COMADEM 2018 ABSTRACTS – Part 2

The 31st International Congress and Exhibition on Condition Monitoring and Diagnostic Engineering Management (COMADEM) was jointly hosted by the North-West University and University of Pretoria in the Sun City, Rustenburg of South Africa during the 2nd to 5th July 2018. The main conference theme was on Energy and Environmental Issues facing the 21st Century and beyond. Delegates from 20 countries actively participated in this four day event. A wide range of topics were covered which included Mechanical Systems, Electrical Systems, Integrated Maintenance Management, Renewable Energy Systems, Energy Storage Systems, Asset Management, Signal Processing, Diagnosis and Prognosis, Structural Health Monitoring and Fault Detection and Localization. The abstracts of some of the papers that were presented by the authors are presented in this second instalment.

1. **Investigations on Augmented Reality based maintenance practices within SMEs**
   M. Müller, D. Stegelmeyer & R. Mishra
   Abstract: Maintenance services provided by Original Equipment Manufacturers (OEMs) play a fundamental role in industrial asset management. The vast majority of OEMs provide maintenance services to their customers, as most customers now outsource complex maintenance tasks. For many OEMs the economic value of operations has even shifted from manufacturing traditional products, to providing services required to operate and maintain their installed base. In general downtime is expensive and maintenance activities are often conducted under time pressure. However, maintenance processes are knowledge intensive and field service technicians have to cope with increasingly complex and diverse systems. To stand out from competitors and to satisfy customer needs, productivity improvement in maintenance processes is urgently required. Augmented Reality (AR) technologies, e.g. head mounted displays (HMD) can assist field service technicians in improving efficiency of maintenance operations. Systems for mobile collaborative AR supported maintenance are commercially available, and the benefits of AR supported maintenance work are generally evident. Still, on a wider scale in the industrial maintenance service delivery, the technology is far from established. From the perspective of small and medium-sized enterprises (SME), with a limited number of field service technicians, remote support for customers and service partners might be an opportunity to enhance resources availability. This study investigates ten business cases of mobile collaborative AR systems using HMDs for services delivery. The research strategy follows an exploratory approach. Based on focus group discussions with representatives of SMEs and semi-structured interviews with industry experts, enablers and barriers for the use of mobile collaborative AR systems are determined.
   Keywords: augmented reality, head mounted displays, industrial asset management, maintenance, servitization
   Number of References cited: 30
   Corresponding author: Maike Müller (maike.mueller@hud.ac.uk)

2. **Discrepancy analysis for gearbox condition monitoring: A comparison of different healthy data models**
   S. Schmidt, P.S. Heyns & K.C. Gryllias
   Abstract: Discrepancy analysis is a novelty detection technique that uses diagnostic information, extracted from vibration signals that were acquired from a rotating machine, and a model of the healthy historical machine data to infer the condition of the gearbox under varying operating conditions. In discrepancy analysis, various

healthy data models such as Gaussian mixture models can potentially be used to model the healthy features, however, the performance of these models have not been compared in a systematic way for discrepancy analysis. In this work, a principal component reconstruction-based model is considered for discrepancy analysis. Moreover the ability of Gaussian models, Gaussian mixture models, hidden Markov models, and principal component-based reconstruction models to detect bearing damage in gearboxes operating under varying speed conditions is evaluated and compared. The gearbox data are generated using a phenomenological numerical gearbox model and the performance of the different models is compared by investigating the sensitivity of the models to detect changes in the magnitude of impulses induced by bearing damage and to compare the models' robustness to changes in operating conditions. The results provide further insight into the properties of the different models and can assist with model selection when investigating new datasets with discrepancy analysis.

Keywords: Condition monitoring; Diagnosis; Discrepancy analysis; Fault detection and localisation
Number of References cited: 8
Corresponding author: Stephan Schmidt (stephanschmidt@zoho.com)

3. **A Generalized Synchro extracting Transform for Fast and Strong Frequency Modulated Signal Analysis**

Peng Chen, Kesheng Wang & Ming J. Zuo

Abstract: High-quality time-frequency representation (TFR) is vital for signal analysis and condition monitoring. The blurred time frequency (TF) energy distribution in TF plane may lead to uncertainty in TFR and inevitably result in ambiguous results. Synchro extracting, with an adaptive and reconstructive natured transform, is used to improve the readability of STFT- based TFR. However, the standard synchro extracting method is based on the assumption that the analysed signal is purely harmonic, as a result, it is more applicable to deal with signals with small amplitude and slow frequency modulations, whereas, signals with fast and strong nonlinear and non-stationary nature are of not suitable for the current synchro extracting method. To tackle this problem, a generalized synchro extracted transform (GSET) is proposed to cope with fast and strong nonlinear and nonstationary signals. In the proposed method, the generalized Fourier transform is first used to map the original frequency time-varied signal to a constant frequency signal. The constant frequency signal is further analysed through synchro extracting operation so that the energy concentrated TF ridge can be obtained for a fast and strong nonlinear and nonstationary signal. Numerical simulated case study is provided for the demonstration of the efficiency of the proposed GSET method.

Keywords: Time frequency representation (TFR); Instantaneous frequency; Generalized Fourier transform; synchro extracting; short time Fourier transform
Number of References cited: 13
Corresponding author: Kesheng Wang (keshengwang@uestc.edu.cn)

4. **A Deep Statistical Feature Learning Method Based on Stacked Auto-Encoder for Intelligent Diagnosis of Rolling Bearing**

Te Han, Quan Long, Chao Liu & Dongxiang Jiang

Abstract: To avoid redundancy and interferential information, feature fusion and dimension reduction is a critical step to improve the recognition accuracy in the fault diagnosis of mechanical system. The paper presents a novel feature fusion method based on one kind of deep neural networks (DNN), namely stacked auto-encoder

(SAE). First, 29 popular statistical features in time domain and frequency domain are extracted from the raw vibration signals to form a statistical feature set. Then, the SAE is utilized for deep statistical feature learning to reduce redundancy. With the aid of supervised fine-tuning, the feature learning ability can be further promoted, and the diagnostic results can be given by the top-layer classifier of SAE. An experiment analysis using rolling bearing fault dataset indicates that SAE-based method possesses superior feature learning ability in comparison with conventional dimension reduction algorithm. Meanwhile, contrast results demonstrate that the proposed method can achieve higher recognition accuracy.

Keywords: Deep Learning, Stacked Auto-Encoder, Feature Learning, Intelligent Fault diagnosis, Rolling Bearing.

Number of References cited: 20

5. **Research and Application of Weak Fault Diagnosis Method Based on Asymmetric Potential Stochastic Resonance in Strong Noise Background**

Zhixing Li, Jianguo Wang, Songjiu Han, Jian Kang, Zedong Li, Furui Shi & Wenjing Liu

Abstract: When machinery is used for fault diagnosis and status detection, mechanical equipment is often in a strong noise environment, The fault signal is often weak and can easily be submerged in other noise. Therefore, For this reason, this paper studies a method of stochastic resonance based on noise enhancing weak fault signals to detect weak fault signals. In this paper, a stochastic resonance phenomenon based on an asymmetrical potential system is studied. For the symmetry of the traditional stochastic resonance potential model, The shape of the potential model cannot achieve structural optimization problems. Study the effect of asymmetric potential stochastic resonance model on weak signal extraction, The effect of the asymmetric potential stochastic resonance model on weak signal extraction was studied. A non-symmetrical stochastic resonance model is proposed to achieve optimal structure. Comparing this model with traditional classical stochastic resonance. Finally, combined with experimental data of bearing weak fault diagnosis and computer simulations. Numerical simulation is consistent with the approximation theory.

Keywords: Strong noise, Stochastic resonance, Weak fault diagnosis, Asymmetric potential function

Number of References cited: 32

6. **Fault diagnosis method of rolling element bearing based on relative wavelet packet energy and Hilbert envelope analysis**

Junchao Guo, Haiyang Li, Dong Zhen, Hao Zhang, Zhanqun Shi & Fengshou Gu

Abstract: Rolling element bearings are widely used in rotating machinery, faults occurring in bearings may lead to fatal breakdowns in rotating machinery and such failure can be catastrophic, resulting in costly downtime. Therefore, it is significant to accurately diagnose the existence of faults at an early stage. Vibration signals collected from bearings contain rich information on machine health condition . Here, it is possible to obtain vital characteristic information from vibration signals through the use of advanced signal processing techniques due to their intrinsic advantage of revealing bearing failure. This paper proposes a new study to take advantage of the relative wavelet packet energy (RWPE) and Hilbert envelope analysis. Relative wavelet packet energy (RWPE) can reflect the energy distribution information of the signal in each wavelet packet transform frequency band. Then

apply the Hilbert envelope analysis separate the modulation components to extract fault frequency. The results show that the outer ring fault features of the rolling bearing can be clearly identified through simulation and experimental analysis. It verify the proposed method is effective and feasible in the condition monitoring and fault diagnosis for rolling bearing.

Keywords: relative wavelet packet energy; Hilbert envelope analysis; rolling element bearings; fault frequency； health condition.

Number of References cited: 10

Corresponding author: d.zhen@hebut.edu.cn

7. **Application of Adaptive Variable Scale Stochastic Resonance in Bearing Fault Diagnosis**

Jian-guo WANG, Chao ZHANG, Yuan-yuan HE and Teng-fei ZHU

Abstract: An algorithm of bearing fault diagnosis is proposed in this paper, which is based on human cognitive self-regulating particle swarm optimization and variable-scale stochastic resonance. In the algorithm, an objective function is first determined with the stochastic resonance structural parameters a and b considered. Then the objective function is optimized with self-regulating particle swarm optimization algorithm. Thus the optimal values of a and b corresponding to the maximum of signal-noise ratio are obtained. Bring optimal a and b into variable-size stochastic resonance system and filter out noise signal in bearing vibration signal. Finally, spectrum analysis is applied find the bearing fault characteristic frequency. Experiment results show that this method is effective in bearing fault diagnosis.

Key words: particle swarm optimization; stochastic resonance; fault diagnosis

Number of References cited: 9

Corresponding author: Chao ZHANG (zhanghero123@163.com)

8. **Characterization and modelling of a customs operation**

A.J. Hoffman

Abstract: Effective risk management is a prerequisite to find an acceptable balance between the objectives of a customs operation and the streamlined flow of goods. This requires the use of well-designed customs risk management models that scrutinize all cargo consignments in cyber space based on the analysis of rich data sets that can be used to accurately determine the risk represented by a cargo consignment without physically stopping it. The use of such models results in much reduced physical inspections without increasing the risk to customs of either losing income or allowing the influx of illegal contraband. It therefore represents a much more optimal compromise between the interests of customs and those of trade, reducing the economic cost to the region and making the region more attractive to global economic partners. In this paper we utilize different classification techniques to recognize patterns in electronic data transacted between customs and trade that characterize the risk attributes of cargo consignments. We subsequently extract models that can be applied in real time to minimize disruption of trade flows while reducing customs risks to below set thresholds. We quantify the impact of a variety in input factors and demonstrate how an optimal set of inputs can be selected to arrive at an effective risk management model. The diagnostic abilities of linear regression, neural network and classification tree techniques to predict both customs stops and infractions before they occur are compared.

Keywords: Diagnosis, pattern recognition, customs operations, root cause analysis, input-output modelling.

Number of References cited: 5
Corresponding author: Alwyn Hoffman (alwyn.hoffman@nwu.ac.za)

9. **The Improvement of Instantaneous Angular Speed Estimation using Signals from a Dual Read Head for Monitoring Planetary Gearboxes**
Qiang Zeng, Ibrahim Alqatawneh,,Yuandong Xu, Yimin Shao, Fengshou Gu, Andrew Ball
Abstract: The Instantaneous Angular Speed (IAS) signals obtained from the shaft encoders are influenced by inevitable manufacture and installation errors of encoder wheels. These errors can lead to low accuracy or unsatisfied estimation of IAS and fault diagnostics. To improve the accuracy of IAS estimation, this paper presents a novel IAS extraction method based on a dual read head sensing system. The analysis of common encoder errors shows that the amplitude of error changes with angular positions on the encoder whereas the IAS to be monitored is independent of the angular position. Therefore, a dual read head IAS estimation method is proposed to estimate the erroneous IAS online, and subsequently is taken from overall IAS measurement. In this way, the estimate of rotor IAS is significantly improved for more accurate monitoring and diagnostics. Experimental evaluation shows that the new method allows the small planet fault in a planetary gearbox to be detected over a wide range of operating conditions.
Keywords: Instantaneous angular speed; Planetary gearbox; Encoder error modelling; Dual read head; Diagnosis
Number of References cited: 16
Corresponding author: Qiang Zeng (q.zeng12357@gmail.com)

10. **Novel Bearing Fault Detection using Generative Adversarial Networks**
S. Baggeröhr, W. Booyse, P.S. Heyns & D.N.Wilke
Abstract: Bearing fault detection and diagnosis (FDD) are important if one is to avoid the more catastrophic failure consequences of large rotating machinery. Faults usually manifest as marginal defects that intensify over time, allowing for well-informed preventative actions with early FDD. Detection of the fault begins with capturing signals from a machine in various forms, such as vibration response signals. Numerous methods exist to extract either time, frequency or time-frequency based diagnostic features from these signals. Traditionally, handpicked descriptive statistical features (mean, RMS, skewness, Kurtosis, etc.) or spectral diagrams are used for FDD. However, machine signals are usually generated under non-stationary operating conditions of varying loads and speeds, which makes FDD with these methods more challenging. A wealth of research has been invested towards machine learning based signal processing techniques to circumvent the problems associated with non-stationary signals. Many of these methods require vast amounts of historical data to train. Since a machine spends most of its life operating in a healthy condition, most historical data is occupied with data that comes from a healthy machine condition. Training these methods are difficult, due to the shortage of data from a machine running in an unhealthy condition. Generative Adversarial Networks (GANs) are proposed as a novel method to perform condition-based diagnostics on assets. This method has the advantage that it can be trained exclusively with Healthy data. The GAN, when trained, learns a statistical manifold on which the healthy data lies. A deviation from this statistical manifold can indicate a fault within an asset. This paper presents a preliminary study on the use of GANs to detect and diagnose faults in bearings. It was found that GANs can detect faults in bearings. Also, by tracking the

manifold describing the healthy data, one can locate and assess the type of fault. This method has the added benefit of training on the entire data set, as opposed to supervised learning methods, which require the data to be divided into training, validation and test sets.

Keywords: Condition monitoring, Fault detection and localization, Diagnosis, Bearings, Deep learning
Number of References cited: 16
Corresponding author: Stephan Baggeröhr (u12017095@tuks.co.za)

11. Condition Monitoring of a Fan using Neural Networks

K.Passi, B. Zhang & M. Timusk

Abstract: Fans are widely used in various industrial fields and it plays a key role in cooling the machinery. For the machinery to work properly, the fan system should remain in stable and error-free condition. Condition monitoring is introduced as a maintenance tool for the failure diagnosis of a fan system. Some methods used in condition monitoring are vibration monitoring and thermal monitoring. Vibration monitoring method was used in this experiment. A fan system based on Machinery Fault SimulatorTM (MFS) was used to simulate different conditions of a fan in the laboratory. An accelerometer was installed on top of the bearing housing. It was used to detect the vibration signal of a running fan. A data acquisition program designed in LabVIEW was used to record and pre-process the raw vibration signal. The collected data was used to detect the condition of the fan system. Neural Network was used for the fault diagnosis. The raw vibration signal is a one-dimensional time domain series data, while the neural network requires multidimensional features as input data. Therefore, it is important to pre-process the raw vibration signal data. Two different pre-processing methods, time-domain features and Auto Regressive (AR) model features were used to pre-process separately. The neural network model was trained by these two methods respectively. The results show that the AR model gave better features than the time domain features method. The condition monitoring system
consisted of the following parts: data acquisition, data storage, data pre-processing and the display of results. Some methods were programmed in Matlab, which were called by Matlab scripts in the LabVIEW software. The hybrid programming method helped to generate an efficient program which provided high accuracy of fault diagnosis.

Keywords: Fan, Failure diagnosis, Vibration analysis, Neural Network, LabVIEW, Matlab
Number of References cited: 12
Corresponding author: Kalpdrum Passi (kpassi@cs.laurentian.ca)

12. Time-frequency domain analysis of varying speed vibration response of dual-rotor system

Yizhou Yang, Chao Liu, Dongxiang Jiang and Wenguang Yang

Abstract: Dual-rotor is a common form of rotor system where two rotors are coupled via an inter-shaft bearing and the speeds of the rotors are usually different and variable. When the vibration signal of a dual-rotor system is non-stationary, traditional frequency-domain signal processing methods are not suitable. In this paper, variable speed vibration responses of a dual-rotor system dynamic simulation model is acquired and analyzed by a time-frequency domain signal analysis approach called frequency slice wavelet transform (FSWT). The dual-rotor system model is established under an inertia coordinate using finite element method. Then the rotor

system model is solved by the explicit Newmark-β method to acquire the unbalance response under a fixed rotor speed or a varying speed, which could be movement of uniform angular acceleration or randomly fluctuating speed. By choosing the suitable scale coefficient, FSWT could achieve a good balance between time and frequency resolution, thus reflecting the detailed features in the vibration response. Meanwhile frequency components of the complex signal could be reconstructed by a FSWT representation.

Keywords: dual-rotor system, varying speed, time-frequency domain analysis, advanced signal processing, frequency slice wavelet transform.
Number of References cited: 15
Corresponding author: Dongxiang Jiang (jiangdx@tsinghua.edu.cn)

13. Remaining Useful Life Prediction and Uncertainty Modelling with Bayesian Deep Learning

C.J. Louw & P.S. Heyns

Abstract: The linearly decreasing remaining useful life modeling strategy was successfully implemented on the FD001 NASA turbofan engine degradation simulation data set time series regression problem, with 4 different Bayesian Deep Learning network architectures. This included a Dense Network, Simple Recurrent Network, Gated Recurrent Unit Network and Long Short-Term Memory Network, with Monte Carlo Dropout for remaining useful life prediction and uncertainty modeling. The Long Short-Term Memory Network was the most accurate at predicting the remaining useful life from the condition monitoring information for the turbofan engine examples in the testing set, due to its advanced sequence modeling architecture. The complex distributions and the model uncertainty associated with remaining useful life predictions were successfully and efficiently modeled with Monte Carlo Dropout. This made it possible to better understand the model uncertainty associated with remaining useful life predictions, which was previously given extremely limited attention in prognostics and health management research with Deep Learning. The Long Short-Term Memory Network model uncertainty drastically decreased, and model prediction accuracy drastically increased close to failure for all the turbofan engine examples in the testing set. The Long Short-Term Memory Network could on average very accurately predict the remaining useful life for all the turbofan engine examples 50 cycles before failure in the testing set, with a mean absolute error of only 1.954 cycles.
Keywords: Bayesian Deep Learning, Prognostics, Remaining Useful Life Modelling, Condition Monitoring, Pattern Recognition
Number of References cited: 9
Corresponding author: Carel Johannes Louw (u12032876@tuks.co.za)

14. Rolling Element Bearings Prognostics Using High-Frequency Spectrum of Offline Vibration Condition Monitoring Data

Mehdi Behzad, Hesam Addin Arghand and Abbas Rohani Bastam

Abstract: Remaining useful life (RUL) prediction of rolling element bearings (REBs)
with offline condition monitoring (CM) data is the purpose of this paper. A data driven algorithm based on feedforward neural network (FFNN) is proposed for this aim. Since, usually the number of offline measurements are not enough, the generalized Weibull failure rated function is used for producing the auxiliary points that are employed for training. Considering the physics of the bearing degradation, vibration level in the high-frequency bandwidth of the spectrum is used as a

feature and its performance in REB prognostic problem is compared with that of using popular recommended features in the diagnostic standards. Bearing accelerated life test data as well as data from two industrial bearings are used to investigate the purpose of this study. The results show that using the high-frequency vibration level features rather than the proposed frequency bandwidth in guidelines and standards for recording the vibration of rotating machines produce more accurate prediction of RUL.

Keywords: Prognostics, Offline Measurement, Neural Network, High-Frequency Vibration Level, Remaining Useful Life.
Number of References cited: 16
Corresponding author: Mehdi Behzad (m_behzad@sharif.edu)

15. **Investigation of Infrared Thermography as a Dual Online Diagnostic Tool for Dynamic Structural Health Monitoring**

D.A. Desai, S.M Talai & P.S. Heyns

Abstract: It is well known that infrared thermography (IRT) has fully matured as a tool for temperature condition monitoring. However in this paper, an experimental investigation of IRT as a dual online diagnostic tool in terms of temperature and vibration frequency characterization of dynamic structures is carried out, as such studies have not as yet been adequately investigated. Tests were conducted on both healthy and defect-induced cantilever beam-like structures coupled with a lacing wire subjected to forced excitations. Thermal images were acquired at the frictional interfaces, employing two infrared cameras. The analyzed frequencies obtained from the frictional temperature evolution time domain waveform using a Matlab FFT algorithm compared well with alternate accelerometer data acquired with the maximum relative error being 0.30%. Moreover, the beam with the induced defect showed a temperature increase of 8.1^{o}C compared to the healthy one and exhibited multiple spectral peaks around the dominant frequency, hence revealing successful discrimination between them. This study in essence proves that IRT is capable of reliably describing structural vibration behavior in terms of frequency. These findings are particularly useful in overcoming many limitations inherent in some of the current contact vibration measuring techniques operating in turbulent, unclean environments.

Keywords: Frictional heat generation, structural health indicators, condition monitoring, structural defect, non-destructive testing and evaluation (NDT&E)
Number of References cited: 19
Corresponding author: Dawood Desai (desaida@tut.ac.za)

16. **Experimentally validated numerical simulation of prediction of structural vibration frequencies from interfacial frictional temperature signature**

S.M. Talai, D.A. Desai & P.S. Heyns

Abstract: Friction studies have shown that the contact interface of dynamic structural components generally results in a temperature increase due to periodic motion of the boundary. Furthermore, the well-known heat conduction equation yields the temperature distribution. Subsequently, the aim of this study was to investigate the prediction of vibration frequency from the interfacial frictional temperature signatures of structures under excitation. In this work, an experimentally validated finite element (FE) model was developed using the commercial software ABAQUS. Tests were done on AISI 304 steel of healthy

cantilever beam-like structures coupled with a friction interface and subjected to forced excitations. A coupled temperature-displacement transient methodology was utilized to predict the frictional heat generation and subsequently the vibrational frequencies extracted from the temperature wave form, which in turn were validated by comparing them to the experimental results employing infrared thermography. The results confirmed the feasibility of using the interface frictional temperature signature to describe the vibration frequency with good accuracy and may be used to overcome some limitations encountered with conventional instrumentation such as strain gauge failures due to fatigue.

Keywords: Frictional heat generation, structural health indicator, condition monitoring, vibration frequency, infrared thermography.
Number of References cited: 24
Corresponding author: Stephen M. Talai (stevetalai@gmail.com)

17. Corrosion monitoring with Acoustic Emission of steel embedded in concrete that is subjected to different environmental conditions

T. Sigoba, M. Howse & Q.I. Sikakana

Abstract: The use of steel reinforcement in concrete structures is an established building code requirement for structural integrity. The Acoustic Emission (AE) technique has been used in industry to evaluate corrosion in reinforced concrete since the late 1970's and early 1980's [1,2]. The AE technique is well suited for limited access applications as the waves travel along entire structures. This study utilized five samples of mild steel imbedded in concrete subjected to different environmental conditions and the AE activity and intensities were recorded and compared. The environmental conditions were to simulate actual locations where concrete structure are built. The five samples consisted of uncoated mild steel bars embedded in concrete, which were then submerged in, drinking water; salt water; salt water (insulated steel); hydrochloric acid; salt water and copper forming a galvanic cell. The samples were kept at ambient temperature and monitored over a seven week period utilizing AE sensors with a resonant frequency of 30 kHz. The hydrochloric acid sample exhibited the highest cumulative AE energy, followed by the galvanic cell, salt water, drinking water and lastly salt water (insulated steel). The cumulative number of AE activity followed the same trend except for the saltwater and galvanic cell samples obtaining the fewer hits than the drinking water. These findings were confirmed, with the exception of the galvanic cell sample, by visual examination of the surface corrosion present on the samples post concrete removal.

Keywords: accelerated corrosion of steel; acoustic emission; unloaded reinforced concrete; environmental conditions; structural health monitoring
Number of References cited: 16

18. Variations in vibration responses of an ice-going vessel during wave slamming

C.M van Zijl & A. Bekker

Abstract: A polar supply and research vessel was instrumented with an accelerometer network to determine full-scale dynamic responses of the operational ship structure. The vessel in question is pre-disposed to problematic stern slamming. In a recent voyage to the Marginal Ice Zone, the vessel encountered extremely rough weather, including storm in a field of brash ice. During this voyage wave slamming occurred and ice debris was flung onto deck spaces. This work investigates the variation in vibration and modal responses, which result from harsh operational conditions. The aim

is to examine the feasibility of modal tracking towards potential long-term structural health monitoring and inverse force estimation. Three case studies are identified from operational data. The vibration responses are subjected to conventional time history analyses and newly developed slamming response analyses. LMS PolyMax automatic parameter selection is used to identify the changes in modal frequencies under stormy conditions. These values are reflected against results from a finite element analysis and earlier measurements in a harbor environment. In the investigated cases, the fundamental modal frequencies varied by 0.1 Hz in different operational conditions. It is found that rotational speed of the propulsion shaft corresponds to the modal frequency of the first bending mode. As such, this mode is not ideal for modal tracking because of harmonic contamination. The excitation of higher order bending modes could be an indicator of wave slamming, as these modes are not significantly excited in moderate seas.

Keywords: Operational modal analysis, ice-going vessel, modal tracking
Number of References cited: 16

19. **Remote Monitoring of Wind Turbine Blades based on High-speed Photogrammetry**

Miaoshuo Li, Xianghong Wang, Fulong Liu, Xiaoli Tang, Fengshou Gu & Andrew D. Ball

Abstract: The wind turbine energy industry has been growing rapidly in recent years. Due to extreme operating environments, condition monitoring of wind turbine blades is a challenging task and received extensive studies.The conventional methods based on contact transducers such as ultrasonic or fibre-optical strain gauge are expensive and complex to install and the measurement range is also limited to discrete points. To overcome this issue, this paper presents a new way of condition monitoring for the wind turbine blades based on a high-speed photogrammetry in combination with a scheme a non-contact excitation. The research progress is reviewed regarding to the condition monitoring techniques of wind turbine blades and development on photogrammetry. A photogrammetry system is built to identify the vibration modes of wind turbine blades without mounting any sensors on blades. An air impulse excitation system that consists of a solenoid valve and high-pressure air from air compressor is used to produce the artificial impulse excitation. A high-speed industrial camera captures the image and measures the dynamic displacement of the blades. The results obtained by photogrammetry is accurate and reliable, compared with that of conventional accelerometer-based measurements. Moreover, the faults caused by snow or ice covering are simulated by changing mass of blades, likewise fault of loosening the screws was also tested. The modal parameters extracted from baseline and faulty conditions show significant distinctions, which has affirmed that this vision method is effective and sensitive to blade faults.

Keywords: condition monitoring, wind turbine blades, photogrammetry, modal analysis, high-speed camera.
Number of References cited: 17
Corresponding author: Fengshou Gu (F.Gu@hud.ac.uk)

20. **An improved resonance demodulation technique based on spectral kurtosis and fault characteristic harmonic-to-noise ratio**

ChangYan, Jing Lin, Ming Zhao, liang Zeng

Abstract: Rolling bearings are widely used in energy, construction machinery and high-speed railway because of its strong load-bearing capacity and small start-up

torque. The faults of rolling bearings as the core component of the machine can lead to huge economic losses and even fatal accidents. The health monitoring and fault diagnosis of rolling bearings have attracted increasing attention over the past decades. Traditional spectral kurtosis (SK) method is commonly implemented by kurtogram to determine the resonance frequency band for demodulation. However, there exist problems when SK is applied to signals containing random strong interferences. As a result, envelope harmonic-to-noise ratio (EHNR) is proposed to reduce the influence of random strong interferences and strengthen the periodic components in the signal. Unfortunately, EHNR is not sensitive to fault impact when the periodic components in the signal are not related to the failure such as rotational frequency interferences and power frequency interferences. To overcome these limitations, this paper proposes an improved resonance demodulation technique (RDT) based on SK and fault characteristic harmonic-to-noise ratio (FCHNR). Compared with SK, the improved RDT has two distinct advantages. Firstly, the proposed method can be applied to the rolling bearings under the working condition with variable speed through integrating with order tracking technique. Secondly, the resonance frequency band is no longer solely determined by the maximum value of kurtosis or EHNR. Instead, the periodicity and impulsivity of rolling bearing fault can be taken into account simultaneously, thus the improved RDT has higher robustness. Finally, the improved RDT is validated by real fault data of railway bearings. The results show that the improved RDT can detect the fault of rolling bearing under variable speed with higher efficiency and superiority.

Keywords: spectral kurtosis; fault characteristic harmonic-to-noise ratio; resonance frequency band; order tracking

Number of References cited: 11

21. A vision of energy-based visualisation of large scale industrial systems for the purposes of condition monitoring

G. van Schoor & K.R. Uren

Abstract: Most large scale industrial systems can be viewed as processes that convert energy from one form to another. Energy is a universal quality of which the distribution holds meaning across physical domains i.e. thermal-fluid, mechanical, electrical and chemical. This paper presents a vision of using energy information of a process to visualise or characterise what is happening in the process with regards to energy. This energy information is then represented in a form that retains the structural information, making it possible to relate patterns in the representation to specific locations in the process. The energy attributes considered include energy flow rates between components of the system and the change in exergy flow rates across components. An energy representation of a process can form the basis for fault detection and diagnosis (FDD) or optimal control through the definition of a reference energy representation. The use of energy information linked to specific locations in the system, classifies the approach to FDD in the hybrid class which represents a hybrid between a pure data-driven and model-based approach. Attributed graphs are considered in this work as a structure that can describe the system's energy attributes while retaining structural information. The usefulness of the energy representations for the purpose of condition monitoring is illustrated through a few case studies. The case studies include a heated two tank system, a gas to liquids process and a Brayton cycle. The results illustrate that energy-visualisation as a means to condition monitoring shows promise in terms of detecting and diagnosing typical faults in large scale industrial processes where energy conversion is the main concern.

Keywords: energy visualisation, condition monitoring, large scale industrial systems, attributed graphs
Number of References cited: 20

22. A low-cost condition monitoring solution for industrial bakery equipment
H. Marais & J. Black
Abstract: Artisanal bakeries perform a critical function in many societies all over the world. However, artisanal bakers struggle to compete with commercial bakeries' efficiencies due to the lack of technology deployment. One aspect that could lead to significant improvements of up to 36% are improved maintenance processes. Unfortunately the prohibitive costs associated with commercial condition monitoring equipment and a lack of proven efficiency improvements in the artisanal bakery hamper the adoption of such technologies. In this work a low-cost, remote, condition monitoring and measurement system is developed that makes use of commercial off-the-shelf technology. The prototype system provides immediate return on investment to the baker and maintenance staff while at the same time gathering high-resolution data for the development of more advanced diagnostic algorithms. The latter is especially of importance due to the lack of diagnostic algorithms capable of handling the variance introduced by the viscosity characteristics of dough and other mixer products.
Keywords: Practical, Low-Cost, Condition Monitoring
Number of References cited: 16

23. Online Performance Monitoring of Discrete Legs in a Convective Heat Exchanger of a Coal Fired Power Plant Boiler
G.T. Prinsloo, P.G.Rousseau & P. Gosai
Abstract : The convective pass of a coal fired power plant boiler consists of several heat exchanger stages. Knowledge about the real-time performance of these heat exchangers is valuable for informing operational practices, preparing maintenance strategies and performing root cause analysis. For the specific boiler being studied, the steam in each stage is split into four legs that run in parallel across the boiler width. These legs alternate between the sides and across the centre of the boiler to disperse the effects of an uneven heat profile along the cross section of the flue gas flow path. Previous work has shown that the typical measurement setup in these boilers allows the performance parameters of each complete heat exchanger stage to be determined online using one-dimensional mass and energy balance equations[1][2]. However, flow and temperature maldistribution occurring in steam headers and the flue gas flow path leads to a non-uniform distribution of the performance of individual legs. We present and compare two methods of determining the performance of the individual heat exchanger legs online from process measurements. The first method employs soft sensors based on a thermo-fluid process model that not only accounts for the mass and energy balance, but also solves for momentum conservation. This allows the prediction of the flow distribution in common headers and ducts. The Flownex one-dimensional thermo-fluid network software is used for the modelling effort. The second method is based on the reconstruction-based contribution method which compares measured data to plant performance signatures that allows identification of deterioration of individual heat exchanger legs. These signatures are originally generated with the aid of the process model developed above for different fault scenarios. A case study of a final superheater stage is presented to assess the benefits and limitations of each method. These methods enable the performance of individual legs to be monitored online from

process measurements and therefore provide higher resolution results within a heat exchanger stage.

Keywords: heat exchanger modelling, model-based performance monitoring, fault signatures, data reconstruction, diagnosis
Number of References cited: 12
Corresponding author: Gert Thomas Prinsloo (prnger003@myuct.ac.za)

24. Simulation Based LOX/Methane Rocket Engine Fault Features Analysis

Jingyu xiong, Jianjun Wu & Yuqiang Cheng

Abstract: LOX/Methane Rocket Engine has attracted widely attention due to its advantages, such as economy, nontoxicity and good comprehensive performance. In order to solve the problem of parameter selection and optimization for LOX/methane rocket engine health monitoring, the fault features of reusable LOX/methane rocket engine are investigated and the key parameters are selected for engine health monitoring. Due to the lack of fault sample data, it is difficult to obtain the features of fault modes. So the modular model library was built on the basis of lumped parameter approximation, and the dynamic simulation of the work process for the engine was carried out on the basis of MATLAB Simulink system. To establish fault simulation model, fault factors are added into the balance equations of components. Comparison results show that the simulation results are in good agreement with the real test data of the engine. It can complement important fault sample data in the research of fault detection and diagnosis methods for the engine. Using these data we can analyze the change of parameters in the dynamic transition process from a normal state to a fault state. Finally, the key parameters for typical fault detection and diagnosis are obtained.

Keywords: LOX/Methane Rocket Engine; Modelling and Simulation; Fault Features Analysis; Parameter selection; Fault Simulation
Number of References cited: 7
Corresponding author: Jianjun Wu (jjwu@nudt. edu. cn)

25. Pipe network leak detection: Sensor placement optimization using Support Vector Machines and a model-based leak detection technique

J.C. van der Walt, P.S Heyns & D.N Wilke

Abstract: This paper investigates a model-based method to detect leaks in water distribution networks. The model is used to generate data on which a Support Vector Machine is trained to locate and estimate the size of leaks on an experimental network. In this paper the leak location and size for an experimental network are shown as well as the effect of pressure sensor placement. The experimental investigation includes model calibration and the estimation of two simultaneous leaks in the network. The estimated solution for the experimental network showed the leaking pipe to be detectable with the leak sizes estimated within 0.7mm. The sensor placement optimization was completed with an exhaustive search algorithm and by removing sensors with the smallest impact on the detection accuracy, where it was found that training time of the SVM can be reduced significantly by using less sensors. Additionally, using less sensors for the estimation of the leaks was found to increase the probability up to 38% in finding the leak.

Keywords: Condition Monitoring, Fault Detection and Localization, Practical Low-Cost Condition Monitoring, Leak Detection
Number of References cited: 16

26. Performance visualisation of a transcritical CO_2 heat pump under fault conditions

J.J.A. de Bruin, K.R. Uren, G. van Schoor & M. van Eldik

Abstract: Heat pump systems have gained acceptance and appeal as an energy efficient alternative to electrical geysers for the purpose of water heating. This paper investigates a next-generation transcritical heat pump system using carbon dioxide as its working fluid. The water-to-water heat pump system used in this study simultaneously produces cooled and heated water. The heat pump system consists of four components. An evaporator is used to extract heat from a stream of water in order to evaporate and then superheat the working fluid. Chronologically after the evaporator comes the reciprocating compressor that raises the pressure and temperature of the working fluid to enable its circulation through the system. The gas cooler follows the compressor and is responsible for transferring heat from the working fluid to the second stream of interacting water. The expansion valve causes the working fluid, that leaves the gas cooler component, to undergo a large pressure drop and phase change. The working fluid that leaves the expansion valve enters the evaporator component for evaporation and superheating. The continuous conversion between different forms of energy, as enabled by the heat pump's components, make heat pumps susceptible to many different types of fault conditions. In this paper, the identification of faults that can occur during the operation of a heat pump and the degrading effects thereof on system performance were investigated. Fault detection and monitoring of the heat pump system via various visual representations are proposed. Specifically; fouling, working fluid leakage and coinciding water pump failure as system faults were investigated. The visual representations could uniquely identify and distinguish between the investigated fault conditions. The graphs were also able to monitor the severity and progression of system faults and their contribution to performance degradation.

Keywords: Transcritical heat pump, carbon dioxide, diagnosis, system performance, performance visualisation

Number of References cited: 14

Invitation to Call for Papers & Exhibits for the
32nd International Congress & Exhibition on
Condition Monitoring & Diagnostic Engineering Management
COMADEM 2019
3rd to 5th September 2019
University of Huddersfield, West Yorkshire, UK

The University of Huddersfield is delighted to invite the worldwide Asset Management and CM communities to this premier event. We are confident that that the Congress will be an outstanding international event proving ground for industrialists, scientists and exhibitors.

Main conference theme:

The Congress will cover a wide range of subjects in the field of maintenance, condition monitoring, structural health monitoring, non-destructive testing and related subjects and will include:

- plenary keynote presentations
- specialised keynote presentations
- invited overview presentations on hot topics of asset management and condition monitoring
- scientific-technical presentations
- industrial case study presentations
- poster sessions
- themed masterclasses, industrial sessions and workshops
- an exhibition and exhibitor plenary presentations
- a panel session "Novel directions in condition based maintenance"

Papers that will be submitted will be subject to peer review by the well-known CM scientists. Selected papers will be published in the: International Journal of COMADEM and International Journal of Engineering Sciences (SCMR). The proceedings of COMADEM 2019 will appear in the Open Access Journal of Physics, Conference Series (JPCS), which is part of IOP Conference Series.

Important Dates and Deadlines

Call for papers	15th October 2018
Deadline for submission of abstracts	11th February 2019
Notification of acceptance of abstracts	8th March 2019
Deadline for submission of papers	10th March 2019
Notification of acceptance of papers	24th March 2019
Delegate early bird fee deadline	7th June 2019

We are pleased to offer four sponsoring packages: Platinum, Gold, Silver and Bronze and we will world-wide disseminate sponsor activities. For up-to-date information, please visit our website: **www.comadem2019.com**

Aim & Scope of this Journal

The International Journal of Condition Monitoring and Diagnostic Engineering Management (COMADEM) is the major interdisciplinary and proactive-based international journal covering all aspects of monitoring, diagnosing, prognosing, maintenance & smart management of all industrial assets (both human and physical) throughout its useful life-cycles. Its primary aims are: (a) to discover, generate & disseminate up-to-date knowledge, (b) to network and collaborate between industries, academic and research establishments, (c) to promote entrepreneurial and innovative culture, (d) to promote international standardization, d) to promote education and training at all levels.

This Journal is published in collaboration with the University of Huddersfield, UK & Lulea University of Technology, Sweden.

Authors Instructions

Manuscript Submission The work submitted must be original and should be written in good English. It also implies that the paper has not been published anywhere else and that it is not under consideration for publication by any publishers. All the authors (if there are multiple authors) have the tacit approval and permission from their organization (s) to publish their paper they have submitted. The publisher will not be held legally responsible should there be any claims for compensation.

Permissions: Authors wishing to incorporate any figures, tables, or text passages that have already been published elsewhere bear full responsibility to obtain permission from the copyright owner(s).

Online Submission: Authors should submit their full-length paper in A4 size format using the template prescribed in the journal's website: **www.comadem.co.uk.** Papers not prepared as per COMADEM template will not be accepted for publication. All figures, tables and sketches should be of the highest quality. All figures, tables and sketches must be inserted in the appropriate places in the main body of the paper. It is the authors' responsibility to ensure complete compatibility of submitted paper. The finally prepared full-length paper should be submitted in the WORD format on line to **rajbknrao@btinternet.com**

Copyright Transfer: Authors whose manuscripts are accepted for publication must transfer copyright to COMADEM International. This transfer involves publication only and does not in any way alter the author's traditional rights regarding his/her manuscript. The journal and all papers published herein are protected by copyright. No part of this journal may be translated, reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission of the publisher. COMADEM International supports the need for author(s) to share, disseminate and maximize the impact of their research findings by publishing and reproducing their paper as they wish. Authors are required to fill in a Copyright Form

Obligation: The corresponding author is supplied with a free complimentary copy of the journal in which the author's paper has appeared. Additional copies of the journal in electronic form can be purchased online by visiting our website: http://www.comadem.co.uk

INTERNATIONAL JOURNAL OF COMADEM

Volume 22 Number 1 January 2019 ISSN 1363 – 7681

CONTENTS

This Journal is indexed in

Elsevier Bibliography Index (SCOPUS INDEX H), INSPEC, Acoustics Abstracts, Engineering Index Monthly, International Aerospace Abstracts, etc.

Published by

COMADEM International, 307 Tiverton Road, Selly Oak, Birmingham B29 6DA, UK

Tel/Fax: +44(0)121 472 2338 E-mail: rajbknrao@btinternet.com Website: www.comadem.com.uk