The Society for Machinery Failure Prevention Technology

2021 Winter Newsletter

Letter from the Chairman

I pray this newsletter finds you, your colleagues, and your family keeping healthy and safe. We at MFPT are hopeful 2021 will be an improvement over 2020, and ultimately, we can return to face to face meetings and conferences. I know I truly enjoy sharing a meal with my friends and colleagues.

As we begin our new year, MFPT continues to provide educational webinars and discussion forums related to machinery failure prevention technology. I encourage each of you to participate, perhaps by sharing a project you are working on. I'll share my project(s) within the Data Management and AI Focus Group.

In review, MFPT had some high points in 2020.

- If you missed it, you can still view our MFPT 2020 virtual conference sessions at: https://www.mfpt.org/mfpt-2020-keynote-session-and-workshop-listing/. You can interact with MFPT regarding any of the sessions at our discussion forum on LinkedIn: https://www.linkedin.com/groups/8920840/
- We hosted our first Webinar, "Motion Magnification and Other Approaches to Machinery Diagnosis" which you can review here: https://www.screencast.com/t/bhxOeRQD5bl
- We have also hosted a second Webinar, "Induction Motor Diagnostics Using Motor Current Signature Analysis" which you can review here: https://www.screencast.com/t/LDcR93Fww6ML

Be sure to share comments and questions on any of these materials in our online discussion group at https://www.linkedin.com/groups/8920840/

Subscribe to our mailing list at https://www.mfpt.org/contact/ to receive this newsletter in your inbox and to be notified of additional educational events. MFPT is planning additional webinars this winter and spring. Stay tuned for additional webinars.

We look forward to your participation in MFPT and our unique LinkedIn group.

Stay Safe and Healthy,

Preston T. Johnson

Chairman Preston Johnson

Focus Group Discussion

MFPT 2020 Conference Archive

Articles:

Electric Motor Mounting Consideration for Failure Prevention.

by: Mantosh Bhattacharya, Focus Group Chair: Failure Analysis

Normally, we can see that small electric motors up to range of 55 KW are mounted for Fin Fan Lube air coolers as shown in picture below. Some end users do experience repetitive bearing failure at fin fan cooler especially at bearing motor.

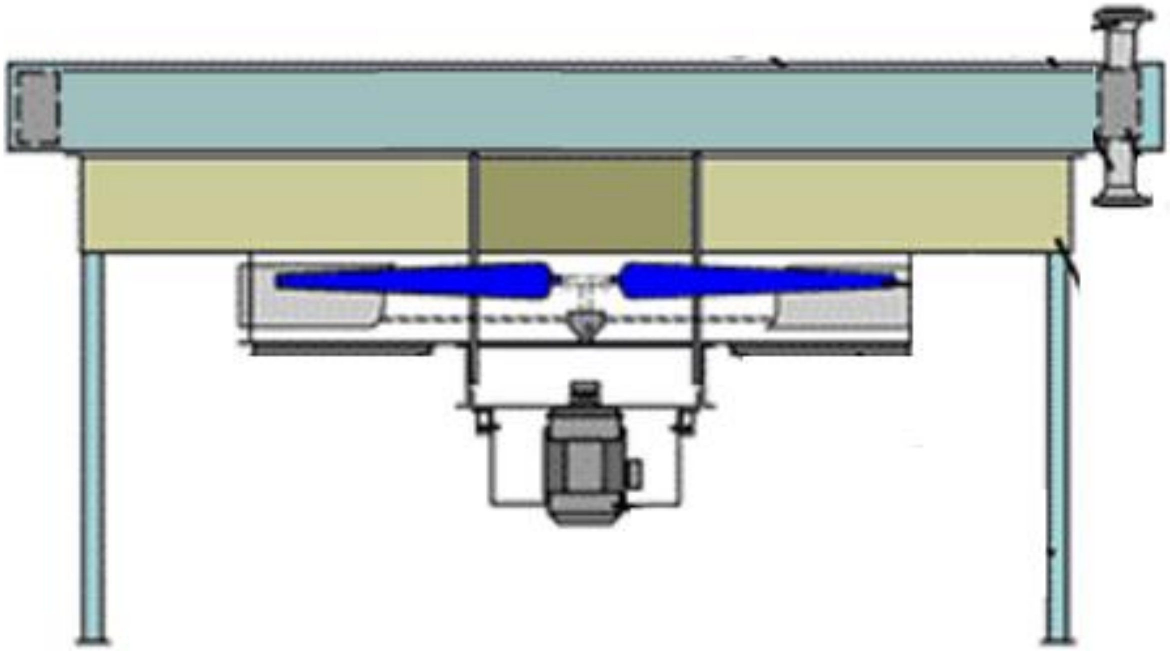


Fig 1: Fin Fan cooler with vertical mounted motor

After much iterative solutions, it is found that horizontal motor type is mounted vertically. This had led to higher vibrations when run. Although field service technicians tried to resolve the issue by strengthening the base, but it did not solve the basic issue of wrong installation. Additionally, this issue had created issues including failure of windings and lead to failure of some motors. In many cases Lube Oil Air cooler supplier provided Foot Mounted (Horizontal) Motor instead of Flange Mounted (vertical) Motor which is generally not correct.

There are two different standards—NEMA and IEC. The standard IEC mounting position as per IEC 60034-7 places the junction box on the top of the motor, known as the IM B3 mounting position in IEC frame (or F3 in NEMA frames). As we can see that there is no difference on two design - IM 1001 / IM B3 Horizontal on Floor Foot and IM 1031 / IM V6 Vertical on wall Foot. In a general glance we cannot differentiate the two types.

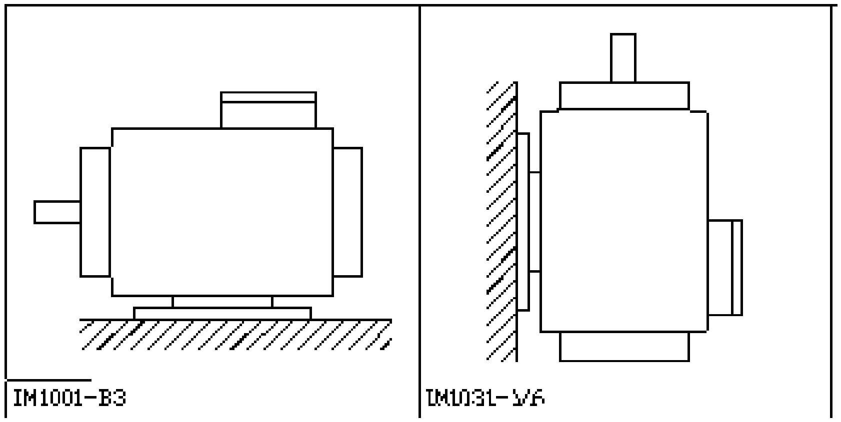


Fig 2: IEC 60034-7 based motor mounting (left – Horizonal mounting right – vertical mounting with plate)

When bearings designed for a horizontal oriented mounting operation the axial load carrying capacity is lesser as they do not have to take rotor and motor casing load due to vertical orientation and operation. The bearings systems are different between the two motor types. Horizontal motors use either ball or roller bearings designed to handle the rotor weights. Vertical motors use single / double thrust bearings along with a single guide bearing. Thrust bearings can handle significantly more load than the bearings in a horizontal motor.

So, axial load incurred in bearings mounted in vertical orientation (designed to be installed in horizontal direction) shall be higher and bearings may not be meeting L10 life with additional axial load.

Vertical mounted motors are expected to handle the additional axial thrust associated with motor weight itself. They typically have a single thrust bearing, along with a single guide bearing. Thrust bearing selection for vertical pump has the axial load much higher than typical horizontal motor.

Following are actions while converting motors from horizontal mount to vertical mount. Examine the mechanical factors that should be considered when applying a horizontal ball-bearing motor in a vertical mounting position.

To solve this, we will need the weight of the rotor assembly on the bearings and ensure it is lower than 50% of axial load carrying capacity of selected bearing. If dealing only with axial load, a simple method can be used. The axial load capacity of a deep-groove ball bearing is 0.5 times the basic static load rating, designated C0 in bearing manufacturer data tables. Consider dynamic loads as well such as radial load should be combined with the axial load The bearing life value can be obtained using an online bearing-load calculator available at several bearing manufacturer websites. All factors such are to be used with good deliberation. Based on comparison with calculated L10 life and required L10 life as mandated in project specification, the bearings may be changed to ensure suitability of vertical mounting of horizontal motors.

A drip cover may be added to a drip-proof motor that is mounted shaft down to provide additional protection against entry of liquids such as rainwater.

Please post your comments and questions about this article on our LinkedIn discussion forum!

Data Management at Small Refinery, an Ongoing Use Case

by: Preston Johnson, CBT, Focus Group Chair: Data Management and AI

In my work for CBT, I am working to setup a predictive analytics platform for a small refinery. There, I am monitoring both vibration data from critical pumps and process data. Together, these promise to provide insight to operations and maintenance. Here is a status update on this project.

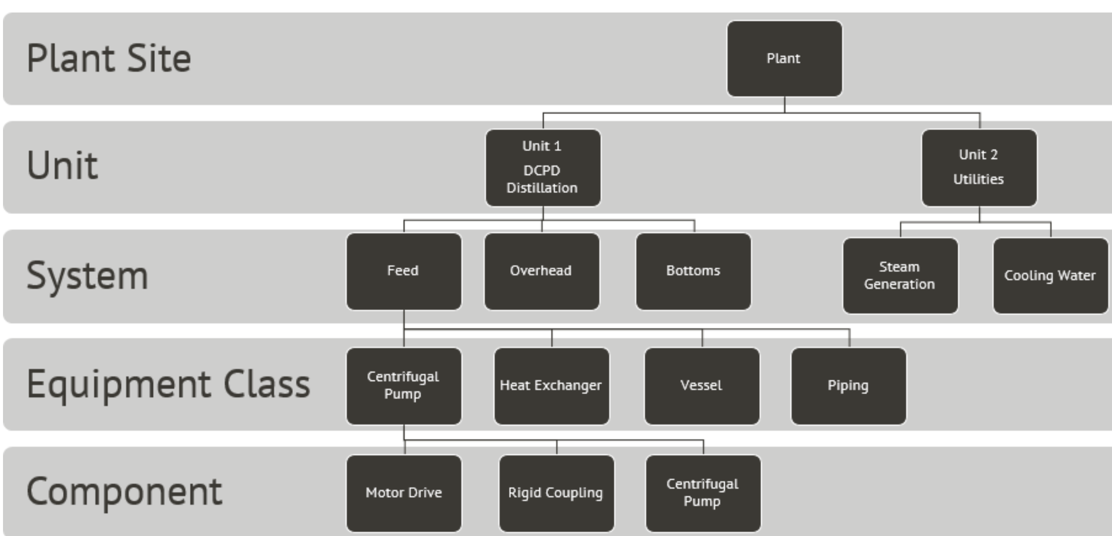
Introduction

With the advent of low cost industrial IoT data collection tools, data collection becomes available daily, and is available to merge with operational data. With synchronized asset monitoring, operational data, and advanced analytics, predictions of future maintenance and operational adjustments are made. This improves maintenance efficiency, increases uptime and output, and lowers operational costs.

To reach the objective of monitoring equipment and integration with maintenance and operations applications, an ecosystem of IT and OT technologies and vendors is often the norm. To bring the ecosystem together, it is first necessary to build a roadmap that includes an understanding of the assets and asset modeling process, of the tools for remotely monitoring assets, and of the analytics that drive maintenance and operations activities. The roadmap then includes asset digital modeling, industrial IoT for monitoring, a range of analytics to drive outcomes, and delivery of information to human decision makers.

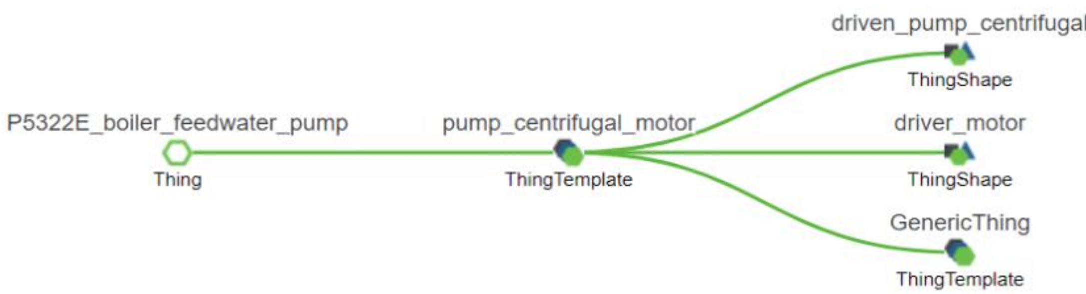
The Modeling Process

In understanding our assets, we should build a series of models that describe the important assets in the facility. These do not need to be high end digital twins, instead this author recommends building an object-oriented asset registry of the equipment. Consider starting with the ISO 14224 asset registry hierarchy to build the equipment object with the plant, unit, system, and equipment type with equipment ID and geographic coordinates.

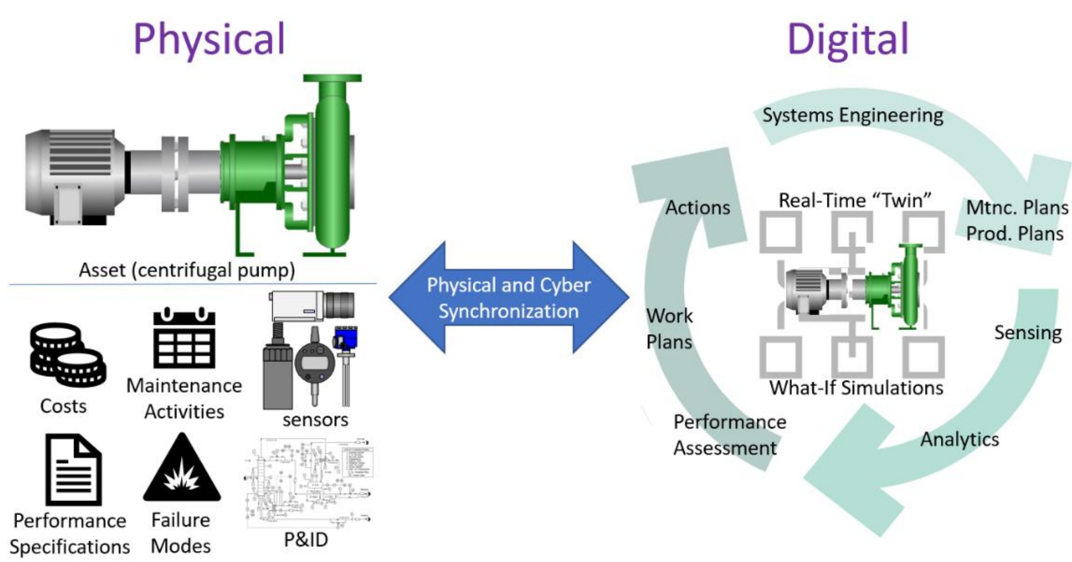


Consider building inheritable components with details such as a motor, gearbox, belt drives, fan, centrifugal pump and other driver and driven units. The equipment object then inherits components and their properties to create a specific equipment instance. In this way, it is possible to describe a plant with a core set of objects that can be updated over time. We can add sensor packs to the equipment instances, as well as analytics. We then add displays at the unit level with drill down ability to systems and equipment inclusive of alerts and alert management. These displays provide operations and management with dashboards to see plant function at multiple levels.

At Texmark Chemicals for example, the plant is comprised of several distillation units and utilities including cooling water, steam generation, hot oil, and water treatment. Common equipment types include motor driven centrifugal and vacuum pumps, valves, motor driven cooling tower fans, distillation columns, heat exchangers, condensation pots, tanks, and piping. By connecting to engineering documentation and process values from the control system we are building a digital twin, first at the equipment class level and by association, at the system and unit level.



For each instance of equipment, our digital twin pulls several classes of information from the “physical” world including engineering documentation, likely failure modes, plant location and function, financial costs, maintenance costs, and real time sensor data.

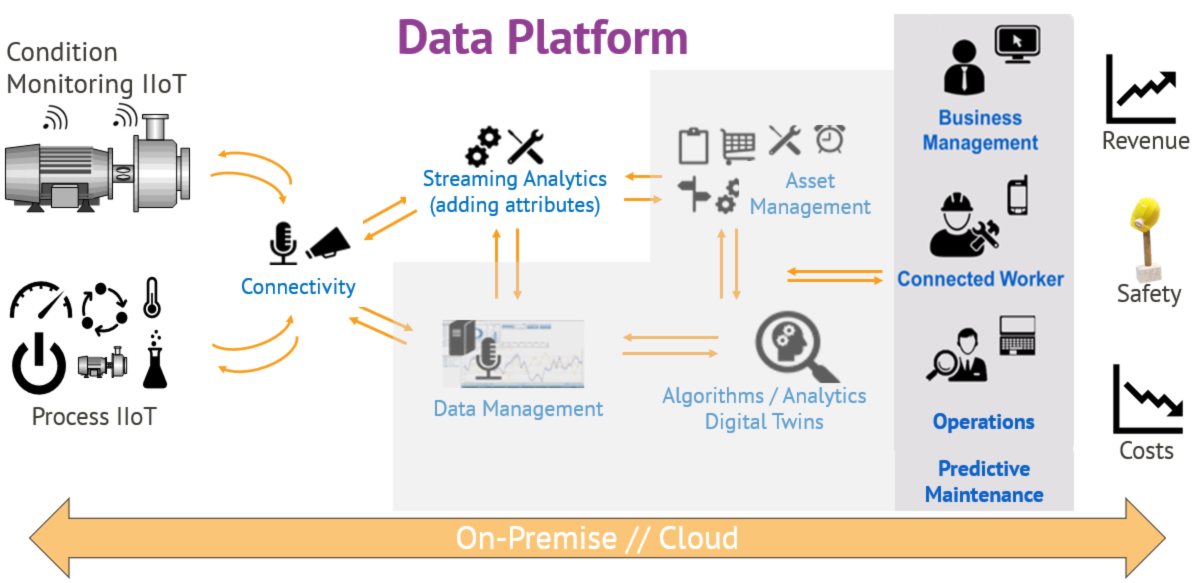


Digital Twin Concept

We use the engineering data to derive maintenance schedules, performance expectations, and threshold levels for field measurements. We try to use existing process sensors with supplemental Industrial IoT sensors to monitor for performance and the existence of equipment failure modes. We may need to schedule human observations using digital connected worker tools for route-based monitoring. This first pass of monitoring and alerts yields a level of anomaly detection now available outside of the control room.

Data Management

Connections to most real-time data uses KEPServerEX® to connect to the control system and pull tags associated with each piece of equipment. This provides equipment activity and performance information. The digital model is equipped with performance specifications such as a pump performance curve. In some cases, vibration sensors have been added to watch for mechanical condition degradation. Process data is stored in the plant historian and shared real-time with the digital twin model. High density vibration data that is 10's of thousands of samples per second are stored in binary files indexed with time stamps and calculated attributes. KEPServerEX subscribes to the calculated attributes using the OPC UA protocol.



Data Synchronization

It is important for all data to have time synchronized time stamps. Time synchronization of data is needed to determine sequence of events and to determine cause and effect. Control systems data and condition monitoring data typically are provided with time stamps from computers with network time protocol synchronized clocks. Time synchronization is improving with the advent of Time Sensitive Networks (TSN) which is a new IEEE standard for time synchronization that works at the control system level. Going further, it is also necessary to have time accurate time values for quality control laboratory results, operator adjustments to control parameters, and maintenance activities such as lubrication. These latter "events" play a role in our more advanced analytics.

Analytics

Our current work is building out the models, connecting the data, and providing the base dashboards for viewing data and ascertaining performance. Using the performance specifications of the model, as well as baselines from historical data, we are defining alert thresholds and implementing an alert management system. We expect to have laboratory quality reports from production, and to use a range of machine learning to identify the "drivers" of high quality. We will use machine learning to anticipate equipment performance degradation and applications integration to post work requests to prevent machinery failure.

Summary

This machinery and process failure prevention project is ongoing. We have the compute and software resources to gather, analyze, and report data driven findings. Stay tuned for updates each quarter. Please post your comments and questions about this article on our [LinkedIn discussion forum]!

Induction Motor Diagnostics Using Motor Current Signature Analysis (MCSA)

by: Suri Ganeriwala, SpectraQuest, Focus Group Chair: Signal Analysis

Induction motors are the main prime mover in industrial applications. Fault diagnosis of an induction motors fault detection is a serious issue for improving plant reliability. To perform proper fault diagnosis, it is essential to understand underlying principles of an induction motor operation and the effect of loading on the defect signatures. Motor current signature analysis (MCSA) is a powerful tool for diagnosing induction motor problems. A tutorial was presented by Dr. Suri Ganeriwala, providing attendees with the fundamental principles of an induction motor in a simplified manner without resorting to the underlying complex mathematical structure. Presentation discussed results of experiments conducted with seeded faults in bearings, mechanical unbalance, broken rotor bars, air gap eccentricity, and shorted turn. Tests were performed on intentionally faulted motor with varying degrees defects. Results indicate significant components in motor current spectrum due to electro-mechanical malfunctions.

The rotor of an induction motor must run slower than the line frequency. The difference between the speed is called slip. Proper understanding and application of the slip frequency is crucial in the application of MCSA for diagnostics. When a balanced voltage is applied to the stator, a rotating magnetic field is generated at the line frequency. This stator field induces a rotating magnetic field in the rotor as discovered by Michael Faraday around 1820. The interaction of theses to fields produces sufficient torque to turn the rotor shaft and the mechanical load attached to it. A few of the equations used in the MCSA analysis are as follows:

Slip frequency, s: $f_s[Hz] = \frac{2f_l}{p}$

Broken Rotor Bar: $f_{sb} = f_1 \pm 2sf_1$

Airgap Eccentricity: $f_{ec} = \left\{2(R.k \pm n_d)\left(\frac{1-s}{p}\right) \pm v\right\} f_l$

Shorted Turn: $f_{st} = \left\{2k\left(\frac{1-s}{p}\right) \pm v\right\} f_l$

f_s = synchronous speed of induction motors, f_l = line frequency, p = number of poles
R = number of rotor bars, f_{ec} = frequency component of eccentricity faults,
k = positive constants or zero
n_d = 0 for static eccentricity and 1, 2, 3 … for dynamic eccentricity
f_{st} = components that are a function of shorted turns, k = 1, 2, 3 … and v= 1, 3, 5...

Readers can view the video at: https://www.screencast.com/t/LDcR93Fww6ML

A copy of slides is available by contacting Dr. Suri Ganeriwala at suri@spectraquest.com

MFPT Focus Group Areas: https://www.mfpt.org/focus-groups/

The Society's mission (of providing an interchange of technical information for the benefit of owners and operators of mechanical machinery) is facilitated within our focus groups. The focus groups include:

All the focus area disciplines interact with each other. For example, systems engineering identifies functional requirements of equipment and their likely failure modes in the application. This engineering work drives human inspection tasks as well as automated inspections. Sensors give us quantifiable data about the physical world, and signal analysis transforms that data into condition and performance indicators about our equipment. Exploring and interpreting these indicators are diagnostic, prognostic, multivariate data analytics, and analysis of failures. In each of these areas, the performance of the human is always an element of success and efficiency.

Thru discussions in our focus groups, participants gain knowledge that helps drive towards failure prevention within the participant's organization. Our discussion forum (see link above) makes it easy to post a question, comment, article, etc., for all the MFPT community to see.

Each year, we host sessions in each of these areas at our annual conference and our webinars. Join our mailing list to stay informed.

Systems Engineering

FG Chair: John Lucero, NASA, Glenn Research Center

The Systems Engineering Focus Group (SEFG) provides a forum to foster the development and application of a systems approach to complex technical problems. Due to the interdisciplinary technical structure of MFPT, technical processes representing System Design, Technical Management and Product Realization are instrumental in the development and integration of new technologies into mainstream applications. The SEFG will encourage the application of these Systems Engineering tools to problems posed by the MFPT community.

MFPT 2020 included 2 sessions in the Systems Engineering track:

- Additively Manufactured Metal Powder Gas Atomized in a Mobile Foundry from Recycled Scrap for Lightweight Protection Applications
- Resonance Effect, Critical and Resonance Velocities Applied to Diagnostics, Stability and Balancing Methods of Turbine and Generator Rotors over 40 MVA

You will find these in our MFPT 2020 conference proceedings.

Sensors

FG Chair: Ed Spence, Machine Instrumentation Group

The Sensors Focus Group (SFG) facilitates the discussion of sensors for Machinery Failure Prevention. Discussions include new sensor technologies and the means to connect them, data driven approaches to data analysis, and developments under the Industrial IoT umbrella.

Ed Spence, our Sensors Focus Group Chair, hosted a tutorial:

- Accelerometers for Machine Health Monitoring and Diagnostics

And we hosted several sessions with sensors as the focus:

- Complimenting acceleration measurements with advanced strain gauge technology
- Miniature Solid-State Batteries for High Temperature Industrial Sensors
- Combining Wear Debris and Vibration for a More Complete Understanding of Machinery Health

You will find these in our MFPT 2020 conference proceedings.

On Oil Condition Monitoring

By Christopher Nemarich and Paul Howard

The SFG and the MFPT community are looking to build on the progress we made to establish the foundation for the development of a standard for Online Oil Condition Monitoring. It is our goal to hold additional technical sessions on Oil Condition Monitoring. If you have research, applied experience or products that support online oil condition measurements we would welcome your input.

Signal Analysis

FG Chair: Suri Ganeriwala, SpectraQuest

The Signal Analysis Focus Group (SAFG) facilitates the discussion of data acquisition, signal analysis, diagnostics, artificial intelligence, logicians, etc. A core focus is signal processing (of all sensor type data) to assess the condition of components, subsystems, systems accurately and reliably in enough time to maximize reliability and minimize costs.

MFPT 2020 offered several sessions from our Signal Analysis group:

- Signal Processing to Reduce the Effect of Gear Dynamics (1st place paper)
- Improved Spectral Estimation of Signals using Quadratic Interpolation
- Synthetic Signal Modeling – Parts 1, 2, and 3
- Three-dimensional spectral analysis of large data sets

You will find these in our MFPT 2020 conference proceedings.

Also, MFPT hosted a motor current analysis webinar, "Induction Motor Diagnostics Using Motor Current Signature Analysis" which you can review here: https://www.screencast.com/t/LDcR93Fww6ML

Data Management and AI

FG Chair: Preston Johnson, CBT

The Data Management and AI Focus Group (DM&AIFG) supports the discussion of data management tools, capabilities and standards that facilitate the detection and measurement of failure modes; that facilitate monitoring machinery and structural health; and that facilitate maintenance decision making. Participate in discussion of best practices and options for collection, advanced analysis, and dissemination of technical information for all sensed parameters.

MFPT 2020 offered several sessions from our Data Management and AI focus group:

- Data Driven Method for Detection of Malfunctions of Large Turbomachinery During Transient States
- A Journey from Reactive to Proactive Maintenance using Industrial IoT Technologies in a Chemical Processing Plant
- A Method of Fusing Acoustic Emission and Vibration Data for Gearbox Fault Diagnosis

You will find these in our MFPT 2020 conference proceedings.

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Diagnostics and Prognostics

FG Chair: Hoffy Hoffmeister, Ridge Top Group

The Diagnostics and Prognostics Focus Group (D&PFG) provides a forum to foster professional collaboration in the practice and technology of Prognostics and Health Management (PHM). The D&PFG provides and entry point for members new to the field of PHM and a forum for experienced professionals to collaborate on the most pressing problems. D&PFG encourages the use of standards and the application of PHM techniques across multiple domains.

The MFPT D&PFG is a group of professionals working to advance the field of PHM by collaborating on technical issues and sharing relevant industry information. Sample discussion areas include: Mechanical and electronic PHM, Prognostic methods and technology, PHM Standards, PHM case studies.

MFPT 2020 offered several sessions from our Diagnostics and Prognostics focus group. Our FG Chair provided an excellent tutorial on *Prognostic Health Monitoring.* Other sessions included:

- Unlocking the Mysteries of the Load Zone in Rolling Element Bearings
- A Two-Plane Balancing Method for Detection and Correction of Shaft Unbalance
- Induction Motor Diagnostics Using Vibration and Motor Current Signature Analysis (MCSA)
- New Motion Amplification Developments
- Using Accelerometers to Detect and Determine the Severity of Pump Cavitation
- Cases of Motion Magnified Video (AKA Video Vibration Amplification) Applied to Machinery Diagnosis
- Combining Wear Debris and Vibration for a More Complete Understanding of Machinery Health

You will find these in our MFPT 2020 conference proceedings.

We also hosted our first Webinar, “Motion Magnification and Other Approaches to Machinery Diagnosis” which you can review here: https://www.screencast.com/t/bhxOeRQD5bI

Failure Analysis

FG Chair: Mantosh Bhattacharya, Petrofac

The Failure Analysis Focus Group (FAFG) fosters the development, utilization, and enhancement of failure analysis techniques and methodologies. Lessons learned are conveyed to the MFPT Community, to prevent recurrence of failures, saving precious resources. The FAFG engages with other MFPT Focus Groups to show why failure analysis is an integral part of the product life cycle.

MFPT2020 offered several sessions from our Failure Analysis focus group:

- Tutorial: *Root Cause Analysis: It's a Money Maker, Not a Money Taker!!*
- Right Sizing of Gear Box for a Centrifugal Compressor with Synchronous Motor as Driver
- Cases of Vibrations in High Speed Pinion in Low Load Condition in API 613 Turbo-gears.

You will find these in our MFPT 2020 conference proceedings.

Human Systems Monitoring

FG Chair: Mark Derriso, US Airforce

The mission of the Human Systems Monitoring Focus Group (HSMFG) is to create an international forum where academia, industry and government agencies can discuss the state of the art in the area of human monitoring systems technologies. Topics of interest include but are not limited to wearable sensor technologies, data acquisition and management architectures, data analytics and assessment methodologies and health, fitness, and human performance monitoring techniques for industrial and military applications.

The MFPT HSMFG is a group of professionals working to advance the field of human systems monitoring by collaborating on technical issues and sharing relevant methodologies and approaches from academia, industry, and government to advance the state of the art.

MFPT 2020 offered several sessions from our Human Systems Monitoring focus group:

- Connected Worker for Work Execution Performance Enhancements
- Management of Stress– A Mechanical System Simulation Approach

You will find these in our MFPT 2020 conference proceedings.

Publications:

MFPT members have published several books on failure prevention technology subjects. These include:

- "Prognostics and Health Management: A Practical Approach to Improving System Reliability Using Conditioned-Based Data", co-authored by James P. Hofmeister

  Prognostics and Health Management provides an authoritative guide for an understanding of the rationale and methodologies of a practical approach for improving system reliability using conditioned-based data (CBD) to the monitoring and management of health of systems. This proven approach uses electronic signatures extracted from conditioned-based electrical signals, including those representing physical components, and employs processing methods that include data fusion and transformation, domain transformation, and normalization, canonicalization and signal-level translation to support the determination of predictive diagnostics and prognostics. Written by noted experts in the field, Prognostics and Health Management clearly describes how to extract signatures from conditioned-based data using conditioning methods such as data fusion and transformation, domain transformation, data type transformation and indirect and differential comparison.

- "Condition Monitoring Algorithms in MATLAB®": Offering the first comprehensive and practice-oriented guide to condition monitoring algorithms in MATLAB®, by Adam Jablonski. This book is available from Springer at the above link.

  This book offers the first comprehensive and practice-oriented guide to condition monitoring algorithms in MATLAB®. After a concise introduction to vibration theory and signal processing techniques, the attention is moved to the algorithms. Each signal processing algorithms is presented in depth, from their basics to the applications, including extensive explanations on how to use the corresponding toolbox in MATLAB®. In turn, the book describes several techniques for synthetic signals generation, as well as vibration-based analysis techniques of large data sets. Finally, it shows readers how to directly access data from industrial condition monitoring systems (CMS) using MATLAB® .NET Libraries. Bridging between research and practice, this book offers an extensive guide on condition monitoring algorithms to both scholars and professionals.

Other Publications

You will find many of our conference publications at MFPT.org, https://www.mfpt.org/publications/. We are working to improve the listing and indexing, yet feel free to search today for your key words.

MFPT

Going Forward

The Society for Machinery Failure Prevention Technology (MFPT) continues its mission of providing a technical interchange of MFPT topics. We look forward to our conversations, and our in person meeting the week of July 12, 2021 in Arlington Texas at "Live at Loews". Save the "date" and stay tuned for more details.

Please also follow MFPT
at https://mfpt.org
and on our LinkedIn discussion forum at MFPT: Society for Machinery Failure Prevention Technology (https://www.linkedin.com/groups/8920840/).
and on Twitter
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