevention

Co Authors: Fred Discenzo, Rockwell Automation; Kenneth A. Loparo, Ph.D. Professor Case Western Reserve University

Abstract:

Early detection of abnormal metal wear is important for fault detection and failure prevention for rotating machinery. Progressive wear of a machine often results in the release of wear debris that is transported in the lubricant. An electrochemical cell implemented as an on-line MEMs sensor can be operated in a lubricating fluid to provide an indication of the chemistry of the fluid. The type and amount of wear metal ions detected in the lubricating fluid can be an effective indicator of the amount of wear debris in the lubricant and therefore can help determine the condition of the machine being monitored. Interpreting the rate of change of wear metal ions using wear models can provide unique insights into the components incurring wear, the wear mechanism occurring, and the remaining useful life of the lubricant and the machine.

The results reported indicate that a small, real-time multi-element sensor with an electrochemical cell will be able to detect wear metal ions and provide an early indication of unusual material wear. The wear metal ion information reported can be interpreted in the context of wear models to provide a warning of atypical wear patterns and characterize the type of wear, the mechanical components experiencing wear, and what future wear rates can be expected for a given operating scenario.

Topic: 1D - Sensors

Presenting Author: Mike Platt

Organization: Mechanical Solutions, Inc.

Country:

Paper Title: Non-contacting Measurement of Turbomachinery Blade Vibration

Co Authors: John J. Jagodnik

Abstract:

There are several ongoing challenges in non-contacting stress measurement systems (NSMS) that have challenged technology for general purpose blade health monitoring. Two of the most pressing needs to address are the undersampling that is inherent in time-of-arrival data processing and the uncertainty that is introduced by inferring, as opposed to calculating, the mode of vibration. Significant advancements have been made in NSMS capability by utilizing multiple blade tip sensors at predefined circumferential and axial locations. While this has somewhat reduced the uncertainty with identification of the vibration mode, the spatial resolution of such a system is limited to the deflection at the blade tip. Using a large number of blade tip sensors has also reduced the undersampling error, but this works against the real-world limits on the size, weight, and reliability of the measurement system as a whole. The use of multiple blade tip sensors is also strongly dependent on a-priori knowledge of the vibration modes that are present in order to determine the required number of sensors and their optimal locations. This dependency limits the adaptability of the system for general blade vibration surveys, engine high cycle fatigue troubleshooting, etc. This paper describes ongoing work that addresses the limitations in current NSMS systems by developing an innovative continuous monitoring system with the following capabilities:

• Provides a continuous time series of blade displacement data over a portion of a revolution (solving the undersampling problem).

• Includes data reduction algorithms to directly calculate the blade vibration frequency, modal displacement, and vibratory stress (solving the mode inference problem).

• Uses a single sensor per stage to monitor all of the blades on the stage.

Topic: 1D - Sensors

Presenting Author: Surya Narayanan Sundaramurthy

Organization: University of Cincinnati

Country:

Paper Title: New Continuous Sensors for Condition Monitoring of Machines and Structures

Co Authors: Sai Lalitya Mullapudi, Vignesh Ravindran, Kranti Bharath Tadipatri, Karthik Subramanian, Vesselin N. Shanov, Chaminda Jayasinghe, Jandro Abot, and Mark J Schulz

Abstract:

Conventionally, machinery condition monitoring is done using many sensors. The drawback of using many sensors is that signal processing and data acquisition is expensive. The continuous sensor was developed for efficient and reliable health monitoring of structures and to reduce the number of wires and channels of data acquisition needed to monitor large areas. The continuous sensor uses highly distributed interconnected sensors to form a sensor that produces a signal that is the combined output of the individual sensors. Processing of the signal from the continuous sensors enables in-situ real-time condition monitoring. The concept of continuous sensors was implemented with new types of continuous sensors based on accelerometers and strain gauges. The information from the sensors can represent anomalous structural events that might occur at multiple locations. The advantage of having a combined signal is that hallmark events can be detected at any sensor, but only one channel of data acquisition is needed. In another embodiment, a new continuous sensor was developed based on carbon nanotube thread. Strain in the nanotube thread leads to a change in the electrical resistance, which indicates the potential for use as a strain or crack sensor. The nanotube thread can be embedded into structures to provide a continuous strain signal which can be processed to detect high strains and damage. Overall, continuous sensors represent a new approach to efficiently monitor large structures for damage.

Topic: 2A - Health Management Tools and Capabilities 2

Presenting Author: Zbig Karaszewski

Organization: Giotto Technologies Inc

Country:

Paper Title: Forward Looking Diagnostics

Co Authors: C Kello, Saunora Prom, Daragh Sibley, Michael Wade

Abstract:

Forward Looking Diagnostics (FLD) approach is an assessment technique that provides a simplified way to determine overall condition of systems using the knowledge of their component/ equipment degradation. FLD was conceived to make it easier, faster and more economical to determine the type and severity of system level performance determination for a wide variety of operating modes.

In its short history, FLD has evolved from an informal network of loosely associated information utilized in techniques that apply only to simple or common cause failure events to a dynamic mechanism for collecting data and investigating complex failure modes from a variety of perspectives, alternatively dissecting them into their underlying (yet often unknown) root cause patterns. There seems to be almost no limit to the possible uses for FLD in the lifecycle support of complex electromechanical systems.

Lifecycle applications that can make use of FLD have several advantages over traditional prognostic-based failure determination methods. Among these are high cost, high uncertainty and single point type of failures, thereby making the use of FLD ever more necessary as systems become increasingly more complex over time.

Topic: 2A - Health Management Tools and Capabilities 2

Presenting Author: Jamie Coble

Organization: The University of Tennessee, Department of Nuclear Engineering

Country:

Paper Title: Development of a Prognostics Toolbox with an Application to GPS Degradation Data

Co Authors: J. Wesley Hines

Abstract:

Prognostics refers to a class of algorithms used to estimate the remaining useful life (RUL) of a component or system. Prognostics can play an important role in increasing safety, reducing downtime, and improving the corporate bottom line. Commonly, prognostics is one of several modules in an overall condition surveillance system, which typically also includes condition monitoring, fault detection, and fault identification modules. Over the past two decades, many prognostics techniques have been developed and applied to a wide variety of applications. These algorithms use a variety of information for making RUL predictions. The MATLAB-based Prognostics Toolbox being developed at the University of Tennessee supports three types of prognostic estimates: traditional reliability-based, condition-based, and individual degradation-based. Several methods are available or in development for each prognostic type. The toolbox's purpose is to provide functionality for developing, testing, and comparing competing prognostic models. The toolbox also aids in determining which prognostic type and modeling method may be best suited to a given situation. This paper discusses the development of the Prognostics Toolbox and presents an example of its application to the degradation of a Global Positioning System (GPS) unit.

Topic: 2A - Health Management Tools and Capabilities 2

Presenting Author: Matthew Ballew

Organization: Southwest Research Institute

Country:

Paper Title: F108 Transient Performance Data Analysis

Co Authors:

Abstract:

Previous work with gas turbine engine system-level health assessments lead Southwest Research Institute (SwRI) engineers to believe that currently ignored high-stress/high-temperature transient data contains information that is more useful for fault detection than the currently analyzed low-stress steady-state data. The F108 Transient Performance Data Analysis Internal Research and Development (IR&D) project consisted of developing a set of analytical tools and using them to perform an analysis of transient (non-steady state) gas turbine engine data for Engine Health Management (EHM) purposes.

The main objective of this project was to determine if more accurate system-level fault detection tools could be developed by analyzing transient engine performance data that is currently being ignored during the Engine Trending and Diagnostics (ET&D) process. This paper will outline the technical approach taken during the project and summarize project results.

The primary challenge of this study was to correlate multiple engine parameters over a range of transient conditions when parameter values are varying due to throttle excursions, ambient conditions, aircraft loads, and mission profiles. This correlation effort required the development of algorithms that quantified the parameters' relationships during these varying conditions. Another challenge was to define an automated process that filters flight data and extracts the desired transient data.

Topic: 2A - Health Management Tools and Capabilities 2

Presenting Author: Dustin Garvey

Organization: Baker Hughes INTEQ GmbH

Country: Germany

Paper Title: Pattern Recognition Based Fault Detection of Advanced Directional Drilling Tools

Co Authors: Jörg Baumann; Jörg Lehr, Baker Hughes; J Wesley Hines, Ph.D., University of Tennessee

Abstract:

Modern drilling equipment operates in increasingly severe environments, with down-hole temperatures in excess of 200°C and high impact vibration events being common. Additionally, rig operators are asking tools to perform mission profiles that have previously been impossible, thereby increasing the stress on the down-hole tools. All the while, customers are beginning to contractually demand high reliability to help them prevent costly down-hole failures and ensure profitability. The current periodic maintenance practices are proving to be insufficient or cost intensive to meet these new challenges. Because of this, industry is shifting towards simple condition based maintenance approaches, which use design guidelines and rough operational thresholds to assess individual tool health. While there is value in the latter approach, there is a large amount of tool performance and environmental data collected during operation that has yet to be effectively incorporated into the health assessment process. This paper presents a new, empirical model based approach for detecting faults prior to failure in components of bottom hole assembly (BHA) tools. This approach can be briefly described as using real world examples of “good” runs to establish a statistical definition of un-faulted tool operation. To determine whether or not another tool is operating normally, a statistical test is used to determine if the tool is operating in a nominal (i.e. statistics are similar to un-faulted behavior) or degraded (i.e. statistics are not similar to un-faulted behavior) mode. In this way, it is possible to assess tool health on the basis of its actual performance, as opposed to its expected performance for quantized environmental factors (i.e. elevated static loads like bending, dynamic loads like lateral vibration, the combination of static and dynamic loads, etc.). This approach is demonstrated with operational data collected from a rotating steering system tool. The developed system will allow service providers to make more agile maintenance decisions and provide operators the means to incorporate reliability into the well planning and operations processes, enabling monetary savings for both parties.

Topic: 2A - Health Management Tools and Capabilities 2

Presenting Author: Dennis Moore

Organization: RJ LeeGroup Inc

Country:

Paper Title: Reliability Centered Maintenance Support Tools

Co Authors:

Abstract:

Topic: 2A - Health Management Tools and Capabilities 2

Presenting Author: Tianyi Wang

Organization: NSF I/UCR Center

Country:

Paper Title: On Performance Evaluation of Prognostics Algorithms

Co Authors: Jay Lee

Abstract:

Prognostics and Health Management, as an emerging engineering discipline, has been facing difficulties in algorithm performance evaluation, validation and benchmarking. Over years, various metrics have been developed to assess algorithm performance from different perspectives. Lack of methodology in selecting metrics from the large metric pool has made it hard for a business case of prognostics to be translated into measurable technical metrics to guide algorithm development. The situation, however, may be alleviated if the many performance metrics are properly prioritized from the end-user point of view. In this paper, we propose to adopt the simple but widely accepted performance metrics from classification discipline. The basic measures such as False Positive, False Negative, etc. and the performance metrics derived wherefrom are redefined in prognostics context. And then a new concept called algorithm Performance Profile, which characterizes the performance of an algorithm by the accuracy score at each estimated RUL (Remaining Useful Life), are proposed. The Performance Profile is obtained during design phase, and will become a priori at run time of the algorithm. It can be interpreted as the algorithm's trustworthiness score for people to make maintenance decisions, or utilized by the maintenance scheduling program to assess risks in response to a given RUL prediction.

Topic: 2C - Electronics and Power Systems Health Management

Presenting Author: Bob Snyder

Organization: UE Systems Inc

Country:

Paper Title: How Ultrasound Can Prevent Electrical Failures by Non Invasive Inspection

Co Authors:

Abstract:

Ultrasound inspection is an effective screening tool for detecting the potential for arc flash incidents and can assist in Infrared inspections. When hand-held ultrasonic instruments are used to scan enclosed electrical apparatus the procedure is fast, accurate and simple. It can help inspectors by eliminating the need for wearing cumbersome, uncomfortable PPE during a preliminary survey. On-line continuous monitors can alarm personnel of the presence of arcing, tracking and corona in advance of an inspection.

Topic: 2C - Electronics and Power Systems Health Management

Presenting Author: Joe Sheeley

Organization: Arnold AFB, AEDC

Country:

Paper Title: Initial Operational Evaluation of a Novel Corona Monitoring System

Co Authors: R Xu, Z Ren, B Ayhan, W Lee, M S Sahni, Hu Qiaohui, T McClerran

Abstract:

Initial operational evaluation of a novel system for monitoring large electric motors for partial discharge activity has been started using one of the large motors at Arnold Engineering Development Center (AEDC) as a demonstration platform. This system uses split-ring Hall effect sensors on the motor leads to monitor motor current for ripples characteristic of partial discharge activity. Use of these sensors is advantageous in that it is not necessary to break the motor circuit for installation and monitoring equipment is inexpensive when compared with systems on the market. The system uses elaborate pattern recognition algorithms to monitor for partial discharge activity. Indicators used by these algorithms include the spectral level at motor operating frequency and various harmonics which were selected based on laboratory testing of small motors with synthesized partial discharge faults. As part of system evaluation, the system was placed on an 85,000 HP, 13.8 kV motor at AEDC. Data for tuning of the diagnostic algorithms were collected during motor operation and the spectral content of these data were analyzed to determine if harmonic content seen in the laboratory was indeed seen in operational data. It was found that content at the frequencies of interest was present, and the levels of these components remained fairly constant during the monitoring period of several months. This was to be expected since the motor had recently been rewound and partial discharge therefore should have been minimal. The paper will describe the monitoring system and present the initial data collected with analysis.

Topic: 2C - Electronics and Power Systems Health Management

Presenting Author: Shunfeng Cheng

Organization: CALCE, University of Maryland College Park

Country:

Paper Title: A Fusion Prognostics Method for Remaining Useful Life Prediction of Electronic Products

Co Authors: Michael Pecht

Abstract:

Prognostics and health management methods can provide advance warning of failure; reduce the life cycle cost of a product by decreasing inspection costs, downtime, and inventory; and assist in the design and logistical support of fielded and future electronic products. This paper presents a fusion prognostic method to predict the remaining useful life of fielded products. This method uses the data-driven method to detect anomalies and trend the parameters related to the failure of the product. A physics of failure analysis is then used to identify and prioritize the failure mechanisms and create the corresponding failure definitions in terms of the parameters related to the failure. Based on the parameter trending and the failure definition, the remaining useful life of the product can be predicted.

Topic: 2C - Electronics and Power Systems Health Management

Presenting Author: George Zeigler

Organization: Signals Power and Grounding Specialists, Inc

Country:

Paper Title: Implementing Industry Accepted Standards to Prevent the Restoring, Repairing and Replacement of Electrical Equipment (PRRR)

Co Authors: Levi Zeigler SPGS, Inc

Abstract:

Power disturbances will cost United States companies an estimated $126-$229 billion dollars in 2008. Power disturbances typically are classified as total or partial power failure, power outage, equipment failure and power quality phenomena. 72% of all companies have an average of three (3) power disturbance issues each year. Generally total cost of the restoration process is seldom logged or tracked the focus is always to restore the equipment ASAP. Management accepts these electrical equipment failures as a normal cost of doing business. Preventing (P) power disturbances from causing the restoring of power to the device (R), repairing the device (R) or total replacement of the device (R) PRRR within facilities could have saved companies $100-$183 billion dollars in 2008. Where the holistic approach has been used return on the investment is typically less than two (2) years.

Topic: 2C - Electronics and Power Systems Health Management

Presenting Author: Sonia Vohnout

Organization: Ridgetop Group, Inc.

Country:

Paper Title: A Comprehensive Fault Dictionary Solution for Power Systems Health Management

Co Authors: Neil Kunst, Justin Judkins, and Doug Goodman

Abstract:

There is a growing need for innovative human-system integration methods to effectively convey detailed status information to pre-flight check-out crews, ground operations, and mission support staff, especially under off-nominal and emergency conditions. As a solution, the authors propose an innovative fault-dictionary solution to detect and isolate off-nominal and catastrophic fault conditions in power systems using condition-based maintenance. In addition, innovative digital signal processing techniques are discussed for database storage and analysis of captured fault signatures for a “best-fit” solution. In spacecraft and launch vehicles, power system integrity is critically important to safety and mission effectiveness. Based on Ridgetop’s extensive experience in electronic prognostics design for critical applications, the firm developed a methodology for a non-intrusive method for assessing off-nominal or failure conditions in power systems. This capability, in turn, can be linked to an Integrated Vehicle Health Monitoring System to facilitate corrective actions, such as fault-mitigation or load-shedding. The innovation centers on extending Ridgetop’s expertise in eigenvalue extraction by performing additional signal processing to develop an effective fault dictionary specifically for faults in vehicle components. Ridgetop’s creation of an off-nominal or analog fault dictionary, of this kind, is unique and can be linked to Case-based reasoners to reduce maintenance costs.

Topic: 2C - Electronics and Power Systems Health Management

Presenting Author: Herb Hecht

Organization: SoHaR Inc

Country:

Paper Title: Failure Prevention in Aircraft Electric Power Supplies

Co Authors: Steven Burnett, Leach International, Buena Park, California

Abstract:

Cockpit instruments, autopilots, and communication with air traffic controllers are essential for safe flight when night or weather obscure view of the ground. Navigation systems and FADEC (full authority digital engine control) provide the shortest routes and minimize fuel consumption. Weather radar helps to avoid bumps and proximity warning devices prevent mid-air collisions. Without these functions modern air travel would be unthinkable, and all of them require continuous electric power. Sources of electric power are engine driven generators (AC or DC), independent generators (auxiliary power units or APUs), batteries and occasionally wind driven generators. These are built to stringent specifications but, like most artifacts, they fail occasionally. Because they may fail, the aircraft designer provides excess capacity (limited by weight considerations) and means for isolating failed units. When actual power consumption approaches the remaining capacity some less essential loads must be turned off because overloading the remaining power sources is an invitation to additional failures. The isolation of failed sources and load shedding provisions are usually implemented in an electric power distribution panel (EPDP). Large aircraft may have more than one EPDP. Of necessity, most power sources and many loads are connected to the EPDP, and some of its failure modes may therefore compromise the continuous availability of electric power to essential functions. Large design safety margins are provided for avoidance of inter-bus shorts and bus-to-ground shorts as well as in elements associated with load shedding. But what human ingenuity has put together it can also undo. A distribution panel was designed in compliance with all pertinent safety requirements. It was installed under a lavatory area, and when the toilet overflowed it created conduction paths that no one had considered. The aircraft lost most instrumentation but fortunately there was good visibility and it landed safely. In another instance a transformer in a distribution panel developed a short circuit and overheated. This had been identified as a creditable fault and there was mitigation for it. The mass of the transformer was such that the heat affected the entire circuit board on which it was mounted and this prevented switching to the alternate. More details on these and other malfunctions will be provided, SAE ARP 4754 points to analysis methods that could have prevented these occurrences but these were apparently not properly carried out. The paper will identify tools that aid in compliance review. An effective test methodology is to perform Highly Accelerated Life Testing (HALT) to eliminate design flaws and to enable a thorough production testing regimen through Highly Accelerated Stress Screening (HASS). This approach will be further outlined in the paper. And finally, collaboration between equipment suppliers and aircraft primes to optimize the combination of design requirements, system architecture, and installation is essential for the overall failure prevention effort.

Topic: 2Da - Signal Analysis

Presenting Author: James Robinson

Organization: Emerson Process Management

Country:

Paper Title: Diagnostic Aid Provided by Autocorrelation

Co Authors: Alan Collette

Abstract:

In this paper, the focus is placed on the analysis of the output of an accelerometer placed on rotating machinery (generally attached to the bearing housing) in an industrial environment. The emphasis will be on the diagnostic aid provided by a not widely used function identified as the Autocorrelation Coefficient Function. The autocor¬relation coefficient data are computed from the same digital time waveform from which the widely used spectra data are computed. It will be demonstrated through case studies the autocorrelation coefficient are very complimentary to the spectra for diagnosis of vibration data.

Topic: 2Da - Signal Analysis

Presenting Author: Arun Menon

Organization: Data Physics Corporation

Country:

Paper Title: Factors Influencing Paper Machine Roll Related Vibration and Techniques for their Identification and Analysis

Co Authors:

Abstract:

Vibration problems in paper machines continue to play a leading role in limiting their runnability, production speeds and operating efficiencies. The condition of paper machine rolls is the most dominant contributor to vibration issues and presents a myriad of challenges for both paper machine operators and roll manufacturers alike. The answers to these challenges lie in the use of a combination of test and measurement strategies that continue to benefit from advances in sensors and signal processing techniques. This paper discusses some of the primary factors leading to roll related vibration and offers insight into their identification and analysis.

Topic: 2Da - Signal Analysis

Presenting Author: Hossein Davari-Ardakani

Organization:

Country: Iran

Paper Title: Fault Detection and Diagnosis of Vehicle Gearboxes Using Vibration Analysis and Neural Networks

Co Authors: Morteza H Sadeghi, Mohammad-Taghi Vakil-Baghmisheh, Hossein Davari-Ardakani

Abstract:

This paper investigates a fault detection and identification technique applied on a passenger car gearbox system using artificial neural network. The inspected gearboxes are the Nissan Junior 5-speed manual gearboxes collected from the Charkheshgar Company's production line. The novelty of this work is the implementation of a fault diagnosis technique on 14 gearboxes collected from an assembly line which contain completely dissimilar and uncontrolled fault types. The time domain approach is used for feature vector extraction. Eight parameters, which are used extensively in the literature for gearbox fault diagnosis, are calculated and four of them are found to be more informative than the others which are consequently used in feature vector construction. Finally, the multilayer perceptron neural network is used for monitoring the incurred changes in the patterns. The obtained results demonstrate the good performance of the suggested scheme for fault diagnosis of the gearboxes.

Topic: 2Db - Data/Knowledge Management

Presenting Author: Amit Deshpande

Organization: TechSolve, Inc.

Country:

Paper Title: The Open Source Manufacturing Stack

Co Authors: Pierce Kuhnell

Abstract:

Manufacturing is plagued by communication issues due to proprietary and closed architecture systems. In this paper, we outline the various methods, utilizing open source applications, to create Open Source Manufacturing Stack (OSMS) for use in the manufacturing sector. These open source applications include Ubuntu, LinuxCNC, MTConnect, and Firefox. The OSMS has been implemented as part of the supervisory system thrust area for the Smart Machine Platform Initiative (SMPI). MTConnect is a royalty-free, open communication standard for interconnect ability in manufacturing systems. MTConnect's free and open standard allows devices and systems to send out understandable information in the required format. The importance of the architecture, found in OSMS and MTConnect implementation, is also explained. Additionally, this paper provides details regarding why an open source bundle is so vital to the manufacturing community as well as the potential benefits of applying open source to manufacturing data management solutions. These benefits include knowledge management, real-time data access, scalability, plug-and-play functionality, and data mining capabilities.

Topic: 2Db - Data/Knowledge Management

Presenting Author: Assaad Krichene

Organization: Impact Technologies, LLC

Country:

Paper Title: Aircraft Operational Improvements Gained Through Knowledge Discovery

Co Authors: Irtaza Barlas, Scott Valentine

Abstract:

Advances in sensing, health monitoring and condition assessment coupled with large increases in computer storage capacity, make it possible to collect and store huge amounts of aircraft usage, operational and maintenance data. The collected data is often minimally analyzed. Analysis is often complicated by problems such as corrupt or missing data and by the need for making an accurate assessment in often a very short time. A better understanding of how a given maintenance action will affect future fleet readiness would make a compelling argument towards performing that maintenance and will ensure personnel buy-in. The authors have developed a knowledge discovery toolkit. The toolkit focuses on extracting knowledge from the relevant data, such as operational, maintenance, and PHM, residing in different databases. After data is retrieved; any problems are repaired; the knowledge discovery tools are applied; the extracted knowledge is fused together when appropriate to create an overall picture which is finally displayed to the user. The knowledge discovery tools range from simple statistics through curve and distribution fitting to involved data mining techniques. The resulting knowledge is displayed in an intuitive fashion to provide decision support for maintenance and mission planning thus enabling current availability and future readiness optimization.

Topic: 2Db - Data/Knowledge Management

Presenting Author: Erkki Jantunen

Organization: VTT Technical Research Centre of Finland

Country: Finland

Paper Title: Ontology of Mobile Maintenance Processes

Co Authors: Luca Fumagalli, Marco Macchi (Politecnico di Milano)

Abstract:

The rapid development of hardware and software has made it possible to introduce new and more sophisticated maintenance policy making in case of mobile production machinery or machinery located in isolated places. In such cases, the backbone of the maintenance system is the mobile user interface to CMMS and ERP systems used by the company providing maintenance services. Nonetheless, the adoption of such kind of mobile devices (e.g. PDA) is related with the activities that are carried out: the success or the failure of these tools is related to the processes that are established in the company. It is, in fact, worth noticing that, generally speaking, the adoption of a new ICT solution should go along with a proper activity of processes re-engineering. Moreover, also a further level of details describing the features implemented in the devices is important to understand which are the capabilities of such kind of mobile tools. The paper defines a guideline along the development of a PDA adoption test case. Some schemas referring to the PDA enabled processes are presented together with an ontology of the information that PDA and CMMS server should exchange.

Topic: 2E - Special Presentations Session

Presenting Author: Bob Randall

Organization: University of New South Wales

Country: Australia

Paper Title: New Signal Processing Techniques for Advanced Machine Diagnostics and Prognostics

Co Authors:

Abstract:

In recent years vibration analysis and signal processing have become widely accepted tools for condition monitoring of operating machines, because of the information contained in the vibration signals about changes in condition. The signals from individual components are often strongly masked, however, and must be separated from background noise and possibly corrected for distortions introduced by the transmission path from the source to the measurement point.

This paper describes a number of new signal processing techniques which have been found to give improved separation of particular signals from background masking, for example for faulty bearings in a gearbox, where even healthy gears give strong vibration signals. This separation is based on the fact that the gear signals (even with faults) are deterministic and phaselocked to shaft speeds, whereas bearing signals are always partly stochastic because of minor random slip between the components. Bearing signals can be shown to be “cyclostationary”, and the “spectral correlation” method is able to separate three types of signals occurring in machines; viz, deterministic (discrete frequency), stationary random (eg turbulence noise from gas flow in a turbine), and cyclostationary random, where the cyclic frequencies identify the source (eg bearing faults or combustion in an IC engine) even though the signals are not phaselocked to shaft speeds. Detection of faults in gears and bearings is often based on the fact that local faults give impulsive forces, but the responses to these are often smeared by the transmission path and may not be detected unless this is corrected.

At the same time, the paper describes how considerable improvements can be made to classic diagnostic methods such as envelope analysis for bearing diagnostics. It has belatedly been recognised that this is an ideal method for analysing certain cyclostationary signals, and is in fact related to the spectral correlation. Digital implementations of envelope analysis have often slavishly followed the analogue method, but it can be shown that considerable benefits arise from taking advantage of non physically realisable procedures such as using analytic (complex) signals, since they give rise only to difference frequencies, which contain the diagnostic information (eg sideband spacings) whereas real signals also give sum frequencies which mask the results. Envelope signals were typically produced by an analogue rectifier, but the envelope (mathematically the square root of the squared envelope) also contains extraneous components given by the square root operation, which alias into the measurement range. Other myths that have been debunked are that it is difficult to determine the optimum frequency range for demodulation (for the envelope analysis) but “spectral kurtosis” and the “kurtogram” have solved this problem. Another is that envelope analysis does not work for very low speed bearings, but it has now been demonstrated that the same procedure works on bearings from a high speed turbine and the main bearing from a radar tower (12 s period).

Even though mechanical systems rarely have independent “point” sources, so-called “blind source separation” methods, originally developed for communications systems, have recently been applied to machines and give some potential for diagnostic applications. Once the response to a particular source has been isolated in the response at one measurement point, the “cepstrum” often allows this response to be divided into its forcing and transfer function components, and the diagnosis of a problem might be very

different depending on whether the force or the system properties have changed.

With regard to the aims of the conference, the blind diagnosis of actual real faults can be said to be Success Stories, while the debunking of myths can be said to be Lessons Learned.

Topic: 2E - Special Presentations Session

Presenting Author: Larry Perkins

Organization: AFRL/RX

Country:

Paper Title: Manufacturing Variability as a Key Contributor to Unexpected Equipment Failures

Co Authors:

Abstract:

Topic: 2E - Special Presentations Session

Presenting Author: Leonard Bond

Organization: Pacific Northwest National Laboratory

Country:

Paper Title: Failure Prevention for Nuclear Power Plants through Proactive Management of Materials Degradation (PMMD)

Co Authors: S R Doctor, S Bruemmer, S E Cumblidge, A B Hull, and S N Malik

Abstract:

Failure prevention is central to the operation of nuclear power plants. To meet this goal there is growing interest in new and improved philosophies and methodologies for plant life management, which include the migration from reliance on periodic inservice inspection to include condition-based maintenance. A further step in the development of plant management is the move from proactive responses based on ISI to become proactive, through the investigation of the potential for implementation of a proactive management of materials degradation program and its potential impact on the management of LWRs.

Topic: 2E - Special Presentations Session

Presenting Author: Kirby Keller

Organization: Boeing Phantom Works

Country:

Paper Title: Cranfield IVHM Centre - The Story So Far

Co Authors:

Abstract:

Topic: 3A - Health Management Systems and Architectures

Presenting Author: Sankalita Saha

Organization: NASA Ames Research Center

Country:

Paper Title: A Distributed Prognostic Health Management Architecture

Co Authors: Bhaskar Saha, Kai Goebel (NASA ARC)

Abstract:

This paper introduces a generic distributed prognostic health management (PHM) architecture with specific application to the electrical power systems domain. Current state-of-the-art PHM systems are mostly centralized in nature, where all the processing is reliant on a single processor. This can lead to loss of functionality in case of a crash of the central processor or monitor. Furthermore, with increases in the volume of sensor data as well as the complexity of algorithms, traditional centralized systems become unsuitable for successful deployment, and efficient distributed architectures are required. A distributed architecture though, is not effective unless there is an algorithmic framework to take advantage of its unique abilities. The health management paradigm envisaged here incorporates a heterogeneous set of system components monitored by a varied suite of sensors and a particle filtering (PF) framework that has the power and the flexibility to adapt to the different diagnostic and prognostic needs. Both the diagnostic and prognostic tasks are formulated as a particle filtering problem in order to explicitly represent and manage uncertainties; however, typically the complexity of the prognostic routine is higher than the computational power of one computational element (CE). Individual CEs run diagnostic routines until the system variable being monitored crosses beyond a nominal threshold, upon which it coordinates with other networked CEs to run the prognostic routine in a distributed fashion. Implementation results from a network of distributed embedded devices monitoring a prototypical aircraft electrical power system are presented, where the CEs are Sun Microsystems Small Programmable Object Technology (SPOT) devices.

Topic: 3A - Health Management Systems and Architectures

Presenting Author: Simon Jessop

Organization: Impact Technologies, LLC

Country:

Paper Title: A Model-Based Mission Planning and Decision Support Tool

Co Authors: Thomas C Cook

Abstract:

Impact Technologies developed a model-based decision support framework that facilitates the use and development of decision support tools in CBM environments. The modular structure promotes reusability of independent software components to expedite new product development by embracing the use of open architecture and standardized data interfaces for increased supportability and upgradeability.

An advanced probability-based mission readiness forecasting and assessment tool developed for the U.S. Navy is used to illustrate the framework which combines three separate functional areas - a mission profile modeling tool, a system relational model, and a maintenance optimization module. The resulting product enables comparison of multiple what-if scenarios measuring the effects of scheduling, maintenance and logistics support activities on readiness over an entire mission profile and for any specific mode of operation, accounting for different machinery line-ups, redundancy, system-to-system interactions, and component and sub-system criticalities. The tool incorporates several novel approaches including fusion of multiple independent low-level indicators to predict overall system readiness, methodologies to account for the interactive effects of interconnected subsystems, and a risk-based optimization to select and schedule the optimal maintenance schedule.

This paper summarizes the features of the model-based decision support tool framework and the mission readiness software application developed using this architecture.

Topic: 3A - Health Management Systems and Architectures

Presenting Author: Stéphane Benoit

Organization: Vibro-Meter SA

Country: Switzerland

Paper Title: A Diagnostic Demonstrator: A Platform for the Evaluation of Real Time Diagnostic Data Dedicated to Space Engines

Co Authors: Pierre Bornert, Serge Le Gonidec, Philippe Supié

Abstract:

Compared to automotive or aircraft engines, space vehicle engines are produced in much smaller quantities, whereas their complexity is very often higher due to the non-standard propellants they use and power they provide. These aspects have a direct impact on the development process of such systems, making it complex, long and expensive.

Nowadays, the space industry is facing commercial challenges where the requirements in terms of time-to-market and costs are continuously reduced. These industries must therefore adapt their development methodologies to meet these requirements.

The implementation of Prognostics and Health Management (PHM) techniques at the earliest stage of a new engine development is one of the key aspects considered by the French Space Agency (CNES) to improve the competitiveness of the engine manufacturers by providing more reliable, cost effective and market adapted products. In the frame of CNES R&T program in collaboration with SNECMA, Vibro-Meter has developed an affordable platform dedicated to the development and deployment of advanced prognostic and diagnostic functions on space vehicle engines. This platform will permit a better understanding of the failure modes and Physics of Failure (PoF) of the engine under test and will speed-up the development of such engines by implementing real-time engine failure detection and decreasing the need for post-test analyses. This paper provides details on the key requirements considered for the development of the DIAgnostic DEMonstrator Health Monitoring System (DIADEM HMS), its main characteristics and some performance and operational results obtained with typical PHM algorithms. Future works and a roadmap to the development of space-graded Engine Health Monitoring System are also provided

Topic: 3A - Health Management Systems and Architectures

Presenting Author: Philip Bedard

Organization: Raytheon Integrated Defense Systems

Country:

Paper Title: Prioritizing Prognostic and Reliability Growth Investments

Co Authors: Thaddeus Mateja, Brenda Doyle

Abstract:

Program strategies to improve mission effectiveness often involve competing investments in redundant architecture, prognostic capability and reliability growth testing. The initial investment and lifetime benefits associated with each improvement strategy can differ significantly, depending on the attributes of each maintenance item. In early program stages, managers must quickly determine which approach; prognostics or reliability growth, should be proposed on maintenance items in order to satisfy mission support requirements. Funding constraints, especially during the proposal stage, require rapid system analysis, and often prohibit a decision on maintenance item investment in both prognostics AND reliability growth solutions. Raytheon has developed a technique that is simple enough for a small team of subject matter experts to quickly identify the appropriate improvement method (reliability growth, prognostics, both, or other methods). The approach is based on review of extensive field reliability data, and is designed to quickly identify the optimal approach for most maintenance items. The technique utilizes a categorization tree approach to assess all system maintenance items. The tree considers critical attributes related to each item's compatibility with a prognostics and/or reliability growth solution, and offers a low risk recommendation for most maintenance items in a system. When compared to the complex cost/benefit analyses that are frequently employed to make such decisions, the cost of this new approach is low. As a result, traditional (and more expensive) cost modeling and analysis techniques are required for only a small subset of maintenance items. The presentation will provide an overview of this systems level approach to prognostic/growth development and its application on recent radar development program.

Topic: 3A - Health Management Systems and Architectures

Presenting Author: Nagi Gebraeel

Organization: Georgia Tech

Country:

Paper Title: An Adaptive Prognostic Methodology for Sensor-Driven Component Replacement and Spare Parts Ordering Policies

Co Authors: Alaa Elwany

Abstract:

To date, engineers have primarily focused on the problem of using sensor data to assess the current and future health status of critical components or systems, whereas logisticians have paid a great deal of attention to efficiently controlling the flow of parts and other resources to ensure task/mission readiness. In isolation, these tools have limited impact for two main reasons: (1) Component-specific sensor-based data streams do not capture the traditional reliability characteristics related to the component's population, i.e. reliability and degradation characteristics of other similar components. In addition, they have not been fully exploited in maintenance related operational and logistical decision strategies. (2) Maintenance operational and logistical models generally assume failure to be a random process.

This work addresses these challenges by developing an adaptive degradation-based prognostic framework for estimating statistical distribution of the remaining useful life. The distributions are revised and updated using real-time health monitoring information. These dynamically evolving remaining useful life distributions (RULDs) are integrated with high-level replacement and logistics decision models to enable “sense and respond” adaptive framework for component replacement and spare parts ordering, which is driven by real-time prognostic information.

Topic: 3A - Health Management Systems and Architectures

Presenting Author: David Siegel

Organization: IMS Laboratory, 560 Baldwin Hall

Country:

Paper Title: A Systematic Health Monitoring Methodology for Sparsely Sampled Machine Data

Co Authors: Edzel Lapira, Mohamed AbuAli, Jay Lee

Abstract:

This paper presents a health monitoring methodology for the sparsely sampled snapshot data set using a systematic approach that can be applied to complicated systems or processes. The approach streamlines the data by doing regime segmentation and generates statistical based features from the data; the features from the healthy and degraded machine are used for training the logistic regression based health assessment algorithm which is used to provide real-time health information. The techniques are applied to an industrial robot application, in which the health of the servo motors is determined by converting the motor current snapshot data and converting that data to health information. The real-time health indicator results show promising results in that the degraded condition of the robot can be clearly seen at the early stages and the indicator values returns to normal after maintenance action is taken to repair the robot. Refinement of the robot based health monitoring method is being considered and further extension of this health monitoring methodology can be applied to other applications with snapshot data, including health monitoring of jet engines as well as commercial and military vehicles ground vehicles.

Topic: 3C - PHM for Gears, Bearings and Lubrication

Presenting Author: Oleg Shiryayev

Organization: Wright State University

Country:

Paper Title: Signal Processing For Detection of Ball Bearing Defects From Noisy Data

Co Authors:

Abstract:

Bearing defects are often characterized by the presence of periodic pulses in the time domain data. Measurement data obtained during condition monitoring of bearings can be contaminated with very large amounts of noise. In this work we describe a signal processing method that is designed to amplify spectral features due to the pulses, thus allowing for easier diagnostics in the presence of large amounts of noise.

Bearing fault vibrations are modeled as a series of impulse responses from a single degree of freedom system. In order to better represent reality, the model also includes variability in the periods between the pulses. Even small variability causes the harmonics to be smeared in the spectrum making it more difficult to detect the presence of pulses. The presence of large amounts of noise in the data adds more complexity to the problem.

Spectral subtraction is a technique that is commonly used for de-noising machinery signals as well as speech signals. However, it is not very effective when the noise levels are comparable with the actual signals. Another common way to tackle noise is to employ time domain averaging. Time domain averaging is effective when the noise distribution has zero mean. The proposed processing method is comprised of several steps that include time domain processing and further averaging in the frequency domain to obtain spectral densities. We present the results comparing the proposed method with time domain averaging and spectral subtraction technique.

Topic: 3C - PHM for Gears, Bearings and Lubrication

Presenting Author: Richard Holmes

Organization: VEXTEC Corporation

Country:

Paper Title: Physics-Based Gear Health Prognosis via Modeling

Co Authors: Robert G. Tryon, Raja V. Pulikollu, Kevin Line

Abstract:

VEXTEC has developed a physics based methodology that accurately predicts the remaining useful life of gears to greatly reduce engineering design time and cost. Gears are one of the oldest mechanical devices but remain a critical component in many military and commercial applications. The fundamental approach to gear analysis continues to be based on empirical standards; therefore, today's gear analysis methods cannot predict damage accumulation for conditions outside of the experimental basis. This is a key barrier to accurate assessment of wear, gear health or to prognosticate remaining useful life for complex loading scenarios. Another major flaw in the existing industry approach is that it assumes material homogeneity. A complex load state exists at the surface of meshing gear teeth. Surface stress gradients are very shallow, on length scales similar to the material's microstructural constituents. Current approaches ignore the microstructure inhomogeneity in the highly stresses surface and often predict misleading results.

VEXTEC's methodology accounts for arbitrarily sequenced variable amplitude loading. Damage accumulation in the form of nucleation and small-crack growth within the microstructure of the highly stressed surface is explicitly modeled by accounting for the grain (colony) size, grain orientation, micro-applied stress and micro-yield strength. VEXTEC's crack models incorporate randomness using Monte Carlo probabilistic techniques. The computer simulation is set up with built-in material libraries and appropriate modeling linkages are established to predict the scatter in fatigue life. The probabilistic micromechanical approach is integrated with the CAPRI hertzian contact model developed by Dr. Thomas Farris of Purdue University. This model provides the localized loading at the sub-grain size necessary for the micromechanical approach to predict component durability from fretting fatigue. VEXTEC's proprietary virtual simulation tool provides detailed insight into the gear component fatigue and reliability issues.

Topic: 3C - PHM for Gears, Bearings and Lubrication

Presenting Author: Vaughn Svendsen

Organization: AFRL/RZ

Country:

Paper Title: Current In-house R&D on Bearings

Co Authors:

Abstract:

Topic: 3C - PHM for Gears, Bearings and Lubrication

Presenting Author: Clint Baker

Organization: Sentient Corporation

Country:

Paper Title: Remaining Useful Life Prediction of Helicopter Gearbox Bearings via Vibration Diagnostics and Physics-Based Prognostic Modeling

Co Authors: Nathan W. Bolander

Abstract:

Health monitoring systems are currently fielded in select military rotorcraft to track the health of critical helicopter transmission components (bearings, gears, shafts). For instance, all UH-60M Black Hawk helicopters are equipped with such a Health and Usage Management System (HUMS). The HUMS onboard the UH-60M primarily utilizes vibration-based diagnostics to compute Condition Indicators (CIs) that reflect the health of mechanical components. This paper describes an innovative approach for predicting the remaining useful life (RUL) of a tapered roller bearing in the tail gearbox (TGB) of the UH-60M. The approach integrates vibration-based CIs with two of Sentient Corporation's software packages, CABPro (Contact Analysis for Bearing Prognostics) and the Prognostic Integration Architecture (PIA). CABPro uses physics-based damage progression modeling to predict the onset and progression of fatigue spalling in rolling bearings based on material properties, bearing geometry, lubrication conditions, and operating conditions. The PIA allows diagnostic information (i.e., CIs) to be coupled with CABPro to increase accuracy and reduce uncertainty in the RUL prediction. It accomplishes this by utilizing a particle-based parameter estimation technique with Bayesian fusion of incoming CIs to determine a probability distribution for the current state of health. This distribution is then propagated through future (estimated) operating conditions to determine the remaining useful life of the bearing. The PIA relies on accurate diagnostics; therefore, a CI is required that reliably predicts a bearing's current health. Sentient has conducted extensive laboratory testing of TGB bearings with recorded vibration data and measured (ground-truth) spall sizes to evaluate the numerous CIs used by the industry and those developed in-house.

Topic: 3C - PHM for Gears, Bearings and Lubrication

Presenting Author: Ahmed Onsy

Organization: Newcastle University

Country: United Kingdom

Paper Title: Intelligent Health Monitoring of Power Transmission Systems; an Experimental Validation

Co Authors: Robert Bicker, Brian Shaw, Chris Rowland, and Tom Kent

Abstract:

Power transmissions are one of the most important parts of any mechanical system. In order to achieve the reliable operation of these systems, effective maintenance strategies must be used. Condition based maintenance (CBM) strategies are currently gaining in popularity due to their effectiveness in reducing maintenance costs. However, these require reliable monitoring techniques. Currently, three monitoring techniques are in use in CBM: vibration, acoustic emission, and oil debris analysis. Researchers have studied these techniques to discover which can best support the operation of CBM systems in tracing the condition of the operating transmission, classifying faults, and predicting the onset of failure. These studies have shown the need to apply fusion algorithms to take the best advantage of each technique. This paper presents a novel approach in monitoring different gear faults combining vibration, acoustic emission, oil debris analysis and fuzzy logic sensory fusion algorithms. The intelligent health monitoring system (IHMS) has been implemented on a back-to-back gearbox and can be adapted to monitor the behaviour of transmission systems in automotive, aircraft, wind turbine, and industrial machinery. The study describes the operation of the online IHMS under variable conditions and its capability in detecting transmission gear defects and thus preventing sudden unexpected failures. The results support the recent trend in using IHMSs in CBM strategies.

Topic: 3C - PHM for Gears, Bearings and Lubrication

Presenting Author: David He

Organization: University of Illinois-Chicago

Country:

Paper Title: Using Hilbert-Huang Transform for Gearbox Fault Diagnosis Under Light Loading Conditions

Co Authors: Ruoyu, Li

Abstract:

Successful applications of Hilbert-Huang transform to gearbox fault diagnosis have been reported in the literature. However, when the gear transmission system operates under light loading conditions, due to low signal-to-noise ratio, Hilbert-Huang transform itself may fail to detect the gear fault. In order to address this problem, a scheme, which combining the empirical mode decomposition and the wavelet de-noising technique for gear fault detection under light loading conditions is proposed. A methodology for extracting condition indicators using Hilbert-Huang transform is also presented. Real vibration signal collected from a gearbox with one driving gear fault is used to evaluate the effectiveness of the proposed methodology.

Topic: 3Da - Condition Based Maintenance

Presenting Author: Gary Rosenberg

Organization: Constellation Technology

Country:

Paper Title: Upgrade Fluid System Filter Element Monitoring to Increase Operational Reliability and Support Condition Based Maintenance Capability

Co Authors:

Abstract:

Military aircraft can gain valuable CBM information from the effective monitoring of the change in pressure across a fluid system filter element. Over 90 percent of all military aircraft utilize fluid system filter element monitoring devices that are unable to effectively support the CBM initiative. In recent years, significant improvements in monitoring technology have been developed which can dramatically enhance military aircraft fluid systems' reliability, sustainability, readiness and safety of flight. This paper will review the historical evolution, performance capability and limitations of the existing monitoring devices. Each device will be evaluated on its suitability to support on-condition maintenance of the in-system filter element as well as the ability to provide early fault indication of the fluid system.

Topic: 3Da - Condition Based Maintenance

Presenting Author: Jeff Bagwell

Organization: US Army AMCOM

Country:

Paper Title: US Army CBM Initiative followed by discussion with presenters and attendees

Co Authors:

Abstract:

Topic: 3Da - Condition Based Maintenance

Presenting Author: Michelle Liddon

Organization: Army Aviation & Missile Command (AMCOM/), Univ of Alabama in Huntsville

Country:

Paper Title: US Army CBM Initiative followed by discussion with presenters and attendees

Co Authors:

Abstract:

Topic: 3Da - Condition Based Maintenance

Presenting Author: Chris Sautter

Organization: University of Alabama in Huntsville

Country:

Paper Title: US Army CBM Initiative followed by discussion with presenters and attendees

Co Authors:

Abstract:

Presentations from Chris Sautter, University of Huntsville, Jon Keller, Army RDECOM, Huntsville and Michelle Liddon, AMCOM covering US Army CBM Initiative followed by discussion with presenters and attendees

Topic: 3Db - Advanced Material Inspection Technologies

Presenting Author: Glenn Light

Organization: Southwest Research Institute

Country:

Paper Title: Magnetostrictive Sensor (MsS) Technology for Inspection and Health Monitoring of Structures

Co Authors: Hegeon Kwun, C. J. Thwing

Abstract:

Using the magnetostriction technology, Southwest Research Institute has developed an inexpensive, low profile sensor that can be permanently attached to a structure for inspection and/or monitoring of large areas of the structure. The sensor consists of a thin ferromagnetic strip material with coil placed over the strip. When the coil is activated, the sensor generates guided waves that can travel a long distance in the structure to detect defects in the structure. By periodically acquiring the data and comparing it with the baseline data established at the time of sensor installation, structural changes that have occurred over time can be quickly detected and used for structural management decisions. Basic theory for the technology will be discussed including how parameters such as wave mode, velocity, and attenuation affect the selection of the guided wave used.

This technology has been used in the field for over 5 years to inspect piping, plates, rods, and other components. Examples of applications in a wide range of industries will be discussed. In addition, new technology is being developed to enhance the capability to monitor such as multiplexed sensors and wireless communication capability. Applications to pipeline, plate, and aircraft structure (metal and composite) monitoring will also be presented.

Topic: 3Db - Advanced Material Inspection Technologies

Presenting Author: Roger Crane

Organization: NSWC, Carderock Division

Country:

Paper Title: Structural Health Monitoring of Large Scale Composite Structures using the Structural Irregularity and Damage Evaluation Routine

Co Authors: Colin P Ratcliffe

Abstract:

The U.S. Navy has fielded, and is currently developing, several composite structures with large surface area for fleet implementation. Conventional nondestructive inspection (NDI) methods, such as the commonly employed ultrasonic methods, are limited in their capabilities to inspect these composite structures due to their large size, difficult accessibility, and instrumentation portability. In addition, the complexity of the construction used, which includes thick cores and multilayer composite structures, complicate inspection with standard ultrasonic methods. Techniques to provide rapid nondestructive inspection of large area composite structural components are required for these applications. An inspection technique, Structural Irregularity and Damage Evaluation Routine, SIDER, has been developed by the Navy, U.S Patent 6,799,126, to rapidly interrogate entire structures and locate areas of stiffness variation that result from processing anomalies and in-service damage. SIDER has been used to locate damage related features in numerous large scale structures including a ½ scale composite Corvette Hull section, the M80 Stiletto composite hull, the Composite Twisted Rudder, an Airbus A320 vertical stabilizer, and a composite road bridge. SIDER has been shown to rapidly locate areas on a structure where structural degradation has occurred. Current developments include the extension of this technique to in-service structural health monitoring of composite structures. This paper will present examples of where this technology has been used and discuss current development efforts to allow SIDER to interrogate composite structures in the service environment.

Topic: 3Db - Advanced Material Inspection Technologies

Presenting Author: Ken Heller

Organization: QinetiQ North America/Foster-Miller, Inc.

Country:

Paper Title: Shipboard Remote Inspection and Maintenance Using Minimally Invasive Technology

Co Authors:

Abstract:

Topic: 4A - Health Management for Maintenance and Decision Support

Presenting Author: Simon Jessop

Organization: Impact Technologies, LLC

Country:

Paper Title: Common S2ENCE Maintenance

Co Authors: Johan Reimann, Patrick W. Kalgren

Abstract:

Intermediate level avionics maintenance requires diagnostic assessment, repair, and flight certification steps. The current Automated Test Systems (ATS) are primarily designed to verify equipment end-to-end function (flight certification), so they are not optimized to support diagnostic procedures. An operator typically performs problem diagnosis at the beginning of the end-to-end test without any regard to existing evidence of the likely failure. Test Program Set (TPS) routines can take hours for a functioning unit and much longer if repairs are necessary.

The Common S2ENCE (Smart Support Enhancements for Net Centric Enabled) Maintenance System provides data exchange and diagnostic reasoning services to enable reduced test and diagnosis times. The system acquires operational flight and maintenance data from a variety of sources using open data standards and performs model-based diagnostic reasoning to identify likely failure modes and determine optimal test entry points. These enhancements greatly reduce test times by directing the test to the area of most likely failure. The system also provides diagnostic assistance based on bench testing results as the specific unit under test (UUT) is evaluated.

The system architecture and case studies of the systems as it has been applied to the F/A-18 I-Level avionics maintenance environment are described in this paper. Data acquisition, transfer, and analysis methods are also presented. A discussion of the application architecture details supportability considerations and extensibility to other operating environments.

Topic: 4A - Health Management for Maintenance and Decision Support

Presenting Author: Klaus Blache

Organization: University of Tennessee

Country:

Paper Title: World Class Maintenance Benchmarks - Revisited

Co Authors:

Abstract:

Topic: 4A - Health Management for Maintenance and Decision Support

Presenting Author: Sam Kunselman

Organization: Goodrich - SIS

Country:

Paper Title: Emerging CBM Capabilities on the UH-60 Blackhawk Utilizing IVHMS Data Correlation and Analysis

Co Authors: Rena Durham, Don Estes (QTEC Incorporated)

Abstract:

Until recently, Army Aviation maintenance relied on time based maintenance on many of the dynamic helicopter components. Mandatory checks, overhauls, and replacements were performed either on a flight hour usage or calendar basis. This philosophy did not take into consideration the current condition of the component. The transition to condition based maintenance for these components will allow the Army to perform maintenance on components that are in a degraded state, allowing the maintenance manager to do maintenance when appropriate. Condition-Based Maintenance (CBM) can be defined as a set of maintenance processes and capabilities derived from real-time assessment of weapon system condition obtained from embedded sensors and/or external tests and measurements using portable equipment. This will enable better system reliability analysis thus increase the operational availability of Army aircraft. The ultimate goal of CBM is to know and understand the actual status of equipment, which will reduce unnecessary maintenance. The ability to accurately assess the condition of the dynamic components on the aircraft is essential to the current Army Aviation condition based maintenance philosophy.

Topic: 4A - Health Management for Maintenance and Decision Support

Presenting Author: Nagi Gebraeel

Organization: Georgia Tech

Country:

Paper Title: Prognostic Models for Computing and Updating Remaining Useful Life Distributions under Time-Varying Environmental Conditions

Co Authors:

Abstract:

This paper presents a degradation modeling framework for computing degradation-based residual life distributions of partially degraded systems and components functioning under time-varying environmental and/or operational conditions. Our approach is to mathematically model a sample of degradation-based signals (acquired through condition monitoring techniques) using stochastic models that combine three main sources of information: (1) real-time component-specific degradation characteristics obtained by observing the in-situ degradation signal, (2) historical degradation characteristics of similar components, and (3) real-time status of the environmental conditions under which the component is operating.

Prior degradation information is used to estimate the model coefficients. The resulting generalized stochastic degradation model is then used to predict an initial residual life distribution for the component being monitored. In-situ degradation signals, along with real-time information related to the environmental conditions, are then used to update the residual life distributions in real-time. Because these updated distributions capture current health information and the latest environmental conditions, they provide precise lifetime estimates. The performance of the proposed models is evaluated using real world vibration-based degradation signals from a rotating machinery application.

Topic: 4A - Health Management for Maintenance and Decision Support

Presenting Author: David Baglee

Organization: University of Sunderland

Country: United Kingdom

Paper Title: An Integrated Approach to Maintenance Strategy Development within SMEs

Co Authors: Robert Trimble and John MacIntyre

Abstract:

The importance of maintenance has increased, as high productivity and quality can be achieved by means of well-developed and organised maintenance strategies. However, this assumes that maintenance is controlled in such a way that equipment is stopped for maintenance via a systematic schedule. With the recent advances in technology many methodologies, tools, techniques and strategies have been developed and tested. Unfortunately, the majority of organisations are constrained by certain barriers with the resulting loss of major benefits. These are usually classified as Small and Medium Sized Enterprises (SMEs). Based upon our data analysis a new maintenance methodology, the Advanced Integrated Maintenance Management System (AIMMS) is developed. To enable the implementation, monitoring and evaluation of AIMMS a computerised system - Maintenance Management (MainMan) - was developed and implemented within several case study companies. This paper examines the implementation process within one of these companies. The results indicate that AIMMS supports strategic maintenance decisions, and helps to increase equipment effectiveness through prioritising equipment criticality and focusing on specific resources that will maximise gains based upon a return on investment.

Topic: 4A - Health Management for Maintenance and Decision Support

Presenting Author: Joel Luna

Organization: Frontier Technology Inc

Country:

Paper Title: Strategies for Optimizing the Application of Prognostic Health Management to Complex Systems

Co Authors: Ron Shroder, Nick Frankle, D.C. Conroy

Abstract:

This paper describes a process for evaluating the impact and benefit of Prognostic Health Management (PHM) technologies to specific system components and for selecting an optimum PHM strategy. Contemporary maintenance strategies are focusing on migration to Sense-Respond Logistics and Condition Based Maintenance. These strategies represent efforts to shift time-based scheduled maintenance to preventive and predictive approaches based on evidence of need and are projected to reduce cost of operations while increasing system availability. Within these strategies, PHM provides the opportunity to monitor system health, detect abnormal conditions and identify precursors of future failures before an unplanned service interruption or catastrophic failure results in loss of mission, system, or life. Not every complex system will benefit from application of predictive technologies. Often, there is not enough funding available to provide every component with PHM capability nor is it necessary. Given a large number of systems or system components, the challenge facing system designers and maintenance operators is the identification of those specific components that will return the largest benefit if an investment is made in PHM technology. Factors influencing this decision include, but are not limited to: • Criticality – what is the impact on overall system performance if the component fails unexpectedly • Maintenance strategy – what is the maintenance philosophy associated with the component (e.g. run to end of life, refurbish, replace) • Cost of repair – to include the cost and availability of spare parts and the effort and specialized knowledge required for the repair • Availability of data sources – what data is available or needs to be available to apply PHM techniques to the component. What is the cost of obtaining or collecting the data? Increasing the insight into performance, cost and risk trade-offs early in the product design process is key to identifying and prioritizing where PHM solutions will provide the most significant Return on Investment (ROI). This paper describes a decision support infrastructure that is built upon the integration of community-accepted decision-making methods combined with unique insight into technical system maintenance parameters driving cost. The FTI Integrated Cost as an Independent Variable (I-CAIV) tool facilitates the documentation of both system high-level capabilities as well as the generation of multiple stakeholder priorities. This structure includes performance requirements that are linked to objectives and thresholds in a manner that allows users to understand how requirements drive maintenance costs during the design process. By understanding specific performance areas driving maintenance costs early in the design process, IPTs can conduct trade-off analyses to optimize projected benefits of the addition of PHM to different system platforms and to ensure that application of new maintenance strategies represent the best use of available resources and the optimum investment in PHM technology.

Topic: 4C - Failure Analysis: Engineering Solutions for Failure Prevention

Presenting Author: Marc Pepi

Organization: US Army Research Laboratory

Country:

Paper Title: Analysis of a Failed Tail Rotor from an Army Attack Helicopter and Related Materials

Co Authors: Michael Lister (ARL)

Abstract:

ARL examined aluminum raw material that exhibited staining in an effort to ascertain whether this staining could have led to a catastrophic failure of an Army attack helicopter tail rotor blade. The investigation included visual examination, X-ray photoelectron spectroscopy (XPS) analysis, pit depth measurement, scanning electron microscopy, and metallography. An aluminum Spar 2 web from the fabricator that exhibited staining was shown to contain pits, as did a sheet of raw aluminum material. The chemical composition of the stains differed from the web to the sheet. The staining on the spar was most likely attributable to hard water at the manufacturing plant and/or the remnants of a cleaning agent used in the process. The staining on the sheet of raw aluminum material was most likely aluminum oxide corrosion products. The pits on this sheet of material were much deeper than those on the Spar 2 web. In no instance, did a pit measure as deep as that which led to the failure of the tail rotor on the aircraft. ARL also examined the fractured Spar 2 from the aircraft, and confirmed the findings of the primary contractor. Further, ARL reviewed the the contractor's failure analysis report, and, in general, was in agreement with the findings. Recommendations were provided to ensure the parts are kept free from the onset or corrosion during the life cycle of the part.

Topic: 4C - Failure Analysis: Engineering Solutions for Failure Prevention

Presenting Author: Harold Simmons

Organization: Southwest Research Institute

Country:

Paper Title: Diagnosing the Root Cause of Turbo-machinery Blade Failures, Part 1: Experimental and Analysis Methodology

Co Authors: Timothy Allison, David Ransom, Vishwas Iyengar

Abstract:

A practical methodology is presented to analyze turbo-machinery blade failures that utilize transfer function of stress to pulsation relationships determined either by impulse testing or by FEA model analysis. A step by step introduction is included to guide a failure analyst in conducting site investigations, metallurgical examination, dynamic response testing or simulation, and prediction of turbomachinery excitation sources. The author presents a three part criterion to diagnose the causes of high cycle fatigue failures based on the fleet experiences of the turbine or compressor that suffered the failure. A companion, Part 2 paper presents a case study root cause analysis of an airfoil failure in an axial flow compressor.

Topic: 4C - Failure Analysis: Engineering Solutions for Failure Prevention

Presenting Author: Tim Allison

Organization: Southwest Research Institute

Country:

Paper Title: Diagnosing the Root Cause of Turbo-machinery Blade Failures, Part 2: Case Study of an Axial Flow Compressor Failure

Co Authors: Harold Simmons, David Ransom, Vishwas Iyengar

Abstract:

This paper presents a case study for root cause failure analysis based on Part 1 methodology. A failure of an axial flow compressor blade is investigated, and the steps involved with the failure analysis are described in detail. The scope of the failure analysis includes many analyses that are commonly used to investigate machinery failure, including a site visit, metallurgical analysis, dynamic analysis, and computational fluid dynamics analysis. The blade failure is determined to be a consequence of an inlet guide vane failure, and the root cause of the failure is determined to be resonant excitation of the inlet guide vanes due to the vortex shedding frequency of the inlet guide vanes. Emphasis is placed on the reasoning process behind each step of the failure analysis and the justification for conclusions regarding the root cause of the failure. Specific recommendations for preventing future failures of the same type are also presented.

Topic: 4C - Failure Analysis: Engineering Solutions for Failure Prevention

Presenting Author: Tim Swigart

Organization: US Air Force Research Laboratory

Country:

Paper Title: Using Electron Backscatter Diffraction to Evaluate the Failure of Rocket Components

Co Authors:

Abstract:

Many of the rocket motor components used in the United States Air Force were designed and produced in the early to mid 1960s. The state of the art in the 1960s required the use of several materials that have since been replaced with better alloys. This can have unforeseen repercussions when attempting to reproduce components in order to extend the life of the fleet. This study discusses the specific example of a rocket motor throat support made from pure molybdenum. The difficulties with identifying a supply source of pure molybdenum are discussed. In addition, the steps taken to reverse engineer the manufacturing process are presented. One of the steps in the reverse engineering process was to use electron backscatter diffraction (EBSD) to ensure consistency between modern and legacy hot forming processes. This is the first know use of EBSD to reverse engineer a forming process and to assist in a test article failure analysis. EBSD proved successful in eliminating hot forming processes as a source of variability.

Topic: 4C - Failure Analysis: Engineering Solutions for Failure Prevention

Presenting Author: Gareth Forbes

Organization: University of New South Wales

Country: Australia

Paper Title: Gas Turbine Casing Vibrations under Blade Pressure Excitation

Co Authors: Robert Randall

Abstract:

The non-intrusive measurement of the condition of blades within a gas turbine would be a significant aid in the maintenance and continued operation of these engines. Online condition monitoring of the blade health by non-contact measurement methods is the ambition of most techniques. The current dominant method uses proximity probes to measure blade arrival time for subsequent monitoring. It has recently been proposed however, that measurement of the turbine casing vibration response could provide a means of blade condition monitoring, and even give the prospect of providing an estimation of the blade modal parameters. The casing vibration is believed to be excited pre-dominantly by (i) the moving pressure waveform around each blade throughout its motion and (ii) the moments applied by the stationary stator blades. Any changes to the pressure profile around the rotating blades, due to their vibration, will in turn affect these two dominant excitation forces, such that there will be some correlation between the casing response and blade vibrations.

Previous work has introduced an analytical model of a gas turbine casing, and simulated pressure signal, associated with the rotating blades. The effect of individual rotor blade vibrations has been developed in order to understand the complex relationship between these excitation forces. A simplified turbine test rig has been constructed. Various aspects of the previous analytical modelling are presented, and then investigated and verified using results from the experimental program with this simplified test rig.

Topic: 4C - Failure Analysis: Engineering Solutions for Failure Prevention

Presenting Author: Ying Tan

Organization: Guangdong Inspection and Quarantine Technology Center

Country: China

Paper Title: Fracture Analysis of Manual Hoist: A Case Study

Co Authors: Biao Cao, Ming Chen, Ming-zhen Mo, Xiao-gang Peng

Abstract:

While lifting a 22t steam turbine covering using two sets of 10t manual hoist and a steel wire rope, the manual hoist broke suddenly and the steam turbine covering fell to the ground. The fracture was analyzed by means of SEM analysis、chemical composition analysis、microstructure examination and mechanical testing, it was shown that fixed pin was the first fracture piece of the manual hoist and there was process defects in the fixed pin which decreased strength of the fixed pin, so when lifting the steam turbine covering the fixed pin broke firstly because of lower strength.