Assigned Session: A 1 Failure Analysis

Presenting Author: Onome Scott-Emuakpor **Ser:** 2

Organization: Air Force Research Laboratory

Country:

Paper Title: **Investigating an Improved Ultrasonic Fatigue Test Setup**

Co Authors:

Abstract:

An axial ultrasonic fatigue test setup is being improved for fast gigacycle accumulation. The setup being improved is capable of attaining gigacycles in 75% and < 1% of the respective times required for conventional ultrasonic apparatuses and servohydraulic load frames. The test procedure for the ultrasonic approach has been investigated and parameters were settled upon using a hierarchical Bayesian method that assessed testing repeatability between 10^6-10^10 cycles to failure. Though the ultrasonic test duration is faster than the servohydraulic approach, which is preferred during design against high cycle fatigue (HCF) for critical turbine engine components, previous researchers show contradicting results for the effects of frequency on the endurance limit of metallic alloys. Understanding the discrepancy will improve relevant fatigue behavior assessment. The following work investigates issues on accurate HCF assessment by comparing ultrasonic fatigue data against servohydraulic data. The comparison is motivated by the hope of reducing HCF design conservatism. Aluminum 6061-T6 specimens are fatigued in the range of 10^4 – 10^9 cycles in order to make the necessary comparisons.

Assigned Session: A 1 Failure Analysis

Presenting Author: Will Mars **Ser:** 55

Organization: Endurica LLC

Country:

Paper Title: **Critical Plane Analysis for Computing Fatigue Damage in Elastomers**

Co Authors:

Abstract:

As crack precursors develop in an elastomer, they tend to do so on specific planes that are associated with the particular history of applied loading. This observation is the foundation for a fatigue life calculation method - Critical Plane Analysis - that considers how damage is incurred by each potential crack precursor on each potential crack plane. The method is based upon fracture mechanical principles, and produces estimates of both the fatigue life and the orientation on which cracks initiate. We illustrate application of the procedure to an automotive transmission mount under road loads.

Assigned Session: A 1 Failure Analysis

Presenting Author: Yanlin Zhao **Ser:** 14

Organization: BeiHang University in China

Country: China

Paper Title: **Residual Life Estimation of Steam Turbine Rear Bearings Based on Two-Dimensional Wiener Process as a Degradation Model**

Co Authors: Zhao Yanlin, Yao Jun, Liu Hongjian, and Miao Shuizhuang

Abstract:

One-dimensional Wiener process, when employed as a degradation model, has its problems because it doesn't sufficiently consider the relevance of multiple degradation factors. To compensate, a two-dimensional Wiener process is created in this paper to fit the life degradation trend. The form of reliability analysis is obtained through the construction of a Fokker-Planck equation. Parameters of the two-dimensional Wiener process is then assessed according to characteristics of multiple normal distribution. The residual life of the trust bearing in a certain steam turbine is examined A) in a degradation model developed from a One-dimensional Wiener process based on objective Bayesian analysis; B) in a degradation model based on a two-dimensional Wiener process. By comparing results, a conclusion is made that the two-dimensional Wiener process, when employed as a degradation model in the estimation of residual life in steam turbine rear bearings, is more accurate, requires less measured data, therefore is more helpful in engineering practice.

Assigned Session: B 1 Sensors 1

Presenting Author: Eric Bechhoefer **Ser:** 12

Organization: Green Power Monitoring Systems LLC

Country:

Paper Title: **Verification and Validation of a Smart Vibration Sensor**

Co Authors: Eric Bechhoefer

Abstract:

In the development of a bused architecture for health and usage monitoring system (HUMS), the sensor requires both hardware and software verification and validation testing. While most HUMS or condition monitoring system use commercial off the shelf accelerometers, this architecture uses a packaged MEMS accelerometer. The physical limits of the packaged accelerometers must be determined, including noise, accuracy and bandwidth. Further, the ability of the sensor to perform in situ analysis requires that software test is conducted on the sensor to determine that the application software is performing to specification. In this paper, we will discuss how vibration testing was performed in order to determine the sensor response and if the sensor could meet the design requirements for noise, accuracy and bandwidth. We also demonstrate how software tests to ensure that the desired functionality of the sensor was supported for embedded analysis, such as time synchronous averaging, spectrum, and envelop spectrum, for in situ condition indictor calculation.

Assigned Session: B 1 Sensors 1

Presenting Author: James Hofmeister **Ser:** 39

Organization: Ridgetop Group

Country:

Paper Title: **Accurate Vibration and Speed Measurement on Rotating Shafts Using MEMS and IoT Single Wireless Triaxial Sensor**

Co Authors: James Hofmeister, Douglas Goodman, and Robert Wagoner

Abstract:

Industrial equipment, robotics and gear boxes that incorporate rotating shafts often need to monitor rotational vibration and shaft speed, as part of broader condition-based maintenance (CBM) systems. Existing sensor implementations on rotating shafts, including pinion gears and epicyclic gears, have been limited by cabling and slip-ring approaches and use of multiple sensors to obtain monitoring information.

Ridgetop has developed and tested RotoSense, a practical, self-contained, compact, triaxial sensor design that employs MEMS technology and an IoT wireless monitoring system. This triaxial sensor enables new applications since it is capable of measuring shaft speeds of up to 5500 RPM, while streaming accurate rotational vibration and shaft speed measurement data on a continuous basis. Each sensor possesses its own IP address, which supports remote monitoring over the internet. Applications can range from industrial equipment to transportation systems. The sensor will be described, its linkage to software-based monitoring nodes, as well as examples of its implementation on helicopter gearboxes and railroad track condition monitoring.

Assigned Session: C 1 End User Applications 1: Overviews

Presenting Author: Patrick Carle **Ser:** 68

Organization: Rockwell Automation

Country:

Paper Title: **Why Do We Monitor Machine Condition, a Discussion of Markets**

Co Authors:

Abstract:

A discussion of the markets for condition monitoring technologies.

The historical market definitions for condition monitoring solutions are rooted in 30 year old business requirements that were served by the technologies of the time. The problems that industry have to address today have evolved, changed and expanded, and the technologies available to serve those needs has dramatically changed. Nevertheless, today the common definitions of the markets for condition monitoring solutions are the same as in 1985.

This discussion will present a broader perspective on the markets; what they actually are, which is defined by why customers use the solutions, and how todays technologies can serve them.

Assigned Session: C 1 End User Applications 1: Overviews

Presenting Author: David Baglee **Ser:** 18

Organization: University of Sunderland

Country: UK

Paper Title: **How Does CBM Function in the Real World?**

Co Authors: David Baglee, Erkki Jantunen, Jaime Campos, and Pankaj Sharma

Abstract:

Manufacturing organizations are under increasing pressure to meet customer and corporate demands by implementing improved maintenance initiatives to reduce costs, improve equipment availability, and protect against failure of critical equipment. Condition Based Maintenance (CBM) is widely accepted and used as a financially effective maintenance strategy which is used to anticipate equipment or component failure. Recent technological advances in component sensitivities, size reductions, and most importantly, cost has opened up an entirely new area of diagnostics. The economic benefit of CBM is achieved if the approach to maintenance is applied to the right equipment and through appropriate tools. In particular the degradation behaviour of the equipment needs to be understood to correctly deploy a CBM approach. However, an understanding of the degradation is required to enable specific action to specific equipment and or components.

Failure modes can be applied to support and optimise the decision making process. Using failure modes can be an efficient low-risk tool process for the prevention of problems, and is referred to as a deductive technique that consists on failure identification in each component. However, the literature is limited regarding the importance and the role of various failure models in different industrial sectors. Thus, if failure models are not known, understood and utilised correctly the use of CBM will not lead to financial benefits.

The paper examines the relationship between the failure patterns observed in industrial maintenance practice and the corresponding impact on adoption and potential benefits of Condition-Based Maintenance (CBM). The paper will explain the need for accurate and up to date equipment information to support the correct maintenance approach. The paper suggests the importance of further supporting such investments by appropriately addressing the need to collect relevant data as a basis upon which to make the right decisions.

Assigned Session: D 1 Data Handling and Management

Presenting Author: Joe Sheeley **Ser:** 36

Organization: Arnold Engineering Development Center (AEDC), US Air Force

Country:

Paper Title: **Designing Machinery Health Monitoring Software in the Age of Data**

Co Authors:

Abstract:

As recently as 20 years ago, machinery health monitoring data was once extremely difficult to obtain. Machinery diagnostics experts would set up sensors mounted on machinery in various ways and acquire data using whatever data collection system was available. The invention of standardized handheld data collectors opened the field up to more individuals, but data collection was still time intensive, making each dataset precious. Today automated online data collection systems are being developed and placed in the field, resulting in the collection of gigabytes of data over short periods of time. This has flooded the analyst who had difficulty even performing analysis and tracking machinery health state for all of the data from hand-held collectors in a large plant. New tools are required to increase the efficiency of the modern analyst in this "age of data." This paper will discuss how a machinery health monitoring software suite should be designed to enable an analyst to increase his efficiency and take advantage of the opportunity the availability of data affords.

Assigned Session: D 1 Data Handling and Management

Presenting Author: Preston Johnson **Ser:** 48

Organization: Allied Reliability Group

Country:

Paper Title: **An Architecture for the Integration of Data from Fault Detection Technologies with Failure Prevention Knowledge**

Co Authors:

Abstract:

The fields of condition monitoring for machine defects and machine failure prevention leverage a wide range of technologies for detection of defects. These technologies are available from a number of vendors, making integration of data a challenge. Further, determining the action to take once defects in equipment are detected requires a body of knowledge that understands the likely causes of the defect, and the best possible corrective action to take. Combining these elements into a world class monitoring, diagnostics, and reliability program requires integration of many technologies with data and visualization tools available to a wide range of personnel participants. The Monitoring, Diagnostics, and Reliability (MD&R) system often results in a distributed, networked and central private "cloud" oriented data storage and analytics system. This presentation covers design considerations in architecting the distributed, networked and cloud based MD&R system and concludes with short case studies of system implementations.

Assigned Session: D 1 Data Handling and Management

Presenting Author: Brandon Van Slyke **Ser:** 60

Organization: SETPOINT Vibration

Country:

Paper Title: **Using the PI System for Full-Featured Vibration Condition Monitoring**

Co Authors: Brandon Van Slyke, Randall Chitwood, and Steven Sabin

Abstract:

This presentation explores the use of the PI System as the infrastructure for collection and visualization of machinery condition monitoring data, including high-speed vibration waveforms and specialized data presentation formats such as shaft orbits, vibration spectra, bode / polar plots, and others. Historically, the vibration data collection rates necessary to allow detailed machinery diagnostics were too fast to entertain use of the plant's process historian, particularly when a system was going to encompass dozens or hundreds of vibration channels. As a result, stand-alone vibration monitoring software infrastructures with their own proprietary databases, servers, display clients, security models, and network connections evolved out of necessity to handle the data collection speeds required. However, as the capabilities of the PI System have improved, now surpassing one million tags per second, the ability to treat vibration waveforms as simply another type of time series data in the PI database has become practical.

Users can reduce initial and ongoing costs by extending their existing PI infrastructures to handle both vibration and process data rather than deploying one infrastructure for process data and another for vibration data. PI technology also allows users to easily combine process and vibration data from disparate PI Servers throughout their organization and visualize this data in integrated ProcessBook displays - important when diagnosing machinery and determining correlation, cause, and effect between mechanical condition changes and process changes. Because of the robust and proven security models inherent in the PI System, full network security can also be achieved in a cost-effective manner, allowing remote machinery analysis where previously impossible or impractical.

Assigned Session: E 1 Additive Manufacturing 1

Presenting Author: Marc Pepi **Ser:** 3

Organization: US Army Research Laboratory

Country:

Paper Title: **Agile Additive Manufacturing in Austere Environments**

Co Authors: Marc Pepi, Jennifer Sietins, Raymond Wildman, Nicole Zander, and Margaret Gillan

Abstract:

Additive manufacturing provides many advantages to industry in terms of cost savings, the ability to manufacture complex and unique designs and geometries in a timely fashion, as well as providing a more environmentally-friendly means of production (leads to less waste than subtractive manufacturing). The DoD is now interested in additive manufacturing as a means of being able to produce parts "on-demand" in extreme environments such as on a ship, or on a forward operating base. However, there are technical challenges that need to be overcome to fully achieve this capability in the future. One such challenge is part quality, and the qualification and certification of parts produced in this manner to ensure the parts will not fail in service. This paper will discuss this and other challenges in more detail, and will provide a lead for other briefs on additive manufacturing to be featured in the same session.

Assigned Session: E 1 Additive Manufacturing 1

Presenting Author: Todd Palmer **Ser:** 35

Organization: Penn State University

Country:

Paper Title: **Role of Processing-Structure-Property Relationships in Developing Certification Protocols for Ti-6Al-4V Components**

Co Authors:

Abstract:

A fundamental understanding of processing-structure-property relationships is a key prerequisite to the eventual development and implementation of a certification protocol for additively manufactured (AM) components. One unique aspect of the AM process is the role that geometry plays on these relationships and how it can be integrated into certification. These relationships are defined here for specific directed energy deposition AM processing conditions in Ti-6Al-4V by correlating microstructural features with the resulting static mechanical properties. By concentrating on simple geometries, variations in the resulting microstructures and mechanical properties at all locations within the Ti-6Al-4V builds are characterized. As a result, the relationships between the processing conditions and the resulting structure and properties of the build are quantified and used in the selection of processing conditions that assure adequate mechanical properties and performance in the final design. Based on these results, a methodology which establishes fundamental relationships between the AM processing conditions, the microstructural features, and the mechanical properties is under development. As part of this effort, an analysis of the uncertainty in mechanical property data for Ti-6Al-4V AM components and a methodology for identifying minimum design values is being developed.

Assigned Session: E 1 Additive Manufacturing 1

Presenting Author: Jennifer Sietins **Ser:** 5

Organization: Army Research Laboratory

Country:

Paper Title: **Additive Manufacturing Characterization Utilizing X-ray Computed Tomography**

Co Authors: Jennifer Sietins

Abstract:

X-ray computed tomography (CT) is a valuable technique for quality control measures, part inspection, dimensional analysis, microstructural characterization, and void identification and quantification. This nondestructive characterization technique allows for three-dimensional imaging that readily captures defects and voids on the conditions that the attenuation, which is approximately related to the material density, is distinctly different from the surrounding material and the resolution is sufficient for the feature or defect sizes of interest. This work summarizes the CT capabilities at the Army Research Laboratory, with a specific emphasis on the characterization of 3D-printed structures. Analysis examples will include: quantification of tolerance differences between the designed and manufactured parts, void sizes and distributions, in-situ compression tests for brittle and elastic truss structures, and mechanical behavior simulations for meshes generated from the CT scan data. These tools can enable faster process optimization timeframes and ensure that the final part does not have voids above a critical size prior to fielding.

Assigned Session: A 2 End User Applications 2

Presenting Author: Espen Oland **Ser:** 24

Organization: Teknova AS

Country: Norway

Paper Title: **A Review of Condition Monitoring Techniques for Fiber Ropes**

Co Authors: Espen Oland and Rune Schlanbusch

Abstract:

There is a trend within the oil and gas market to shift from steel wire to fiber ropes for lifting, hoisting and mooring applications. While detection techniques for steel wire ropes have been developed over more than a century and has acceptable solutions commercially available, this is not the case for fiber ropes. The current standards for fiber ropes applied offshore today are to count load cycles and do visual inspections of the rope, methods that are not acceptable if the service life of the fiber rope shall be maximized.

By migrating from steel wire to fiber ropes, the weight of the rope is reduced, requiring smaller lifting equipment, reducing the power demand and therefore also the CO2 footprint. This result in large cost savings for the oil companies, but at present there is no satisfactory condition monitoring technique that can be applied to fiber ropes. Hence, the oil companies do not know when to discard the ropes besides using visual inspections and by counting load cycles.

This paper presents a review of the different techniques and ideas that has been published through papers and patents the last decades. The different methods are then analyzed and discussed for possibilities of applying them for the offshore industry. Furthermore, new possibilities that have been identified through this review are also highlighting, which can serve as inspiration for new research within condition monitoring of fiber ropes.

Assigned Session: A 2 End User Applications 2

Presenting Author: Espen Oland **Ser:** 25

Organization: Teknova AS

Country: Norway

Paper Title: **Review of Condition Monitoring Technologies for Offshore Steel Wire Ropes**

Co Authors: Rune Schlanbusch, Espen Oland, and Eric Bechhoefer

Abstract:

In this research, we review condition-monitoring techniques for large steel wire ropes (SWR). Such ropes are used for load handling at up to 3000 meters depth during subsea construction. This requires strong ropes up to 18 cm in diameter, which costs about 2,5MUSD per rope. Todays practice is to discard the rope after a predetermined number of uses due to fatigue from bending over sheaves with a large safety factor. Other sources of degradation are abrasion, fretting, corrosion and extreme forces, and are typically accelerated due to undersized or poorly maintained sheaves, groove type and lack of lubrication.

Non-destructive testing techniques have been developed for SWR during over 100 years. Most notably is the magnetic leakage technique (electromagnetic method), which are widely used within several industries such as mining and construction. One drawback with this technique is its ability to assess interior weaknesses for very thick ropes and for end terminations.

The techniques reviewed in this research are the electromagnetic method, acoustic emissions, ultrasound, eddy current, x and gamma rays, fiber optics, optical and thermal vision and current signature analysis, and their latest developments, both in industry and academia. Each technique is weighted based on pros and cons for the subsea construction application. Evaluated criterias/requirements include ability to detect localized flaws (i.e. broken wire) both internally and externally, estimate loss of metallic cross sectional area, robustness with respect to the rough offshore environment, ability to evaluate both rope and end fittings, autonomy, ability to measure during operation, applicability over range of SWR designs and cost. A recommendation is given for a combination of techniques fulfilling requirements at minimum price and system complexity.

Assigned Session: A 2 End User Applications 2

Presenting Author: Mark Walker **Ser:** 52

Organization: D2K Technologies

Country:

Paper Title: **Enabling Autonomous Propellant Loading Through Model-based Operational Awareness**

Co Authors:

Abstract:

Propellant loading systems associated with spacecraft launch operations have always demanded a high degree of caution and have typically involved excessive human intervention for control. Safety concerns during loading operations have led to the specification of conservative command and control strategies, and the detection of operational anomalies during critical operational phases typically require mandatory interruption followed by safety shutdown. While the safety concerns associated with propellant loading continue, advances in model-based Integrated Systems Health Management for Autonomous Control (ISHM-AC) can now be effectively used to detect and distinguish the difference between equipment failures and instrumentation failures. This improved operational awareness allows users to make more appropriate go-no-go decisions, avoiding unnecessary interruptions while ensuring proper safing of systems in the event of equipment failure. Furthermore, the successful deployment of such model-based operational awareness is an enabler for autonomous control of propellant loading systems, providing mechanisms to trigger automated shutdown procedures when certain conditions are detected during certain phases of operation, while autonomously authorizing continuous operation when benign issues are detected. This paper discusses recent significant advances being demonstrated by the authors at Kennedy Space Center.

Assigned Session: B 2 Signal Analysis 1

Presenting Author: Bob Randall **Ser:** 61

Organization: University of New South Wales

Country: Australia

Paper Title: **Compensating for Speed Change in the Diagnosis of Gear and Bearing Faults**

Co Authors:

Abstract:

The symptoms of faults in both gears and rolling element bearings are tied, at least roughly, to machine speed, but the actual mechanisms of vibration signal generation are quite different. Since gear tooth faults affect the gear meshing in a deterministic way, the forcing functions are inherently deterministic, and for constant speed are primarily at the discrete frequencies representing harmonics of the rotational speeds of the gears involved. The vibration responses are modified by the structural response properties of the machine, and are amplified/attenuated in the vicinity of resonances/antiresonances of the structure. Even so, the responses are basically periodic and can be extracted from extraneous vibrations by performing synchronous averaging with respect to each shaft separately. Changes in the forcing functions are easily detected by this means, since the structural dynamic properties usually remain unchanged. On the other hand bearing responses are usually amplified by high frequency resonances, and the diagnostic information is contained in the envelope of the impulse responses (corresponding to these fixed natural frequencies). Under varying speed conditions, however, the interaction between varying forcing frequencies and fixed resonance frequencies is very different for the two cases. For gears, varying forcing frequencies will mean that gearmesh frequencies, for example, will pass through resonances, making the amplitude of the response a function of speed (and time). Order tracking can be used to convert "time" signals into a rotational angle basis, and spectra into harmonic orders, so as to compare the equivalent components directly, but this removes only frequency modulation, not amplitude modulation. Synchronous averaging of such an amplitude modulated signal will find the "average" amplitude, and when this is repeated and subtracted, the deterministic variations around the average will still be left. If order tracking is used directly on bearing response signals, the fixed resonances carrying the fault information become smeared, and will lose their potency in separating the bearing signals from the rest. This paper demonstrates how a new cepstral method can be used to facilitate separation of the structural response characteristics from the shaft speed related forcing functions before application of order tracking. For gears, the modal information can be removed before order tracking, to make the responses much less sensitive to speed change, so that synchronous averaging again becomes valid. For bearings, the opposite separation can be effected, whereby only the modal information is retained, and discrete harmonic components removed, these usually masking the bearing signals. After such removal, the order tracking then allows detection of the bearing fault frequencies in the envelopes of the residual signals.

Assigned Session: B 2 Signal Analysis 1

Presenting Author: Dongxiang Jiang **Ser:** 1

Organization: Tsinghua University

Country: China

Paper Title: **The Fault Simulation Experiment and Feature Extraction of Rolling Bearing Based On Casing Measuring Point**

Co Authors: Te Han, Dongxiang Jiang, and Nanfei Wang

Abstract:

The working environment of aero engine rolling bearing is extremely harsh. With a high speed, the complex stress situation, the high temperature, rolling bearing failure occurs frequently. So it is significant to extract fault feature which judge the state of bearing in time. Normally, the vibration signal is measured from the bearing chock. However, only the limited sensor which placed in aero engine casing can be used. The vibration signal of the fault bearing is attenuated in the process of transmitting to the casing. And there is the noise signal of the whole system in the casing, which has an effect on the signal of the bearing fault. Nowadays, it is still not certain whether bearing fault diagnosis based on engine casing sensor is valid.

According to this problem, fault simulation test bench for rolling bearing of aero engine was built. Rolling bearings with faults were processed by wire cutting technology. The paper makes a study of simulated experiment. Through the fault simulation experiment of rolling bearing, the vibration data of the outer ring fault, inner ring fault and rolling element fault, which respectively comes from bearing base measuring point and casing measuring point, is acquired. Then in this paper, the data is analyzed in the time domain, frequency domain and amplitude domain. The results show that, there are obvious differences between the vibration signals from normal bearing and fault ones based on bearing measuring points. It is easy to distinguish the fault feature by comparison of time domain waveform, amplitude domain parameters. Through the analysis of the frequency domain, the research proved that the envelope demodulation is an effective method in this field. It can precisely extract the fault characteristic frequency of rolling bearing. While analyzing the data from bearing seat measuring points, due to the attenuation of fault pulse-form signal in the transmission way and the increase of noise on the casing, fault feature of vibration signal was significantly weakened. The method cannot extract effective rolling fault feature from the time domain, amplitude domain and frequency domain. But the fault characteristic frequency can be extracted from the appropriate resonance frequency band. So selecting the appropriate resonance frequency to filter and handling with envelope demodulation are useful. The research of this paper provides a reference for the fault feature extraction of rolling bearing fault feature extraction based on the signal of aero engine casing point.

Assigned Session: B 2 Signal Analysis 1

Presenting Author: Adam Jablonski **Ser:** 47

Organization: AGH University of Science and Technology

Country: Polska

Paper Title: **Advances in Gearbox Condition Monitoring**

Co Authors:

Abstract:

Assessment of technical condition of gearboxes constantly calls for clearer messages, quicker notifications, and more precise assessment. A huge number of signal processing techniques as well as diagnostic methods is used for diagnostics of gearboxes; however, some challenges have not been resolved so far. Major obstacles include small speeds and complicated kinematics, especially for epicyclic gearboxes, equivocal symptoms for slow degradation, multiple, distributed daults, and diagnostics under variable operational conditions. The paper presents results of recent experiments and analysis of industrail data with the use of experimental techniques and novel signal processing methods. In addition, the paper presents results of implementation of existing methods to the same data. Finally, the paper illustrates a summary of techniques, norms, and existing guidelines for gearbox monitoring from different perpectives.

The work presented was supported by the National Centre for Research and Development in Poland under the research project no. PBS3/B6/21/2015.

Assigned Session: C 2 Condition Monitoring 1

Presenting Author: Rhea McCaslin **Ser:** 30

Organization: University of South Carolina

Country:

Paper Title: **Investigation of Condition Indicators, Operational Conditions and Gear Health State Using Data Mining Techniques**

Co Authors: Rhea McCaslin, Abdel Bayoumi, and Paula Dempsey

Abstract:

Power train health is a critical part of a rotorcraft health management system since no other air vehicle relies on the propulsion system for propulsion, lift and maneuvering through a transmission with critical single load paths. Many rotorcraft are equipped with Health and Usage Monitoring Systems (HUMS) that monitor vibration signatures, referred to as condition indicators (CI), to detect transmission dynamic mechanical component health and also monitor operating conditions to track component usage.

Many factors can affect a condition indicator's ability to respond to tooth damage through vibration response. The response of the CI to a specific fault can depend on its method of calculation, operational conditions and type of failure mode. The fault type (gear or pinion), mode, class, degree, magnitude, how it initiates and progresses, how it changes the signature response at the mesh and how it interacts with the rig and gear design all affect the measured vibration response. Assessing whether a change in any particular condition indicator was due solely to a change in damage level, a change in operating condition or some combination of both can be a challenge.

The objective of this paper is assess the relationships between gear condition indicator response, operational conditions and gear health state by applying data mining techniques to data collected in the NASA Glenn Spiral Bevel Gear Fatigue Test Rig during initiation and progression of damage to the gear and pinion teeth. Six gear sets, with varying types and amounts of damage, will be used for this analysis. Relationships will be defined and patterns extracted from five gear condition indicators, five pinion condition indicators, operational parameters and a damage factor. The operational parameters include torque, run-time, debris generated and oil temperatures. The damage factor was defined by quantifying the damage state with a continuous value between inspection intervals per visual observation at inspections of gear and pinion teeth. The data mining analysis will step through the process from data reduction, defining the data mining task and technique, building and applying the model and interpreting the results. Results will evaluate of the effectiveness of each CI with respect to operational conditions and fault mode. The influence of operational parameters on the health state will also be evaluated.

Assigned Session: C 2 Condition Monitoring 1

Presenting Author: David Change **Ser:** 8

Organization: Dytran Instruments Inc

Country:

Paper Title: **Introducing CAN-MDTM: A Bus-based, Digital Smart Accelerometer Network for Machinery Health Monitoring & Diagnostics**

Co Authors:

Abstract:

The innovative (patent pending) CAN-MDTM (Controller Area Network – Machinery Diagnostic) platform integrates a bus-based, digital smart accelerometer network with configurable software for machinery health monitoring and diagnostics. In addition to the accelerometers the CAN-MD™ network also accommodates accessories such as Rotor Track Sensor integration and Speed/Azimuth Tachometers. CAN-MD™ reduces installed weight, simplifies wiring runs, and reduces the complexity of the "Vibration Health" portion of Health and Usage Monitoring Systems (HUMS) on rotorcraft. Additionally, this technology platform can be applied to most any rotating machinery including fixed-wing aircraft, industrial off road machinery and petrochemical plant process machines. Bus-based digital sensors eliminate the need for individual cables from each analog sensor to a central box. CAN-MD™ spreads the digital signal processing (DSP) over the entire network. Raw accelerometer, tach and tracker data is processed within each sensor and results are reported over a single wire as Condition Indicators (CI's) via CAN bus. The analysis software on board each sensor is user-configurable so it can be optimized for any rotating machinery application. Looking ahead, CAN-MD™ is ideal for autonomous vehicle monitoring where no operator is present to identify impending mechanical issues that could affect vehicle safety or operation.

Assigned Session: D 2 Digital Thread

Presenting Author: Pam Kobryn **Ser:** 69

Organization: AFRL

Country:

Paper Title: **Digital Thread/Digital Twin: An Emerging Framework for Lifecycle Management**

Co Authors:

Abstract:

The related concepts of Digital Thread and Digital Twin (DT/DTw) have garnered interest from USAF and DoD Engineering and Logistics communities based on their potential to (a) reduce the time and cost associated with all phases of the weapon-system acquisition lifecycle, and (b) improve acquisition outcomes. The Air Force Research Laboratory is engaged in several activities aimed at developing, maturing, and transitioning technologies which address very specific aspects of DT/DTw for application to the acquisition and sustainment of aerospace systems. This presentation will introduce the audience to DT/DTw and provide details regarding certain AFRL efforts to apply DT/DTw to detailed design, manufacturing, and sustainment of airframe structures.

Assigned Session: D 2 Digital Thread

Presenting Author: Harlan Shober **Ser:** 16

Organization: RJ Lee Group Inc

Country:

Paper Title: **Scientific and Engineering Knowledge Mapping – The Basis for Digital Thread**

Co Authors:

Abstract:

From the early maps of Babylon to the current satellite navigation systems, maps have guided the understanding of significantly complex systems. In information systems terms, maps provide ways to easily index and search complex data sets. In the same way that global maps made the earth seem smaller and more navigable, massive search engines like Google or Yahoo have done the same for the sea of disparate data sources and formats of the internet. Today even novice computer users can navigate through the data provided on the information super highway.

If you concur that finding a specific bit of data amongst all of the scientific and engineering data for all parts, all assemblies, and all weapon systems in the DoD is an undertaking every bit as large as finding one point on the globe…

Then it is clear that a data warehouse, a messaging system, or even a service bus is not the right tool to solve the Digital Thread problem set. What is needed is a "Map".

In fact, a series of information maps at various levels of resolution are needed to answer the questions: Does the information exist? Where is it? Can it be retrieved? Can it be trusted? This series of maps is needed because, like the globe, information is divided by many political and organizational borders and boundaries. Organizations should be able to choose what information to syndicate across such borders.

The SEAMS Solution
RJ Lee Group's Scientific and Engineering data Analytics, Management, and Syndication (SEAMS) platform is a "Big Data" platform developed to deliver a whole and unified information map. The SEAMS platform provides the complete toolset for the collection, indexing, searching, analysis, linking, and syndication of multi-media scientific and engineering data. SEAMS helps stitch together information related to events that affect the life, health, quality, and performance of physical assets. The SEAMS platform can index and link to content produced during these events whether directly collected, syndicated from other SEAMS instances, or contained in remote disparate systems. This linked data set is known as an asset's digital footprint or "Digital Thread".

SEAMS Capabilities
SEAMS provides scalable raw data storage and distributed processing power for your data to make it Available, Searchable, Actionable, Intelligible, and Sharable

Benefits
The SEAMS approach clearly provides the following:
•A low barrier to entry both in terms of cost and time for new and existing programs. The SEAMS approach is to collect, index, extract, analyze, link, and evict or store
•A scalable approach that can expand to support new data formats, data sources, and data volumes
•A data aggregation method that can fully utilize existing data systems and data assets
•Shorter information discovery times with a central point of access
•Support for model execution and short feedback loops from product quality and performance to product analysis and design

Applications
Real life Implementation Examples:

•Digital Thread Infrastructure for Material Review Boards
•The Test Data Aggregation System and Analytics System (TDAAS)

Assigned Session: D 2 Digital Thread

Presenting Author: Harlan Shober **Ser:** 57

Organization: RJ Lee Group Inc

Country:

Paper Title: **Creation of a Digital Thread Architecture Using Scientific and Engineering Data Analytics, Management, and Syndication (SEAMS)**

Co Authors:

Abstract:

The world's increasing use of complex and multiple data sets requires ways to easily index and search them. In the same way that global maps made the earth more navigable, massive search engines like Google or Yahoo have done the same for the sea of disparate data sources and formats of the internet. Today, even novice computer users can navigate through data provided on the information super highway.

Finding a specific bit of data among, for example, all of the scientific and engineering data for all parts, all assemblies, and all systems produced by a company was once an undertaking every bit as large as finding one specific place on the world map. Manufacturers, operators and maintainers of parts, components and assemblies, all the way up to an aircraft or ship, now need to quickly navigate a galaxy of data to investigate quality issues, understand unusual failures, and improve the manufacturing process. The creation of a "Digital Thread" addresses these issues by literally making available all data relating to every individual component since its inception, and all the component's higher assemblies, for life.

The paper will describe a Scientific and Engineering data Analytics, Management, and Syndication (SEAMS) platform that provides the complete toolset for the collection, indexing, searching, analysis, linking, and syndication of multi-media scientific and engineering data. SEAMS helps stitch together information related to events that affect the life, health, quality, and performance of physical assets. It indexes and links to content produced during these events whether directly collected, syndicated from other SEAMS instances, or contained in remote disparate systems. This linked data set is known as an asset's digital footprint or "Digital Thread".

The above described architecture has been applied to a Digital Thread Infrastructure (DTI) for Material Review Boards (MRB). The paper will describe how the system will help shorten the MRB process by weeks or months, and reduce the number of MRBs through the application existing engineering studies to new non-conformances. Connecting product design, performance, non-conformances, and maintenance activities together will provide a complete set of modeling inputs to new part design processes, making it possible to build better parts for less cost.

The paper will also describe how the system has been used to develop a Test Data Aggregation System and Analytics System (TDAAS) to support development, tests, and evaluations in complex environments such as wind tunnels and engine test cells. With a primary focus of improved engineering knowledge management, it is capable of aggregating more than a Petabyte of test data from more than 30 years analysis on aircraft aerodynamics and engine performance.

As with other DTI solutions, the mapping and linking of this disparate data shortens the information feedback loop from performance back to design and will lead to better performing and more cost effective manufactured systems.

Assigned Session: E 2 Additive Manufacturing 2

Presenting Author: Jonathan Miller **Ser:** 91

Organization: US Air Force Research Laboratory

Country:

Paper Title: **Quality Assurance Methods for Additive Manufacturing Processes: Motivation, Challenges and Opportunities**

Co Authors:

Abstract:

There has been significant work to date in the metal powder bed fusion community focused on understanding the influence of global processing parameters on microstructure and defect content (e.g. beam speed, power, spot size). However, a range of other implicit details are important, though they are not necessarily simply described. The present work focuses on the development of a novel technique to assess the impact of the energy input process details on material quality. This requires transformation of both in-situ process monitoring data and build-intent information into a voxelized representation, subsequent fusion with post build x-ray CT measurements, and analysis to identify correlations between processing details and structure. An example case generated in laser powder bed fusion of Ti-6Al-4V demonstrates this process by identifying correlations between location specific processing details and porosity.

Assigned Session: E 2 Additive Manufacturing 2

Presenting Author: Dan Berrigan **Ser:** 92

Organization: US Air Force Research Laboratory

Country:

Paper Title: **Air Force Vision and Challenges for Additive Manufacturing of Functional and Soft Matter Materials**

Co Authors:

Abstract:

Assigned Session: E 2 Additive Manufacturing 2

Presenting Author: Ricardo Rodriguez **Ser:** 78

Organization: US Army Research Laboratory

Country:

Paper Title: **ARL's Additive Manufacturing for the Future Expeditionary Force**

Co Authors:

Abstract:

One major Army focus is in converting our traditional force into a more expeditionary force. This will result in severe reductions in the logistics tail, but will require Army forces to become more adaptive. Units, equipment, and personnel will need to be configurable and re-configurable based on mission parameters. In order to accomplish this, the Army will be conducting more in-field, or point-of-need, manufacturing than ever before. Other areas of concentration include: man-machine interface, capabilities organic to the Warfighter, unmanned systems, networks and robotics. Many of the materials and technologies needed to accomplish these goals are still experimental, if they exist at all. This presentation will cover the Army Research Laboratories Additive Manufacturing activities, and will discuss several research topics that will allow for the success of this future expeditionary force.

Assigned Session: A 3 Failure Prevention

Presenting Author: Alan Oquendo **Ser:** 82

Organization: US Air Force Research Laboratory

Country:

Paper Title: **Confirmation of 17-4 Stainless Precipitation Heat Treatment**

Co Authors:

Abstract:

Improper heat treatment of aircraft structural material was suspected, based on initial hardness and tensile testing. Per MIL STD 1568, precipitation hardenable steels are prohibited when aged at temperatures lower than 1000 °F. If the material was in the H925 condition, it would show unacceptably low resistance to stress corrosion cracking. Replacement of the affected structure on 60 affected aircraft would have been expensive and time consuming. System engineers requested AFRL support to assess the heat treatment condition.

AFRL developed a method to discriminate between the two suspected conditions: H925 and H1025. The assessment was complicated by the fact that the expected properties of the two conditions overlap. The approach involved comparing the response of the submitted material to that of material subjected to known temperature exposures. AFRL showed with high confidence the material had been heat treated correctly, and the material could remain in service and be expected to meet service requirements.

Assigned Session: A 3 Failure Prevention

Presenting Author: Justin Mason **Ser:** 56

Organization: US Air Force Research Laboratory

Country:

Paper Title: **Spall Propagation Characteristics of Refurbished AISI VIM-VAR M50 Bearings**

Co Authors:

Abstract:

During times of restricted supply, refurbishing bearings offers an avenue to maintain operational readiness. However, bearing operation after spall initiation on refurbished bearings has never been assessed. Spall propagation characteristics were compared between new and refurbished M50 bearings. A group of new M50 bearings with M50 rolling elements were evaluated for spall propagation characteristics as a baseline. Another group of M50 bearings accumulated 11.5 billion stress cycles at maximum Hertzian stress of 1.93 GPa and at a temperature of 127 0C before Level II refurbishment. The refurbished bearings were evaluated for spall propagation characteristics and compared to the baseline bearings. Spalls were initiated and propagated at a maximum Hertzian stress of 2.65 GPa and 2.41 GPa respectively. The propagation rates of the bearings were measured using an Oil Debris Monitor (ODM). Posttest bearings were examined for changes in microstructure, micro hardness, residual stress and retained austenite as a function of depth in the circumferential direction.

Assigned Session: A 3 Failure Prevention

Presenting Author: Mantosh Bhattacharya **Ser:** 38

Organization: Petrofac

Country: United Arab Emirates

Paper Title: **Start-Up Issue with Centrifugal Compressors After Short Shutdown and Mitigation to Enhance Reliability and Availability**

Co Authors: Mantosh Bhattacharya

Abstract:

It has been observed that a phenomena known as "Temporary Rotor Bow " sometimes occurs with centrifugal compressor during start up after a short shutdown. The phenomena is similar to rotor bow which occurs in large steam turbines.The occurrence of this phenomena depends on certain operating conditions and loop configuration of centrifugal compressor. The temporary rotor bow may cause rotor –stator rubs due to vibration at high amplitude during restart of compressor in hot condition.

Under low load / lower speed test conditions during API 617 mechanical run test / ASME PTC- 10 type 2 test, it is difficult to apprehend the possible sensitivity to temporary rotor bow. This issue generally crops up only at actual operating condition and actual equipment loop layout.

One of the objective of this paper is to provide a method to assess sensitivity to rotor bow during test at manufacturer's test bed.

The problem of "Temporary Rotor Bow " is tackled by slow rolling the compressor during pressurized restart which is quite similar in principle to what is done with large steam turbines.

Experiences have showed that the solution to slow roll the compressor with a gas turbine driven centrifugal compressor is feasible but not with some industrial gas turbines and large Electric Motor driven centrifugal compressor having similar configuration.

This paper endeavors to meet the second objective , i.e. proposing three plausible solutions to tackle this issue for a large electric motor driven centrifugal compressor . These solutions are based on a) Stribeck curve for hydrodynamic lubrication, b)using vibration trip multiplier and c) comparative study of various bearing arrangements for centrifugal compressor to lower down vibration amplitude of flexible rotor at 1st bending mode during start up.

The risks involved in above three proposed solutions are also identified and actions to mitigate those risks are listed.

Assigned Session: B 3 Sensors 2

Presenting Author: Michael Lipsett **Ser:** 32

Organization: University of Alberta

Country: Canada

Paper Title: **Reliability of Rail Sensing Systems**

Co Authors: Michael Lipsett, Azadeh Shadkar, and Michael Hendry

Abstract:

Condition monitoring of rail cars is done through physical inspection and measurements by fixed wayside detectors. These remote detectors are prone to different failure modes, depending on the geographic location. The reliability of measurements from detectors has been evaluated using time-to-failure data from operations and maintenance databases for a major North American railroad. The five-year dataset was assumed to be complete, such that the failure times of each of the detectors are known. Depending on the quantity and type of the failure data, the analysis method for modeling the reliability and estimating the parameters will change. The number and type of the failure data affects selecting the method for modeling the reliability and estimating the parameters. Maximum Likelihood Estimation (MLE) was the primary analysis method, with Rank Regression being used when the sample size was small. From the maintenance point of view, the impact of a detector failure is downtime as well as the potential error of a detector missing a rail car fault. The date and time of the failures of the 44 detectors in the corridor of study along with the outage time mentioned in the file for the failed systems, were considered as an indicator of failure of the detection system. To model the reliability, the time the systems were operating before the failure occurred is determined from time a detector was put in service to the time it was logged as being in a failure mode. A set of failure distributions was found for different detector failure modes and geographical locations. Mountain failure modes were more seasonally dependent, with cold-weather related failures dominating. Implications are discussed for design modifications to improve overall sensor system reliability.

Assigned Session: B 3 Sensors 2

Presenting Author: Ed Spence **Ser:** 51

Organization: Analog Devices, Inc

Country:

Paper Title: **MEMS Comes of Age - Review of a New Broadband 20kHz MEMS Accelerometer for Vibration Measurements**

Co Authors: Ed Spence and Juan Chong

Abstract:

Condition Monitoring for much of Balance-of-Plant is route based, if at all, due to the high cost of implementation and equipment on continuous monitoring systems. Low cost MEMS-based solutions such as autonomous smart sensors, including wireless and other networked systems have been offered to the market for the last 5 years, expanding into new applications, and new concepts, including wireless sensors, continue to come to market. MEMS based Condition Monitoring systems have reduced the cost per node from $1000's to $100's. MEMS based sensors, with integrated signal conditioning, also offers the capability to integrate various industrial interface options, simplifying system implementation and enabling the development of a new generation of smart sensors.

Although several attributes of MEMS technology- such as size, weight, power, cost and high levels of functionality within the integrated signal conditioning are already compelling, market penetration has been hampered by relatively low levels of performance in terms of noise density and resonant frequencies. High frequency MEMS sensors have been on the market for years, offering resonant frequencies as high as 22kHz and Full Scale Ranges up to ±250g- but with high noise levels. On the other hand, available low noise MEMS sensors have low resonant frequency operation, serving some Condition Monitoring applications where very low frequency operation is of value, but with limited utility for diagnostic evaluation.

Investment in MEMS process technology has progressed to the point where the deficiencies in MEMS performance have been greatly improved, enough to make MEMS a viable option for a wider range of Condition Monitoring applications. Sensors with resonant frequencies to 22kHz and beyond, with noise densities down to 25µg/Hz and below are now possible with Surface Capacitive MEMS structures. Careful design of signal condition electronics fully exploits the low Brownian motion noise of today's sensors. This paper will present data demonstrating the state of MEMS technology development and performance levels, with comparison to low cost Condition Monitoring sensors currently in the market.

Assigned Session: B 3 Sensors 2

Presenting Author: Chris Nemarich **Ser:** 73

Organization: Naval Sea Systems Command

Country:

Paper Title: **Optical Torque Sensor for Adaptive Engine Control and Machinery Failure Prevention**

Co Authors: Christopher Nemarich, Laurence Wesson and Simon Bush, Fred Discenzo, and Leanne Riedthaler

Abstract:

A novel, non-contact optical torque sensor is being adapted for the measurement of torsional load on a U.S. Naval vessel's propulsion diesel engines. The sensor employs birefringence from optical material under torsional strain, low cost materials and pattern recognition software for accurate high speed, dynamic torque sensing. The sensor's compact size, low cost, noise immunity, high bandwidth, high sample rate with no need for rotary coupling make it ideally suited to the short length, small diameter propulsion shaft on the ship's diesel engines. The sensor is intended for real-time feedback and control of the four main engines which are paired to drive a port and a starboard reduction gear and controllable pitch propeller. A production prototype of the optical torque sensor underwent dynamometer load testing in a laboratory to optimize the optics and neural network algorithms. The sensor will be installed shipboard for test and evaluation against a strain gage type torque sensor and to tune the sensor over the propulsion engines' full operating range. The production prototype design will then be finalized and optical non-contact torque sensors will be installed on each propulsion engine and integrated with the ship's engine controller. The current program is to use the optical torque sensor signal for for engine load balance control. However, the high bandwidth torque measurements provided will enable assessing the engine operating condition and the health of the reduction gearbox and other rotating elements in the powertrain.

This paper will describe the design of the optical torque sensor to meet the demanding requirements of marine engine torque sensing, Performance results from optical torque sensor testing will be presented as well as a description of how real-time torque information will be integrated with ship propulsion engine control. Other operational and economic opportunities enabled by this novel technology will be presented including optimal control for fuel economy, engine and drive line fault diagnostics and prognostics.

Assigned Session: C 3 Prognostics

Presenting Author: Jacob Bortman **Ser:** 10

Organization: Ben-Gurion University of the Negev

Country: Israel

Paper Title: **Bearing Health Monitoring Using Optical Fiber Sensors**

Co Authors:

Abstract:

Bearings are vital elements in rotating machinery. Failures in bearings can result in irreversible damage. Therefore, early detection of bearing damage and monitoring of fault severity are necessary for optimization of maintenance decisions.
The classical methods for bearing monitoring are based on analysis of vibration signals captured by accelerometers usually located on the machine case. Two difficulties arise when diagnosing bearings in that manner. The first difficulty is the distortion of the signals due to transmission path to the sensor. The second difficulty is the low signal to noise ratio characterizing the bearing weak signals in the presence of the accompanying strong surrounding noise, originating from the vibrations of other rotating components in the machine.

The goal of the presented work was to study the possibility of using an optical fiber sensor, Fiber Bragg Grating (FBG) sensor that sense strain and temperature changes, for bearing diagnostics. Due to its small dimensions, this sensor can be embedded into the system, close to, or even inside the bearing, therefore presenting a possible solution to the two difficulties which were discussed above.

The results of this study open new options to monitor and detect early failure signs in critical bearings. Clearly, FBG-based diagnostics was found applicable and useful for detecting damage in bearings.

The analysis of signals measured on bearings with various widths of spall demonstrates the power of the FBG-based local sensing methodology. The results show clear detection of early defects, confirming our assumptions that the effects of the transmission path are significantly reduced and the signal to noise ratio is improved.

Assigned Session: C 3 Prognostics

Presenting Author: Anna Mazzolini **Ser:** 6

Organization: University of Tennessee

Country:

Paper Title: **Investigation of Prognostics and Health Monitoring for Bearings under Overload Conditions**

Co Authors: Anna Mazzolini, Cody Walker, and Jamie Coble

Abstract:

Rolling ball bearings are essential in the function of rotating machinery. Taking advantage of prognostics and health management techniques in the maintenance scheme of bearings can translate to increased safety, increased efficiency, and decreased costs of repairs of a system. We aim to expand on the capabilities of current bearing diagnostic and prognostic techniques, which typically rely on vibration data alone, by introducing data from multiple other sensors in our analysis. Our accelerated degradation test bed will fail ¾" open steel rolling ball bearings through 30% overload in the radial direction. We will collect failure data for multiple loading schemes using various sensors measuring temperature, shaft rotation speed, vibration, sound pressure, motor current, and external radial load. After a bearing has failed, we will determine the failure mode through post-mortem analysis of the bearing, looking for discoloration, brinelling, fatigue area, etc. We can then analyze the data to conclude whether the bearing showed signs of early faults or changes in performance. We hope to find relationships among the signals that will allow us to create a more sophisticated algorithm for detecting bearing degradation, predicting bearing failure, and calculating remaining useful life.

Assigned Session: C 3 Prognostics

Presenting Author: George Zusman **Ser:** 13

Organization: Vibration Measurement Solutions, Inc.

Country:

Paper Title: **Resonance Method of Rolling/Ball Bearings Condition Monitoring and Single Sensor for Measurements of Vibration, Bearing Health and Temperature**

Co Authors: George Zusman

Abstract:

This paper compares the different methods of rolling/ball bearings condition monitoring and describes a resonance method and universal single sensor allows measuring vibration in a range of 2 Hz to 20 kHz, bearing health based on shock pulse (resonance) method and temperature in a range of -40 C to +120 C. The sensor design based on flex piezoelectric technology and has integrated electronics. The connection with DIN rail transmitter is realized by current line drive which provided low sensitivity to electrical hazards and possible long cable length without signal loss at high frequencies. Some technical parameters and field application results are presented.

Assigned Session: D 3 Human Monitoring 1

Presenting Author: James Christensen **Ser:** 81

Organization: AFMC 711/HPW/RHC

Country:

Paper Title: **Airman Sensing and Assessment as a Component of System Health**

Co Authors:

Abstract:

This presentation will provide an overview of current work and strategy for research and development in the Human Effectiveness Directorate, AFRL. Recognizing that human operators are, and will remain, a key component of Air Force technical systems, research activities are addressing key challenges necessary for an effective automated human assessment capability that enables closer human-machine teaming and improves overall system performance. This presentation will address the drivers, challenges, and desired future capabilities in the human assessment sphere.

Assigned Session: D 3 Human Monitoring 1

Presenting Author: Nanshu Lu **Ser:** 84

Organization: University of Texas at Austin

Country:

Paper Title: **Epidermal Electronics for Sensing and Therapy**

Co Authors:

Abstract:

Epidermal sensor is a class of skin-mounted, tattoo-like circuits and sensors capable of continuous vital sign monitoring, human-machine interface, as well as transdermal therapies. Their mechanical properties such as thickness, softness, and mass density are well matched with human epidermis and are therefore able to form the most intimate contact with human skin and can provide unprecedented signal fidelity and comfort. Their demonstrated functions include long-term, continuous measurement of electroencephalogram (EEG), electrocardiogram (ECG), electromyogram (EMG), skin temperature, skin hydration, respiratory rate, blood pressure, as well as sweat (e.g. glucose and lactate). They can also be applied for therapeutics including thermal treatment and transdermal drug delivery. However, the widespread use of disposable epidermal sensors hinges on the low cost and high throughput manufacture. We therefore invented a cost and time effective, completely dry, benchtop “cut-and-paste” method for the green, freeform, and portable manufacture of multiparametric epidermal sensor systems.

Assigned Session: D 3 Human Monitoring 1

Presenting Author: Kevin Durkee **Ser:** 85

Organization: Aptima, Inc

Country:

Paper Title: **Machine Learning of Neurophysiological Signals for Real-time Human Workload Monitoring**

Co Authors:

Abstract:

The cognitive health and physical functioning of human operators is a key element of total system performance. Despite being a vital cog in many complex systems – ranging across airspace operations, manufacturing plants, and healthcare, to name a few – the cognitive and physical functional states of human performers are sparsely monitored in real-world work environments. The recent emergence of wearable physiological sensors that are increasingly affordable, ubiquitous, and less obtrusive is rapidly bringing a real-time human functional state monitoring capability closer to reality. However, a key limitation that must be overcome is the translation of noisy physiological signals into robust and reliable indicators of a human's cognitive and physical state. In this work, we have formulated and applied a novel, theory-driven machine learning based approach in which computational model weights are trained from a set of human neurophysiological signal inputs to classify workload in real-time. Resulting workload classifier models are executed by ingesting and processing corresponding neurophysiological signals from human wearable sensors through a set of trained weights running within our Functional State Estimation Engine (FuSE2) technology. The outputs of this technology are real-time human workload classifications that can be used by a teammate or automated system to proactively, and objectively, provide interventions that improve total system performance while mitigating errors.

Assigned Session: A 4 Signal Analysis 2

Presenting Author: Nanfei Wang **Ser:** 4

Organization: Tsinghua University

Country: China

Paper Title: **Diagnosis Method for Rub-Impact Fault of Rotating Machinery Based on EMD and Hilbert Envelop Spectrum**

Co Authors: Nan-fei Wang, Dong-xiang Jiang, and Te Han

Abstract:

Bearing pedestal looseness fault is one of the most common non-linear looseness phenomena, which will causes malfunctions in rotating system. However, as for many rotating machinery, such as gas turbine and aero-engine, only vibration acceleration on casing can be measured, it is relatively difficult to obtain the vibration displacement. Hence, it is very important and essential to study the characteristics and laws of casing vibration acceleration signals for effectively identifying the looseness fault. For this purpose, a model test rig of rotor-bearing system is established to illustrate the looseness fault in the paper. By loosing tap bolts at one side of bearing pedestal to reduce the elastic stiffness of supporting structure, the pedestal looseness fault existing in rotating system is simulated. The complicated acceleration vibration signals with pedestal looseness fault collected from the casing of rotating system are decomposed into finite number of intrinsic mode functions (IMFS) by using empirical mode decomposition (EMD). Through the significance test, the information-contained IMFs are selected to form the neat time-frequency Hilbert spectrum and the corresponding marginal Hilbert spectra. Moreover, shock features of asymmetric stiffness model to casing acceleration signal are studied; detecting that looseness will lead to asymmetrical features of acceleration time domain wave and multiple frequency features of frequency spectrum, which is consistent with the data from test rig. The results clearly show that the intermittent impact and friction signals are generated irregularly when looseness occurs. Vibration fault is caused by improper support stiffness, which results in looseness fault near the critical speed. The proposed diagnosis approach is capable of categorizing the distinction among the marginal Hilbert spectra distributions and thus identify the type of looseness fault in rotating machinery.

Assigned Session: A 4 Signal Analysis 2

Presenting Author: Suri Ganeriwala **Ser:** 71

Organization: SpectraQuest Inc

Country:

Paper Title: **Using Interference of Variable Frequency Drives for Rotating Machine Fault Diagnosis**

Co Authors: Suri Ganeriwala and Nader Sawalhi

Abstract:

VFDs are the most commonly used modes to drive induction motors in applications requiring speed variations. However, vibration analysis for fault diagnosis of such systems poses serious challenges as the signatures are complicated due to the inherent design of the VFD. This paper will explain the basic operation of a typical VFD and present vibration signatures of machines operated using VFDs. The switching frequency, or carrier frequency, of a VFD interferes with vibration or motor current signals. The vibration signal as a result of using the VFD contains discrete frequencies spaced at the carrier frequency and its harmonics. Each peak also contains sidebands around the carrier frequency (and its harmonics) spaced at both the rotor speed and the VFD frequency. There can be side bands associated with other rotational discrete frequencies such as gears and gearmesh frequencies. Analysts examining high frequency content of their data signals needs to be aware of the carrier frequencies and the side bands of their VFD. By understanding these issues one use them for diagnostics purposes.

Assigned Session: A 4 Signal Analysis 2

Presenting Author: Xiaobo Chen **Ser:** 45

Organization: School of Reliability and System Engineering Beihang University

Country: China

Paper Title: **Fatigue Life Prediction of Centrifugal Pump Impeller Based on Virtual Simulation**

Co Authors: Xiaobo Chen, Zhiqiang Li, and Junyi Wu

Abstract:

Centrifugal pump has played an important role in the industrial and agricultural production. Its reliability and total life are getting more and more attention. The impeller is one of the important flow passage components in centrifugal pump, which affects the working performance of a pump directly. When working in the flow media, the surfaces of the impeller blade are suffering not only the centrifugal force produced by its rotation, but also impact from fluid under high speed condition. So its stress distribution is complicated.

In this paper, ANSYS Workbench platform was used to obtain the stress distribution under multi-physical field coupling. At first, by using CFD fluent module, we got pressure and temperature distribution at the fluid domain of the impeller. And through the one-way fluid-solid coupling, fluid simulation results were imported into the steady-state thermal and the static structural analysis module to get the working stress of the impeller. And then we analyzed the pre-stressed mode and random vibration. Finally, by use of the impeller stress distribution under multi-physics coupling and nominal stress method, impeller fatigue life was obtained.

This study not only provides a fast and effective method for the prediction of a centrifugal pump Impeller fatigue life under various load, but also the basis for the subsequent determination of the first repair time and total life of the product.

Assigned Session: B 4 Condition Monitoring 2

Presenting Author: John Reintjes **Ser:** 7

Organization: Sotera Defense Solutions

Country:

Paper Title: On Line Condition Monitoring for Subsea Applications

Co Authors: Sølve Fjerdingstad, John Reintjes, and John Tucker

Abstract:

DynaView is an online condition monitoring system for lubrication and hydraulic systems. DynaView contains the DynaSamp on line fluid sampler that provides accurate sampling of particulates and a LaserNet Fines optical particle analyzer that measures particulate contamination levels and detects mechanical faults through measurements of the size and shape characteristics of particles transported by streaming fluids in hydraulic and lubrication oils. The DynaView system provides online, continuous monitoring and is capable of providing early warning months before a breakdown takes place. We are developing a version of the DynaView system suitable for real time monitoring of the condition of machinery and cleanliness levels of hydraulic control systems in subsea installations at the Ormen Lange gas field located 120 km off the west coast of Norway. In this configuration, the DynaView will communicate through an umbilical connected to a shore-based control room.

The subsea DynaView system development is part of the Demo2000 project, which is financed by the Research Council of Norway, and the oil companies Shell Technology, Statoil and ENI. The project is designed to improve the retrieval efficiency of oil and gas from offshore installations by locating equipment on the sea floor and pumping the oil and gas directly back to shore. It will establish a subsea factory for oil production, avoiding expensive platform installations for offshore oil production. Because of the length of fluid lines from the shore facility to the gas field equipment, contamination of a subsea hydraulic system would take 50 years to be detectable at the shore end of the oil control line. Additionally, the subsea equipment can only be replaced during the summertime when the weather is good. Thus monitoring systems at the equipment location is critical to avoid expensive maintenance costs and production losses.

Prior to subsea installation, the DynaView system is being extensively tested at Shell Oil's shore side test facility on the Island of Aukra, Norway. The shore test facility is much less expensive to operate, and is more available than running subsea tests.

The subsea DynaView system has been tested to 670 bar, and is currently installed on a 420 bar hydraulic control line for equipment at the Ormen-Lange field. When the DynaView is installed subsea, it will be mounted into a pressure balanced container, which can be brought down to the subsea machines to be monitored by a remotely operated vehicle and can be installed at sea depths down to 3000 meters.

We will describe the design and operation of the DynaView system and present representative data obtained from the onshore installation tests.

Assigned Session: B 4 Condition Monitoring 2

Presenting Author: James Hofmeister **Ser:** 41

Organization: Ridgetop Group

Country:

Paper Title: **Advanced Anomaly Detection Method for Condition Monitoring of Complex Equipment and Systems**

Co Authors: James Hofmeister, Douglas Goodman, and Robert Wagoner

Abstract:

For advanced diagnostic and prognostic systems supporting complex electronic and electro-mechanical systems, the key is to rapidly detect anomalies as they occur, and link the detected event to state estimators to provide accurate state of health (SoH) and remaining useful life (RUL) of the monitored equipment or system. This information, in turn, supports condition-based maintenance. (CBM).

This paper will focus on the front-end of the equipment monitoring system, where a library of detection algorithms have been developed to support advanced diagnostics. These detection algorithms can be embedded to provide degradation detection on the monitored data streams. For implementation, the library is incorporated into an easy-to-use soft-fault development platform to enable their application as an embedded component. The embedded component can be wirelessly linked to the internet for remote monitoring from distant locations.

The complete condition monitoring system for board, module or system level can be implemented with linkages to a fault dictionary to aid in the servicing of the equipment for maximum uptime. Application of the algorithms on two different electronic modules will be presented, including analog and digital applications.

Assigned Session: B 4 Condition Monitoring 2

Presenting Author: David Siegel **Ser:** 76

Organization: Predictronics Corp

Country:

Paper Title: **A Peer-Based Health Monitoring Approach for Rolling Element Bearings – A Steel Manufacturing Case Study**

Co Authors: David Siegel, Shanhu Yang, and Edzel Lapira

Abstract:

Rolling element bearings are one of the most widely studied components in condition monitoring, with a wealth of established monitoring approaches and a general understanding of the fault signature patterns for different failure modes. Perhaps the most common approach is based on accelerometer measurements, envelope analysis, and comparing the vibration characteristics to a baseline condition. This particular study deals with a slightly different scenario, in which there are over 300 rolling element bearings that are to be monitored in a steel manufacturing facility without any reference baseline measurement and in which only acoustic sound measurements can be made. The proposed approach combines well understand signal processing and feature extraction methods (envelope analysis, cepstrum, frequency band analysis) with a peer-to-peer distribution based health monitoring approach. A scoring method based on comparing the cumulative feature distributions for bearings !
that are in neighbor locations was able to correctly identify the known faulty bearings and also to recommend a short list of other bearings to be inspected. This peer-based health monitoring approach showed promise in this study and a software program that includes various visualization options and analysis options was provided to the steel manufacturer so they could continue with this monitoring approach. Despite the success of this study, there is still a considerable amount of future work that could be conducted for baseline/reference free bearing health monitoring approaches.

Assigned Session: C 4 Diagnostics and Prognostics

Presenting Author: Renata Klein **Ser:** 62

Organization: R.K. Diagnostics

Country: Israel

Paper Title: **Cyber Defense of Rotating Machinery using an Integrated 'Fuse' Bearing**

Co Authors:

Abstract:

A new concept is proposed for protection against cyber-attacks aiming to create irreversible mechanical damage to critical rotating machines. This novel approach is used as an additional defense layer of cyber protection to prevent hostile entities from breaking into the control system of the critical machines.

The proposed approach integrates a 'fuse' mechanism into the critical rotating machine. It is expected that under attack or abuse, the fuse mechanism (the 'weakest' component in a machine) will be damaged first, ahead of the other critical components of the machine. In this case, the mechanism's fast degradation and early failure will lead to early detection of attack and finally to prevention of a catastrophic damage to a critical machine. A relatively small bearing is used as the weak link, or the fuse, in the critical system. This mechanism allows rapid life degradation under harmful regimes. The detection process is based on techniques of machine health monitoring via vibrations signatures. Advanced signal processing and feature extraction methodologies are applied for initial fault detection and life degradation tracking.

An analytical model was developed, allowing to design the fuse system. The model examines the response of the fuse bearing, through its life degradation rate, by simulating a wide range of attack scenarios. Life prediction and degradation simulations of the fuse bearing and the machine critical bearings at each attack scenario were performed, in order to define the proper requirements for a relevant effective fuse system. The model includes several sub models: models for bearing life estimation and a model for the dynamic response of a mechanical rotating machine.

Endurance experiments were conducted on a fuse bearing in the test facility that was designed for this research. The endurance tests helped to examine our fault detection abilities, and to define reliable condition indicators for early damage detection and for fault propagation tracking.

Assigned Session: C 4 Diagnostics and Prognostics

Presenting Author: Eric Bechhoefer **Ser:** 79

Organization: Green Power Monitoring Systems LLC

Country:

Paper Title: **A Planet Bearing Fault Case Study**

Co Authors: Eric Bechhoefer

Abstract:

Fault detection in planet bearings is difficult. This is particularly true in wind turbines, where the main rotor shaft is under 20 rpm. This papers analyzes a missed fault on a wind turbine planet bearing, and discuses how changes in the analysis configuration then allowed this type of fault to be detected. From raw data from ten machines, a strategy for fault feature identification was developed, which allowed meaningfully appropriate thresholds to be set.

Assigned Session: C 4 Diagnostics and Prognostics

Presenting Author: Jeffrey Arbogast **Ser:** 21

Organization: American Air Liquide

Country:

Paper Title: **Application of the Rolling Pin Method to Detect Anomalies and Fault**

Co Authors:

Abstract:

Since 2011, Air Liquide R&D has collaborated with researchers at the University of Pennsylvania and Drexel University in the area of abnormal situation management. This collaboration aims to develop techniques to provide real-time prediction (leading indicators) and diagnostics (e.g., root cause analysis and fault detection) of abnormal events in industrial process plants. These two concepts can be combined in a complimentary way to identify abnormal situations as they arise, communicate their likelihood and the lead time before consequences become inevitable, and identify the most likely cause so that an operator has actionable (e.g., valid, timely, non-redundant) information necessary to take effective corrective action.

This paper will provide an industrial perspective on a key element of this industry/university collaborative research – reviewing the novel research that has been published in scientific journals with a vision toward industrial application. This research will be discussed in the context of the scientific literature and existing industrial practices.

This research includes new techniques to estimate the probability of rarely occurring events from historical data – even when there is no recorded history of a particular condition. The estimated probabilities of rare events have been applied to Bayesian network models for application in fault detection and online root cause detection. This allows the Bayesian network to consider the probability that an event could occur even if it has not occurred in the past.

However, Bayesian network modeling has several limitations and challenges – including its requirement that continuous variables (e.g., process measurements) be divided into several discrete states, which causes information to be lost in the approximation and increases the computational burden as the number of states increases. This paper reviews and explains the rolling pin method, a novel and efficient alternative to Bayesian network modeling and inference that directly treats continuous variables without requiring such discretization.

In addition to its computational efficiency and greater accuracy, the novel rolling pin method does not require knowledge of the causal relationships among the variables studied. Generally for process applications, the causal structure of a Bayesian network is defined based upon process knowledge. In contrast, such process knowledge is not necessary to apply the rolling pin method, but it can be helpful in evaluating its results. Therefore, the rolling pin method avoids inaccuracies caused by incomplete or incorrect understanding of causal relationships between variables.

The rolling pin method applies standard parametric copulas to model joint probabilities. Copulas facilitate the decomposition of a joint probability distribution into univariate marginal distributions of each individual variable with the structure of relationships between the variables described by the copula. However, standard parametric copulas require monotonic relationships between variables. The key to the rolling pin method is a set of monotonization transformations that 'roll out' the relationships.

Through industrially relevant examples, this paper demonstrates the application of the rolling pin method for anomaly

Assigned Session: D 4 Human Monitoring 2

Presenting Author: Sharon Bommer **Ser:** 86

Organization: Wright State University

Country:

Paper Title: **Cognitve Ergonomics for Manufacturing Processes**

Co Authors:

Abstract:

Assigned Session: D 4 Human Monitoring 2

Presenting Author: Dragan Djurdjanovic **Ser:** 87

Organization: University of Texas at Austin

Country:

Paper Title: **A System-Based Approach to Monitoring the Performance of Human Neuromusculoskeletral Systems**

Co Authors:

Abstract:

This talk will begin with an overview of the research conducted in the University of Texas site of the Industry-University Cooperative Research Center (I-UCRC) on Intelligent Maintenance Systems. Then, the talk will focus on presenting a novel, system-based methodology for monitoring fatiguing and resting in a human neuromusculoskeletal (NMS) system. It is based on dynamic models that link surface electromyographic signals and joint kinematic or force variables in order to track changes in system dynamics, as well as to assess joint level and muscle level contributions to those changes. The methodology is demonstrated on several data sets. One data set consists of EMG and limb movement signals recorded from 12 human subjects completing a repetitive sawing motion until voluntary exhaustion. Statistically significant changes were noted with for all subjects, with fittest subjects displaying the least amount of degradation. Results seem to clearly indicate that the model based approach successfully tracks subjects' fatiguing. Another dataset consists of one subject maintaining leg force until voluntary exhaustion, after which this subject's performance was tracked during the resting period, illustrating tremendously consistent recovery after the subject rested. Finally, relevant muscle EMGs and jaw velocity were concurrently collected from one subject as the subject kept its mouth fully open until voluntary exhaustion. The same data were collected again after the subject rested, once again showing remarkable resemblance of the recovered model to the model initially built on the initial, fresh data set.

Assigned Session: D 4 Human Monitoring 2

Presenting Author: Lloyd Tripp **Ser:** 88

Organization: 711 Human Performance Wing

Country:

Paper Title: **In-Flight Physiological Monitoring: The 5th Generation Fighters and Beyond**

Co Authors:

Abstract:

Assigned Session: E 4 Mechanical Seal Issues and Diagnostics

Presenting Author: Bill Marscher **Ser:** 74

Organization: Mechanical Solutions Inc

Country:

Paper Title: **Mechanical Seal Behavior and Diagnostics**

Co Authors:

Abstract:

Assigned Session: E 4 Mechanical Seal Issues and Diagnostics

Presenting Author: Robert Miller **Ser:** 75

Organization: John Crane

Country:

Paper Title: **Predictive Diagnostics for Pump Seals: Alpha Trial Learnings**

Co Authors:

Abstract:

Traditional condition monitoring approaches provide valuable data that can be used in diagnosing existing conditions before a critical failure occurs. However, these systems rely on an available expert to analyze the data in a timely fashion. Additionally, these systems typically capture data infrequently and therefore often miss the impact of transient events.

Predictive diagnostics aims to go beyond raw data to provide end users with actionable intelligence, identifying incipient failure modes and recommending corrective actions designed to prolong time between critical failures. Continuous monitoring also provides valuable data to diagnose failures that result from transient events such as process upsets or operator errors.

This presentation outlines an approach to applying predictive diagnostics to a mechanical sealing system, along with a case study of a successful application. A predictive diagnostics methodology is presented, along with a system architecture as implemented in the field.

Interim results from a field trial are discussed, along with recommendations for next steps.

Assigned Session: A 5 End User Applications 3

Presenting Author: Michael Lipsett **Ser:** 33

Organization: University of Alberta

Country: Canada

Paper Title: **Condition Monitoring of Rail Car Air Brake Systems Using Ultrasound**

Co Authors: Michael Lipsett, Cynthia Ying, and Michael Hendry

Abstract:

Airbrake reliability during the winter has been an on-going concern for railway operators in North America. Methods to detect air leaks still rely heavily on manual inspection. A noncontact automatic leak detection method may increase airbrake reliability, and save costs associated with prorogated inspection time and delay in schedules. Ultrasound Leakage Detection (ULD) was initially investigated as an alternative to visual inspection and manual testing, with positive results for field trials in a rail yard of a major railway and for bench-scale experiments under idealized cold-room conditions. Simulated leaks using shop air pressure (in the range from 60 to 95 psi) with five different leaking components yielded 100% accurate leak identification and pinpointed faulty components with the initial location of the ULD device being 5 m away and 0° off-axis to the leaks. In laboratory leak classification tests, noises from various leaking components were recorded using the ULD device and digitally processed. Seven parameters in the time and frequency domain were compared among different faulty components. Leak type identification efforts showed no single parameter could unambiguously identify the leak type in the frequency range of heterodyned ultrasound. Distinct trends of Power Spectral Density (PSD) distributions in the entire frequency domain were observed in road noises and distant train noises. Noises from active trains on nearby tracks have large variations, but some noises from sources such as hand brake chains or end-of-train device turbines have unique patterns of PSD distribution. Non-rail noises and distant rail noises can be differentiated from actual leaks in the rail yard environment; however, nearby rail noises interfere greatly with the identification of airbrake system leaks on the train, and so additional knowledge of the train's surroundings is critical for eliminating the false positive results of airbrake leaks. The possibility of using automatic rail side mounted ULD devices is discussed.

Assigned Session: A 5 End User Applications 3

Presenting Author: Jordan Jameson **Ser:** 17

Organization: Center for Advanced Life Cycle Engineering

Country:

Paper Title: **Health Monitoring of Solenoid Valve Electromagnetic Coil Insulation under Thermal Deterioration**

Co Authors: Jordan Jameson, Michael Azarian, Carlos Morillo, Michael Pecht, and Kai Wang

Abstract:

Solenoid-operated valves (SOVs) are widely used components in a variety of industries and systems. Though they are small components, their failure can lead to catastrophic failure of the system in which they are placed. Past studies have revealed the electromagnetic coil insulation to be a weakness, and prior work in the AC motor community on twisted pairs has shown that insulation capacitance measurements can reveal useful diagnostic information. This paper develops a method of detection of the aging of insulation in low-voltage (<24VDC) electromagnetic coils when subjected to elevated temperature environmental conditions by assessing changes in the impedance spectrum. In this experiment, a solenoid valve was powered and subjected to an operating environment equal to its maximum operating temperature. The valve was periodically removed from the temperature chamber and impedance measurements were taken at frequencies ranging from 20 Hz to 2MHz. The complex impedance was split into its real and imaginary parts and the Spearman correlation coefficient was used to find regions of interest within the impedance spectrum. The results indicate that resistance and reactance provide information that can assist in condition-based maintenance procedures for electromagnetic coils. Furthermore, in comparison to prior results in corrosive aging, it is shown that the impedance spectrum can be used to differentiate between insulation failure mechanisms.

Assigned Session: A 5 End User Applications 3

Presenting Author: Mazin El Waseif **Ser:** 65

Organization: University of Central Lancashire

Country: UK

Paper Title: **Online Structural Health Monitoring for Oil and Gas Pipelines**

Co Authors:

Abstract:

Oil and gas pipelines are used to transport flammable petroleum fluids such as crude oil and liquefied natural gas. These pipelines are often exposed to different types of failures including aging, mechanical damages, or natural causes such as ground motion due to earthquakes or landslide. Mechanical failures such as corrosion deteriorate the health of pipelines and risking spills, leaks or explosion. Although pipelines are monitored using leak detection systems and being maintained on regular bases, such process is not enough for online failure prediction. This paper is discussing oil and gas pipeline structural monitoring techniques and the challenges in transferring pipeline's structural health data for long distances. The paper is presenting an online structural health monitoring system that can help to overcome such challenges. The system is being validated in lab environment to monitor different failure modes in pipelines, and predict the onset failure. The system provides a cost effective solution for oil and gas pipelines online structural health monitoring.

Assigned Session: B 5 Diagnostics 1

Presenting Author: Issam Abu-Mahfouz **Ser:** 58

Organization: PSU Harrisburg

Country:

Paper Title: **Fatigue Damage Diagnosis Using Vibration Signals and Genetic Fuzzy System**

Co Authors: Issam Abu-Mahfouz

Abstract:

This paper illustrates the use of vibration signals and a genetic fuzzy system for fatigue damage detection in a cantilever beam. The beam is exposed to a harmonic excitation with varying levels of frequency and amplitude applied close to its fixed end. The accelerometer signals are analyzed for vibration signatures in the form of statistical moments, FFT and Wavelets analysis. It is found that the proposed genetic fuzzy logic system can be used as a successful classifier in identifying the presence and extent of damage in the beam. Keywords: Crack detection, Fatigue, Fuzzy logic, Genetic algorithm, Vibration.

Assigned Session: B 5 Diagnostics 1

Presenting Author: Matt Buzza **Ser:** 19

Organization: University of Cincinnati

Country:

Paper Title: **Fault Diagnosis of Root Causes in Complex Systems using Bayesian Belief Networks**

Co Authors:

Abstract:

Currently most online diagnostic systems are very capable of diagnosing fault symptoms, such as a high sensor reading or a short circuit, but they lack the ability to identify the real root cause of the malfunction. With the current diagnostic information maintenance can still be challenging for complex systems since there are many components that could be creating problems, therefore it is much desired to improve the online diagnostic information. This paper provides the framework for diagnosing probable root causes of fault symptoms of a complex multicomponent system. A Bayesian Belief Network (BBN) is proposed to be the primary diagnostic tool due to its easy interpretability, ability to diagnose simultaneously occurring faults, reliability under uncertainty, and ability to function with incomplete datasets. Since the BBN is well suited for incorporating prior belief of health states, this paper explores the capability and effects of adding outside information to the BBN in order to reduce diagnostic uncertainty. Simulated faulty data from an engine model was used to demonstrate the effectiveness and benefits of the proposed framework, as well as a benchmarking with other commonly used diagnostic tools.

Assigned Session: B 5 Diagnostics 1

Presenting Author: Issam Abu-Mahfouz **Ser:** 59

Organization: PSU Harrisburg

Country:

Paper Title: **A Genetic Algorithm Optimized Support Vector Machine Technique for Rotor Crack Detection and Classification Using Vibration and Displacement Signatures**

Co Authors: Issam Abu-Mahfouz

Abstract:

Rotating machinery are being used at increased speeds and loads to meat high power demands. With modern machine design trends seeking light weight machinery, the ability to detect the crack initiation and propagation at early stage is imperative for a successful diagnosis of machine condition. Undetected cracks in rotors can lead to catastrophic failure and high costs of down-time and maintenance. This paper presents the results of experimental study aiming at detecting and identifying the progression state and location of cracks in a rotor test rig running at different speeds and torque load conditions. Bearing Vibration signals from accelerometers and rotor orbital displacement measurements using inductive proximity sensors are analyzed for feature extraction and pattern recognition. Two techniques, namely the genetic algorithm (GA) and support vector machine (SVM) are implemented in a hybrid form for rotor crack fault diagnosis. The study shows that the proposed techniques greatly improved the SVM classification performance.

Assigned Session: C 5 Autonomy and Self-awareness

Presenting Author: Jephin Philip **Ser:** 63

Organization: University of Central Lancashire

Country: UK

Paper Title: **Intelligent Management of Driverless Vehicles**

Co Authors:

Abstract:

Automotive industry is immensely developing and transportation is becoming a major role of every human's daily activities. One of the costs of this is thousands of road users killed every year and commuters experience tremendously long halts due to congestion and road accidents. Review reports showed that the majority of road accidents are due to human errors, the proliferation of on-the-road safety risks affects all types of road users, and prolonged inconveniences for commuters affect the society as well as the environment. Therefore, various car manufacturing companies and research (DARPA, GOOGLE) have increased significance by developing intelligent driverless vehicles, by employing intelligent systems. Driverless vehicle development focused on level five of the SAE J3016 automotive automation standard which will improve commuters' satisfaction and reduce both emission and fuel cost. However, several aspects with current development are still required to be addressed such as on road safety and integration. This paper is discussing current development of driverless vehicles, and introducing the development of new driverless pod including an intelligent management system that may addresses one of the current issues in

Assigned Session: C 5 Autonomy and Self-awareness

Presenting Author: Ankit Patel **Ser:** 31

Organization: Drexel University

Country:

Paper Title: **Health and Usage Monitoring: Adaptive Controls**

Co Authors: Ankit Patel and John Lacontora

Abstract:

The following paper presents a work in progress related to the use of Health and Usage Monitoring System (HUMS) data to actuate an adaptive control system on an autonomous vehicle. The autonomous passenger vehicle has rapidly matured from a speculative concept to a reality that is quickly appearing within our sightlines. Autonomous (also called self-driving, driverless, or robotic) vehicles have long been predicted in science fiction and discussed in popular science media. Recently, major corporations have announced plans to begin selling such vehicles in the near future, and some jurisdictions have passed legislation to allow such vehicles to operate legally on public roads.
Autonomous vehicles will be performing intelligent function (navigation, maneuver, behavior, or task) by perceiving the environment and implementing a responsive action. Once begin operating on public road as a norm, safety and reliability becomes a major risk. The implementation or expanded use of HUMS can perceivably render these systems reliable and safe to operate.
This work depicts a notational framework for adaptive control of autonomous vehicles.

Keywords: Health and usage monitoring systems, reliability, adaptive systems, autonomous vehicles.

Assigned Session: D 5 Electronic and Power Systems

Presenting Author: Dan Schweickart **Ser:** 20

Organization: US Air Force Research Laboratory

Country:

Paper Title: **Arc Fault Testing to Support Standards Development for Robust DC Electrical Power Systems**

Co Authors:

Abstract:

Modern electrical power system designs in both airborne and terrestrial vehicles are utilizing dc at voltages above the traditional levels of 12 to 42 Vdc. Certain military aircraft are already employing 270 Vdc. Some commercial aircraft use 270 Vdc in a bipolar arrangement with a 540 Vdc differential. The use of high dc potentials create flash-over and arcing risks that are much more problematic than the traditional ac or low-voltage dc. At higher dc voltage levels, the propensity of arcing to continue undetected for significant periods of time creates a need to monitor and mitigate arcing conditions.

Recent arcing incidents in the field have evidenced the requirement to replicate 270 Vdc arcing events in a controlled laboratory environment, to better understand how electrical faults develop. Procedures are being investigated to reproduce typical arcing faults that could be experienced in aircraft, with a reasonable degree of repeatability. To this end, an aircraft generator has been used as a source to characterize and record arc fault events of various types. It is intended that appropriate results will be shared for SAE-International's standard development activities to support publication of test methods for validating the performance of prospective 270 Vdc arc mitigation technologies and equipment.

A brief review of the need for arc-fault detection will be presented. Background and rationale for the testing apparatus will be discussed along with the setup, methodology, and representative results from the initial phase of this work.

Assigned Session: D 5 Electronic and Power Systems

Presenting Author: Adrian Messer **Ser:** 28

Organization: UE Systems Inc

Country:

Paper Title: **Electrical Equipment Reliability with Ultrasound & Infrared**

Co Authors: Adrian Messer

Abstract:

Ultrasound and infrared technologies are a perfect match when conducting inspections of electrical equipment. At any voltage, thermal anomalies and sources of ultrasound such as tracking and arcing can occur. Corona can also occur at 1000 volts and greater. Any of these conditions threaten the reliability of the equipment being inspected.

Typical electrical components that can be inspected with ultrasound and infrared include switchgear, load interrupter switches, breakers, transformers, motor control centers, and terminal transition cabinets. This paper will provide information on how using both infrared and ultrasound together for electrical inspections can allow for more problems to be found sooner, and will also discuss how safety is increased when using ultrasound to scan enclosed electrical gear prior to opening for further inspection.

As a further complement to infrared inspections and to aid in the proper diagnosis of the condition heard, recorded ultrasound examples will be shown in both FFT and Time Wave Form from a spectrum analysis software to show how to properly diagnose electrical anomalies. This form of analysis is referred to as ultrasound imaging.

Assigned Session: D 5 Electronic and Power Systems

Presenting Author: Yang Liu **Ser:** 53

Organization: Beihang University

Country: PR China

Paper Title: **Method for Fault Characterization Parameters Calculation of Electronic Products Based on Physics Failure and Reliability Sensitivity Analysis**

Co Authors: Yang Liu, Yufeng Sun, Weiwei Hu, and Yaqiu Li

Abstract:

In this paper, a method for determining the failure characterization parameters of electronic products is presented. First, analyze the multi task load profiles and the design parameters of products in the whole life cycle from internal and external causes. On this basis, determine the failure mechanisms and failure models using FMMEA. Furthermore, Using Monte Carlo simulation, the reliability level of electronic products in life cycle of multi task load profiles is analyzed quantitatively combined the failure physical models. The average failure time of electronic products is calculated, and the time function of failure rate and reliability is established. Finally, the quantitative relationship between product reliability and electrical parameters is described by using Proportional Hazards Model. The reliability sensitivity of the product to different electrical properties is presented, which is used to measure the influence of the parameters on the reliability. Select the most sensitive parameter to characterize the faults of electronic products. A new method for monitoring and fault prediction of electronic products is provided.

Assigned Session: A 6 End User Applications 4

Presenting Author: Alven Kuruvilla **Ser:** 66

Organization: University of Central Lancashire

Country: UK

Paper Title: **Solar Panel Advanced Management System (SPAMS)**

Co Authors:

Abstract:

Solar energy is the energy given out by the sun as radiation; this can be harnessed by several technologies. One example is using a Photovoltaic (PV) system. PV systems convert the sun's radiations into electricity, which can provide the world with a renewable energy source that helps towards the greenhouse effect. However, to get the most out of this technology, PV system performance must be maintained. This paper is discussing the development of a solar panel advanced management system (SPAMS) that can achieve several functions to maintain PV systems performance including solar power management, solar energy tracking, and automated maintenance tasks. The SPAMS sensors – actuation system is being implemented on 100w solar panels and testing is carried out in the laboratory environment.

Assigned Session: A 6 End User Applications 4

Presenting Author: Ahmed Abufroukh **Ser:** 64

Organization: University of Central Lancashire

Country: UK

Paper Title: **Intelligent Management of Wind Turbine Bearings**

Co Authors:

Abstract:

Most countries nowadays moved to renewable and sustainable energy sources as they are a cleaner source. These sources will contribute to a strong economy and will not compromise human health or climate change since they are environmentally friendly. Wind energy is one of the fastest growing sources of electricity generation in the world, since the 1990s, at different scales. However, wind turbines operate under high cycle fatigue and at harsh conditions. With the use of advanced maintenance strategies such as condition based, predictive or proactive maintenance strategies, wind turbines life can be maintained and their performance can be improved. These maintenance strategies utilize online condition monitoring systems that use different techniques such as vibration analysis, Acoustic Emission (AE) monitoring or Online Debris Analysis (ODA) to provide useful information about wind turbines condition. However, most online condition monitoring systems usually focus on detecting onset failures, prevent catastrophic failures or identify failure mechanism to perform reliability analysis. A few of these systems utilize intelligent algorithms with monitoring techniques such as vibration analysis to provide failure prediction. This paper introduces the development of an intelligent management system for wind turbine bearings that is able to predict failures of bearings using intelligent analysis approach and support proactive maintenance strategy. The system is being validated on micro-scale wind turbine bearings and can be adapted for different wind turbine bearings.

Assigned Session: A 6 End User Applications 4

Presenting Author: Michael Lipsett **Ser:** 34

Organization: University of Alberta

Country: Canada

Paper Title: **Using Unmanned Aerial Systems for Condition Monitoring of Rotating Equipment and Structural Health Monitoring**

Co Authors: Michael Lipsett

Abstract:

The preferred approach for assessing equipment condition in an operating plant is to analyze condition-monitoring data from sensors rather than to interpret a physical inspection report. Data are collected continually over hard-wired networks for critical components. Less critical data are collected periodically using portable data loggers. As well, periodic physical inspections are still necessary for some equipment and structures. Manual inspections are time-consuming, access may be difficult, and inspection reporting is prone to human error. For these reasons, partial automation of periodic data collection should be considered. A system architecture is presented for a general-purpose unmanned aerial system capable of deploying a set of sensors for condition monitoring, including criteria for sensor selection, payload integration, data collection, processing, archiving, and reporting. Case studies are presented for a robotic fixed-aircraft conducting an idealized pipeline leak detection survey, a rotorcraft for autonomous placement of a magnetically mounted accelerometer for rotating equipment condition monitoring, and a rotorcraft deploying an ultrasonic sensor for structural monitoring.

Assigned Session: B 6 Signal Analysis 3

Presenting Author: Preston Johnson **Ser:** 67

Organization: Allied Reliability Group

Country:

Paper Title: **Remote Non-contact Optical Measurement of Vibration Displacement**

Co Authors:

Abstract:

High speed cameras have been used in automotive crash testing for years. A new and novel use of high speed image analysis brings high speed camera technology to the field of vibration data acquisition and analysis. Vibration is measured pixel to pixel and frame to frame as detected edges in the field of view vibrate. A single camera makes 100s of vibration point measurements as its field of view may cover an entire machine train. This technology offers vibration displacement measurement where equipment is not accessible, or requires interruptions in production. This presentation provides a technical description of the technology and a demonstration of the image analysis that reproduces vibration time waveforms and spectral results.

Assigned Session: B 6 Signal Analysis 3

Presenting Author: Mahdi Heydari **Ser:** 70

Organization: SpectraQuest Inc

Country:

Paper Title: **Continuous Model for Flexural Vibration Analysis of Beams with a Breathing Crack**

Co Authors:

Abstract:

In this paper, a continuous model for vibration analysis of a beam with an open edge breathing crack is presented. Different breathing functions are considered. A displacement field is suggested for the beam and the strain, and stress fields are calculated. The governing equation of motion for the beam has been obtained using Hamilton's principle. The equation of motion is solved with a modified Galerkin method and the natural frequencies and mode shapes are obtained. The results are compared with those obtained by finite element method and experimental data. The accuracy of different breathing function has been investigated by comparing with the finite element and experimental results.

Assigned Session: C 6 Condition Monitoring 3

Presenting Author: Robert Shipman **Ser:** 42

Organization: Epoch Engineering Inc.

Country:

Paper Title: **Industrial Measurement Laser Interferometer (IMLI) System Level Functional Measurement Capability, Including Acoustic Emissions (AE)**

Co Authors: Theodore Goodenow, Martin Karchnak, and Robert Shipman

Abstract:

Measurement systems and their associated post-measurement processing capabilities have historically lacked adequate robustness for providing needed information in harsh environments. Harsh environment functional information and technical interest exists across a variety of functional areas. Examples include structural health assessments and monitoring, rotating machinery health monitoring, aeronautics test programs and fluid systems/components non-invasive characterizations to discern the presence of water, gas and/or steam, without permanently altering or physically modifying the system structure. It is strongly suggested that the correct measurement and post-measurement processing of Acoustic Emissions (AE) can enable the use of wideband, vibration measurement, including AE for improved health monitoring across a variety of harsh environments. An example of this Acoustic Emissions measurement and post-processing capability is presented in this paper to illustrate the technical feasibility under such circumstances.

The concept selected and presented in this paper -- use of AE monitoring in harsh environments -- has been demonstrated (on a not-to-interfere basis) under Department of Transportation/Federal Highway Administration (DOT/FHA) (CRADA) # 2012-01 to present the ability to measure, detect, quantify, track and trend AE events in an exceedingly harsh environment, namely full scale I-beam destruction testing. Under the DOT CRADA, the Industrial Measurement Laser Interferometer (IMLI) "measures the AE" (primary measurement objective) that is generated by shear studs [on a composite (steel and concrete) bridge beam] that is being "stressed to destruction" in dynamic testing. Destruction occurs by forcing the beam past its load limit in a controlled environment. During the test a very large load was periodically applied to the beam at a frequency of approximately 1 Hertz. The beam is bent, with a displacement of several inches, and then recovered about once every second. Measurements are made on the edge of the I-beam flange during the test. All measurements are made for/over a 1-second period. All of the measurement data presented in this paper was measured and post-processed using our Industrial Measurement Laser Interferometer (IMLI) technology.

Data presented includes: i) acceleration at a measurement point during the approximately one cycle of "force applied and force release" over a frequency range from 0.0 Hertz to approximately 200 KHz; ii) crack generated AE measured during the force applied and force release; iii) the 'broadband' AE generated by the cracking and crushing of the concrete; iv) the visibility of crack generated AE,including details such as Energy Measurement (EM) and "Dominant Frequency Range" (DFR); v) discussion and observation regarding correlation processing results as they relate to crack tracking; and vi) summary system level functional characterization of the IMLI measurement system and associated post-measurement processing. There is only a one-of-a-kind prototype system at this time.

Assigned Session: C 6 Condition Monitoring 3

Presenting Author: Alexey Kostyukov **Ser:** 23

Organization: SPC Dynamics

Country: Russia

Paper Title: **Regulatory-Methodical Guidelines on Real-Time Vibroacoustic Monitoring of Piston Compressors**

Co Authors: Vladimir Kostyukov and Alexandr Naumenko; presented by Alexey Kostyukov

Abstract:

The current Russian and the International standards in the field of standardizing parameters for piston machines vibration including piston compressors are reviewed. It is shown that the current standards do not meet safe operation requirements for piston compressors of hazardous production facilities. The Article describes the national standard of the Russian Federation "Condition monitoring and diagnostics of machines. Condition monitoring of hazardous industries. Vibration of stationary reciprocating compressor".

Assigned Session: C 6 Condition Monitoring 3

Presenting Author: Rmdan Shnibha **Ser:** 9

Organization: Hourge Oil Operations

Country: Libya

Paper Title: **Reconstruction of Vibration Signal from Phase Current Signal in Induction Motor**

Co Authors: Rmdan Shnibha

Abstract:

Many processes and systems using three phase induction motors are inherently nonlinear. Thus they cannot be represented by simple and accurate models. A common example of a nonlinear process within the induction motor is the vibration signal measured in order to detect a fault or defect. Yet measurement and analysis of the vibration signal are important in improving motor performance and condition monitoring and this necessitates sophisticated analysis techniques that have yet to be proven in practice. An effective alternative to direct vibration measurement, preferably using easy-to-measure variables would be very attractive to industry.

This study used spectral estimation to investigate the coherence between the driver's current signature (DCS) and the driver's vibration signature (DVS) signals at a particular frequency and in different frequency. Both signals are completely coherent if the magnitude squared coherence (MSC) is equal to 1, if MSC is equal to zero then the both signals are independent to each other. The results show the both signals are coherent at the frequencies at which the MSC is greater than 0.5 and both signals are less coherent if DSC is less than 0.5. Wavelet coherence analysis greatly facilitates the detection of the quasi-periodic component indicative of a system anomaly. Wavelet cross spectrum and wavelet coherence are useful to reveal localized similarities between DCS and DVS signals in the timescale plane and to interpret the results. It may be possible to acquire the DVS signal information from the DCS signal.

This research has demonstrated the possibility a condition monitoring method based on the motor current for reconstruction of motor vibration by applies radial basis function networks to the reconstruction of motor vibration using measurements of one phase of the motor current. It is proved feasible to reconstruct motor vibration effectively by using the current signal from one phase of the motor supply. This method is of high precision and good repeatability. This is a non-invasive technique which can open new possibilities for performing necessary diagnostics and making checks on induction motors without laborious and expensive investigations that are truly rigorous only in laboratory conditions. The method has been tested by statistical analysis and shows a good agreement with the widely used approach that entails making on-motor vibration measurements.

Assigned Session: D 6 Diagnostics 2

Presenting Author: Mami Sato **Ser:** 72

Organization: SpectraQuest Inc

Country:

Paper Title: **Developing a Pattern for Vibration Signature of Shaft/Coupling Misalignment**

Co Authors:

Abstract:

Shaft misalignment is the most common fault in rotating machinery besides unbalance. It causes rotational angle dependent preload forces in couplings which are transmitted to other machine components, reducing their lifetime. A poorly aligned machine can cost a factory up to 30% in machine down time, replacement parts, inventory, and energy consumption. Considering the importance of alignment, the vibration spectrum of misalignment is not well understood and lacks a consensus. This report is based on the analysis of the vibration data to determine a unique vibration signature for misalignment under a varying operating and design conditions such as speed, type and level of misalignment, coupling types and machinery dynamic stiffness. The tests were conducted on machinery fault simulator. Rotors were precisely balanced before each significant configuration change. Measurements were carried out at three different shaft speeds, using three types of couplings – rigid, spiral and rubber –, three shaft diameters and multiple misalignment configurations which include parallel and angular types with three different severity levels. The results indicate that the rotor speed, the coupling and shaft stiffness, have the most profound influence on the vibration signature. However, the data indicate confusing picture of misalignment signature.

Assigned Session: D 6 Diagnostics 2

Presenting Author: Nader Sawalhi **Ser:** 77

Organization: SpectraQuest

Country:

Paper Title: **Experimental Measurement and Calculations of Misaligned Coupling Forces**

Co Authors: Nader Sawalhi and Suri Ganeriwala

Abstract:

Misalignment has long been one of the main common faults of rotary machines. As misalignment is a rotor related fault, it has always been linked to the synchronous rotor orders in the spectrum analysis and has in particular been associated with 2X harmonics. The type and level of misalignment along with the coupling type are responsible for the production of the forcing function, which when convolved with the transmission path gives the measured response seen by the accelerometer. The frequency content seen in the measured signal is a direct reflection of the forcing function content, which gets scaled by the frequency response function (FRF). It is though very crucial from a diagnostic point of view and for modelling purposes to understand the frequency content of the misalignment force. In this paper we propose an experimental setup to measure and calculate misalignment forces as a function of coupling angular position and use it to examine the frequency content of the forcing function for two types of couplings. The calculations of the forcing function involves performing an order tracking on the measured forces and calculating a synchronous averaged signal. Two types of couplings are tested: three-jaw Lovejoy coupling and a spiral beam coupling. The frequency content of the Lovejoy coupling force was found to be dominated by a 3X harmonics, while that of a spiral beam had a 2X dominance. Calculated mean stiffness values were found to be in agreement with published results. The results obtained from the paper will be utilized in a dynamic simulation model to produce faulty signals and compare them with measured ones to develop diagnosis routines to differentiate misalignment faults from other rotor related problems and gain more understating of these faults.

Assigned Session: D 6 Diagnostics 2

Presenting Author: Sergey Boychenko **Ser:** 54

Organization: SPC Dynamics

Country: Russia

Paper Title: **Condition Monitoring and Diagnostics of Rotary Machines Using Coherence Function**

Co Authors: Sergey Boychenko and Vladimir Kostyukov

Abstract:

Rotary equipment (centrifugal pumps, compressors, fans) is the basis of modern techno-logical units for oil and gas production and refinery. The reliability of the process plant is con-siderably determined by the reliability of its equipment. The main methods of condition diagnos-ing of rotary machines are based on the analysis of vibro-acoustic signals in the time or frequency area. An urgent task in order to improve reliability of the diagnostics results is the development of new techniques.

The article considers the issues of application of the spectral coherence function of vibra-tion signals for parallel multi-channel measurements in order to evaluate the rotary equipment condition on the example of a centrifugal pump unit. There are a description of the experimental system, methods of obtaining experimental data, the results of the data processing.

It is shown that the use of a coherence function in the spectral analysis provides more ac-curate division of the components of the signal unit to the synchronous vibration - determined by a common shaft rotation, and asynchronous vibration - determined by bearings performance, as well as hydraulic components. This technique is particularly effective in case of increased noise levels, for instance, pump operation under cavitation conditions. Application of the coherence function can significantly improve the reliability of rotary machinery diagnosing results.

Assigned Session: E 6 System Design

Presenting Author: Mikael Tiberg **Ser:** 26

Organization: Saab AB

Country: Sweden

Paper Title: **Availability Performance**

Co Authors:

Abstract:

Availability performance philosophies with focus on system design in the development of a fighter jet. The process and tools used in the design of a system for maximum mission generation capacity to a minimal maintenance effort and cost.

Assigned Session: E 6 System Design

Presenting Author: Tomasz Barszcz **Ser:** 46

Organization: AGH University of Science and Technology

Country: Poland

Paper Title: **Embedded Integrated Health Indicators for Low Power Embedded Systems**

Co Authors:

Abstract:

The vibration monitoring rapidly expands into the area of Internet of Things paradigm. No longer only the large machines are equipped with online condition monitoring systems. Trends in IT technologies allow to implement low power and low cost systems, which are being applied to a multitude of machinery. Such a trend results in an information overload at the higher level of systems, in most cases SCADA. If an embedded system monitors more than only basic rms vibration velocity level, but also frequency selective features, the amount of data and events from hundreds or even thousands of sensors reaches levels which can not be handled by human operators. Therefore, for efficient condition monitoring it is necessary to include key functionalities in a small embedded system: vibration signal validation, efficient calculation of vibration signal features and intelligent aggregation of alarm levels violations. The paper presents architecture of embedded wireless vibration sensor. It will describe numerical and efficiency consideration of the implementation of numeric algorithms. Then, it will also present the idea of integrated health indicators. In such a way it is possible to provide to the users useful information including localization of a machinery fault with proper filtration of details, not necessarily relevant for human operators.

The work presented in this paper was supported by funding from the research project co-financed by the KIC InnoEnergy Project Agreement number 32_2014_IP110_XSENSOR.

Assigned Session: F 6 Human Monitoring 3

Presenting Author: Kimberly Bigelow **Ser:** 80

Organization: University of Dayton

Country:

Paper Title: **Human Movement Variability and Postural Control: Monitoring Balance to Identify Health-Related Changes**

Co Authors:

Abstract:

Measuring postural control through the use of a force plate or wearable sensors can provide insight into health-related changes of an individual. Individuals often exhibit reduced postural control in situations of disease progression, subtle but non-obvious balance deficits, or even sleep deprivation. Individuals may also exhibit improved control over the center of pressure indicating improved balance after effective rehabilitation, intervention and physical training programs, indicated by reduction in sway and slower, more controlled sway speeds.Non-linear analysis techniques have recently been used to study the underlying patterns in physiological signals - including postural control. These techniques have proven to better identify subtle differences between populations and testing condition as compared to traditional analyses. This presentation focuses on our work applying non-linear analysis to postural control data to monitor balance over time. Specifically, we focus on some of our work concentrating on the development of a logistic regression model that seeks to identify individuals who have high likelihood of sustaining a fall. We found that incorporating select traditional measures, non-linear measures, and physical attributes provided the best differentiation between fallers and non-fallers with a sensitivity of 75% and specificity of 93.7% in the eyes closed, comfortable stance condition.

Assigned Session: F 6 Human Monitoring 3

Presenting Author: Ellen Gamel **Ser:** 89

Organization: University of Cincinnati

Country:

Paper Title: **Quantifying Performance of Athletes using Prognostics and Health Management Methods**

Co Authors:

Abstract:

Prognostics and Health Management is an ever-expanding field that no longer focuses solely on mechanical and electronic assets and components, but has grown from predicting the failure and remaining useful life of such assets to predicting health conditions of humans. The IMS Center at the University of Cincinnati has been working with the University of Cincinnati Sports Medicine Department to focus on monitoring athletes to create a more accurate and descriptive definition of performance, which will allow better analysis and prediction of the fitness and condition level of athletes in all sports, thus allowing for better player conditioning, preventing player injuries and ensuring for more winning games throughout the season. Current methods of performance monitoring use the rudimentary analysis of one variable at a time provided by the sensor software. This project hopes to expand upon current methods by using SOM, SVM, clustering techniques, and more to make the analysis more encompassing to allow for a more thorough analysis involving several body signals. The focus of this collaboration is on men's football and women's soccer, but there are a number of additional applications to which this method can be expanded: rehabilitation, long-term care, and primary care.

Once this method is tested and verified it can be used to monitor and assist anyone and everyone who wears a health monitor with any topic from general fitness to tracking severe illnesses.

Assigned Session: F 6 Human Monitoring 3

Presenting Author: Ed Downs **Ser:** 90

Organization: Proterf

Country:

Paper Title: **Exploring Factors Affecting Human Performance: from the Professional to the Tactical Athlete**

Co Authors:

Abstract: