Presenting Author: Bob Randall **Ser:** 1

Organization: University of New South Wales

Country: Australia

Paper Title: **Envelope Analysis – A Tutorial**

Co Authors:

Abstract:

Envelope analysis, sometimes known as the "high frequency resonance technique" (HFRT) is by far the most successful method for rolling element bearing diagnostics. It was developed in the 1970s, by pioneers from MTI and Shaker Research, primarily Jack Frarey. This tutorial describes the history of the development of envelope analysis, from its origin, which was before the widespread use of FFT analyzers. The initial procedure used an analogue rectifier and RC smoothing circuit to obtain the envelope signal which was then frequency analyzed by the available means. It was often found to be beneficial to first bandpass filter the original signal (with an analogue filter) to extract the resonance frequency(ies) which best carried the bearing fault information, with minimum interference from other sources. By the early 1980s, FFT analyzers were more widespread, and the relationship between the Fourier transform and the Hilbert transform became known, so that the most efficient way of obtaining the envelope was by using digital processing of the signal. Even so, many just copied the analogue procedure in digital form, without gaining the benefits from the "Hilbert" process. These include the fact that the bandpass filtration is by an ideal filter, able to exclude large discrete frequency components immediately adjacent to the filtered band, and that the signal is automatically downsampled, without aliasing, to a rate corresponding to the range of the modulating frequencies, much lower than the carrier. Moreover, the "Hilbert" envelope hugs the signal optimally, without the requirement to decide on a time constant for the RC smoothing. The tutorial explains these benefits, as well as the advantage of analysing the squared envelope rather than the envelope (which mathematically is the square root of the squared envelope). A longstanding question has been how to choose the frequency band to demodulate, and the tutorial discusses this in detail, including an explanation of the current best method based on spectral kurtosis (ie which band gives the highest impulsiveness of the transmitted signal). Many have claimed that wavelet analysis is superior to envelope analysis, and show three or four fuzzy blobs in a wavelet diagram, while claiming to be able to determine their spacing to four significant figures. In fact, there is no conflict, as wavelet analysis is a viable way of processing signals to obtain a (squared) envelope. The "wavelet kurtogram" makes use of complex Morlet wavelets as a precursor to envelope analysis, and the "fast kurtogram" uses a series of filter banks analogous to wavelet packets (over which they have advantages). The most significant (almost the only) technical advance in CM data analyzers in the last 15 years is PeakVue analysis, and the tutorial explains how it relates to conventional envelope analysis. Even though it introduces aliasing, it is shown how this is of the carrier frequencies, which do not carry information, whereas the modulating frequencies are correctly retained. A more recent development, claimed to be better than envelope analysis, is the Teager Kaiser Energy Operator (TKEO). For a displacement signal, this obtains the instantaneous "total energy", including both kinetic and potential, but the tutorial shows that the squared envelope of the velocity signal (sum of squares of the velocity signal and its Hilbert transform) is thus equal to the TKEO. More generally, the TKEO of any signal (eg acceleration) is simply the squared envelope of its derivative, so can be obtained by standard envelope analysis procedures. The tutorial discusses the pros and cons of the different approaches.

Comments:

1.5 hrs

Presenting Author: Chris Pomfret **Ser:** 2

Organization: MFPT Society

Country:

Paper Title: **Perspectives on Generating Business Case Analyses for Implementing Health Management Capabilities**

Co Authors:

Abstract:

Technology developed over the last 20 years has generated impressive tools and capabilities for PHM. Now, potentially interested end-users of such systems are interested in understanding just how a PHM system would provide a return on investment. But, calculating a RoI is complex and a standard computer program or spreadsheet doesn't exist; instead, computations need to be specially created to meet the specific application under consideration.

The tutorial will discuss approaches to creating RoIs and provide insight into the factors to be considered. Additionally, the tutorial touches on those beneficial elements for which a tangible, quantitative cost saving cannot be computed but are nonetheless important and thus need to be included.

The tutorial does not provide a specific way of conducting an RoI exercise but leaves the listener with an idea of the complexity of the undertaking, how to design a cost-benefit analysis and, from the range and depth of factors to be addressed, provides an insight into the fidelity that can be achieved

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Comments:

Presenting Author: John Lucero **Ser:** 3

Organization: NASA John H Glenn Research Center

Country:

Paper Title: **Systems Engineering**

Co Authors:

Abstract:

Due to the ever growing number of complex technical problems facing our world, a Systems Engineering approach is needed to assist in successful design, build and implementation of solutions. The interdisciplinary technical structure of current systems, technical processes representing System Design, Technical Management and Product Realization are instrumental in the development and integration of new technologies into mainstream applications. This tutorial will demonstrate the application of Systems Engineering tools to these types of problems.

Learning objectives include: Understand how to develop and engineer a system; understand the importance of teams, communication, requirements definition, interface control, and focus on deliverables; useful tools and techniques for each aspect of the System Engineering process. Some hands-on problems will be pursued especially in the area of requirements development which is always key to a successful project.

Comments: