Technical Paper

The Secret Behind Effective Machine Condition Analysis Software

The field of predictive machinery test and monitoring has developed a wide range of techniques, methodologies and instrumentation. Although many of the tests are valuable diagnostic tools and are specialized to work well for very specific machines, vibration analysis has proven to be the predictive technology with the greatest application to a general population of machinery. When applied effectively, it's proven to have a consistently high benefit to cost ratio.

Reliability Engineer using Azima DLI's DCX with embedded ExpertALERT machine diagnostic software

Within the realm of vibration analysis for predictive maintenance, there are a wide range of tests and practices with varying effectiveness. An example from the field of vibration analysis: a common approach is to use less detailed, broadband measurements as a screening tool and then to go back into individual cases with more sophisticated, narrowband equipment. This method has severe drawbacks. The broadband screening usually fails to detect the early warning, low level components of the vibration spectra. When narrowband analysis is required, there is no corresponding historical narrowband data for comparison or trending. The practical, more accurate approach is to make a full set of dual frequency range measurements at every monitoring point. This allows for more accurate calls through trending the machine history and requires only an insignificant increase in time/effort.

CONDITION ASSESSMENT FOR CONDITION-BASED MAINTENANCE (CBM)

The problem facing plant management today is not so much one of accepting condition-based maintenance as a philosophy, but rather how to manage the enormous amount of data that the new generation of portable vibration data collectors and/or permanent online collection systems can bring back to the maintenance department's computer. A fundamental goal of plant management is the analysis of the data in a manner that will give concise, accurate assessment of a machine's condition without costly, specialized labor.

The number of machines that can be regularly tested in a monitoring program has grown so large in many plants that the number of machines picked up in the exception reports may overwhelm the human resources available for closer condition analysis. When this happens, the success of the program is limited by the manpower available to manage

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the data, not by the instrumentation used to collect the data. The most common solution is to sacrifice a great deal of capability and utilize a simplistic broadband screening/alarm approach.

Azima DLI's approach is to move plants up the ladder of technology to computer-aided machinery health monitoring, and employ the power of automated diagnostic systems. With fault diagnostic software, the day-to-day management and analysis of the voluminous vibration data reports is shifted away from the specialized staff and onto the computer. The computer with the appropriate diagnostic fault templates, machinery information, and baseline data can process the machinery vibration data and present detailed information on machine condition, faults, and rates of degradation as part of the Machinery Fault Report.

JUST WHAT IS AN AUTOMATED DIAGNOSTIC SYSTEM?

In the context of machinery diagnostic applications, the term generally refers to a computerized means of collecting and applying the knowledge from a pool of machinery vibration engineers, corporate maintenance "folklore" and other valuable expertise. Most intelligent diagnostic systems for machine condition diagnostics are "forward chaining." That is, they begin with a set of facts such as vibration amplitudes, inspection notes or operating conditions and proceed toward a specific conclusion about the machine's condition and its relative need for repairs. They proceed step by step interactively between the computer and the analyst from the observed machinery vibration data and symptoms down a branching network toward a diagnostic conclusion about the machine's specific mechanical fault.

The Azima DLI ExpertALERT fault diagnostic system rapidly processes new vibration data against its extensive library of modeled faults, and operates automatically without the need for human interaction. The automated fault diagnosis software will arrive at specific conclusions about machinery condition, including specific fault trending over time and the need for repairs. Also, because it can operate without human interaction, this type of system can operate on-line to continuously monitor and trend machinery health. While our system generally has a somewhat higher startup investment to configure the system and associate the proper diagnostic fault models, it can ultimately be run in a "lights out" mode in the PC with nearly zero labor expense.

The litmus test for judging the success of the software is to compare its machinery condition diagnoses to those made by skilled vibration analysts. In one such test, Azima DLI furnished its fault diagnostic software with the rules to diagnose any of thirty possible faults in a petroleum product purifier. For this test, the system examined vibration signatures from 113 machines. In all diagnoses, the system matched or exceeded the performance of the human analysts. Further analysis on our database of 11,800 tests has shown a 94 percent agreement between Azima DLI's diagnostic software and experienced analysts.

Certification and debugging of Azima DLI's automated software are simplified because the software prints its diagnostic rationale together with the machinery faults. To help the repair planner allocate limited repair dollars, the diagnostic system can assess the relative importance of each machine fault and suggest priorities for repair planning. Consistent with the goal of reducing the labor required to manage vibration data from the predictive maintenance program, the specific fault trend plots help the maintenance supervisor make quick decisions about machine condition and repair or shutdown plans.

The Azima DLI fault diagnostic system has been used successfully with vibration data from a wide variety of modern data collectors. To realize the full potential of the system, the measurements should include high-resolution narrow band FFT spectral measurements, orthogonal measurements to describe motion in all three axes, and demodulation

of high frequency vibration data. The Azima DLI vibration instruments are routinely programmed to efficiently take all the required measurements. Several vibration data collectors and analyzers from other sources can be used to make the required measurements.

AZIMA DLI AUTOMATED DIAGNOSTIC SOFTWARE, ExpertALERT™

ExpertALERT is software that has been rigorously field tested for Predictive Maintenance of rotating machinery. Azima DLI has proven that two elements are required for consistent and highly accurate results; superior methodology and the proper software foundation. ExpertALERT employs Azima DLI methodology that ensures excellent diagnostic results; stud mounted triaxial vibration data collection automated to consistently and rapidly acquire low and high range narrowband vibration data, from all test points on each machine. The foundation of the software system runs in the PC environment and is comprised of four software modules:

- Vibration Analysis system module for test point setup, route management, conventional vibration analysis, and communication with the portable data collection unit, typical of all vendor systems
- An Order Normalization module that examines the fixed frequency vibration signatures gathered by the data collector and accurately determines the running speed of each machine during its vibration test.
- A Spectral Screening module that automatically extracts significant features and vibration signatures that are necessary for assessment of machine condition by the Expert Rule module.
- An Expert Rule module that has captured over 95 man-years of knowledge and experience in machinery condition analysis.

The Order Normalization module is an internal software module that automatically converts data collected in fixed frequency and without a 1/revolution tachometer into signatures based on an abscissa of shaft rate multiples (orders). The unique Order Normalization module has been refined and tested over a period of several decades and is so sophisticated that it is capable of accurately synthesizing normalized signatures from machinery undergoing speed changes during the vibration test and can handle most motor driven machines with ease.

The Spectral Screening module provides the diagnostic system with its primary spectral data. It has been meticulously designed and developed by Azima DLI's engineers to conduct a thorough examination of the vibration signature data collected from a machine and to distill that data into a matrix summary of numerical and logical constants that completely describe important features of the vibration signature for a machine. The screening module even uses a unique application of Cepstrum analysis to identify low amplitude bearing tones and gear mesh problems. The Cepstrum analysis is also used to detect faulty vibration data such as may be caused by abnormal operating conditions or operator error during the data collection process.

The Expert Rule module contains more than 4,500 individual rules and can recognize 650 specific machine fault patterns in 21 types of machinery components. The rule base is continually expanded and fine-tuned by Azima DLI's experienced vibration engineers to provide optimum diagnostic consistency and agreement with the human analytical process. The Azima DLI diagnostic system is a frame-based backward-chaining system that was written and developed by Azima DLI engineers specifically for assessing machine condition. It is not a generic diagnostic system shell that has been converted for machinery analysis.

Once it has been set up to recognize vibration signatures from the plant's machinery, the diagnostic system automatically handles the entire condition analysis process time after time. It does not need manual direction by an

operator; nor are questions asked of the user. The vibration engineers at Azima DLI have already done the work necessary to ensure that appropriate machinery knowledge in the computer's database is applied. This assures consistent objective analysis of machine condition and faults every time the system is run.

In the design of its Expert Automated Diagnostic System, Azima DLI has taken a component-based approach to automated analysis. That way, the system treats the machine as the sum of its component parts. Thorough analysis is accomplished by considering each component (motor, gearbox, pump, fan, coupling, etc.) as a partially isolated machine and applying groups of rules that are keyed to each component. This component-oriented scheme makes the automated diagnostic system an exceptionally powerful and flexible tool that can easily handle a wide variety of machine types.

Azima DLI's intense emphasis on automation has resulted in a system that can be set to provide a variety of standard outputs ranging from detailed machine repair recommendations to normalized vibration signature plots -- all with no manual user input and at the very lowest cost per machine tested. The system is engineered so that all of the mechanical details to be analyzed from the machines are preset in the system knowledge base and are automatically accessed whenever necessary. No question/answer sessions are necessary to get automated analysis of all your machines.

Intelligent systems empower their users to make accurate, repeatable condition assessments, fault diagnoses and repair recommendations about machinery, and to solve problems that would have previously required expensive skills of several key persons in the plant's maintenance or engineering organizations.

Today, intelligent system software is available that can "screen" machinery vibration signature data and duplicate the expertise of the skilled vibration analyst. With advanced signal processing techniques like FFT, order normalization, and Cepstrum analysis, an intelligent system can search vibration signatures and detect subtle or hidden fault patterns and symptoms that might be missed by even the most skilled human analyst. Because automated diagnostic systems do not tire, change moods or have a limited attention span, they will ensure consistency in machinery fault diagnoses and repair recommendations. The role of the responsible analyst's available time can then be focused on machines with notable faults, rather than wasting time reviewing reams of data from good condition machines.

Intelligent system software can aid planning for repairs and plant shutdowns by automatically setting priorities for repairs based on the relative severity of each of a large number of machinery faults. In this way, a properly installed system will help ensure that the plant's limited repair resources are spent in the way most beneficial to plant operations and profitability.

Automation is a critical component of the most effective machine condition monitoring programs. Without it, human resources and the associated labor costs are wasted and over time this reoccurring cost will significantly impact the overall ROI of your monitoring program. Applying quality automation technologies to your vibration analysis program allows an analyst's valuable time to be spend most effectively investigating specific faults on problem machines, rather than managing and analyzing reams of data associated with healthy machines.

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