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VIBRATION DIAGNOSTIC EXPERT SYSTEM AIDED MAINTENANCE MANAGEMENT

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Key words: maintenance management, automatic vibration diagnostics, on-line expert system, information delivery

Abstract

The Vibration Diagnostic Systems' can make plants, and the rotating machinery more productive by reducing maintenance costs, increasing reliability, reducing down time and avoiding the unplanned sudden shutdowns due to machine failures.

Monitoring machinery by Off-line or On-line Vibration Diagnostic Expert System the Maintenance Management can better plan repair actions and avoid catastrophic failures of machines.

The Predictive Maintenance needs correct, reliable information on the monitored machinery. In case of large companies with enormous quantity of rotating machinery with a very large number of measurements on everyday basis, crucial of the use of Expert System with capability of automated diagnostic analysis. Application of the off-line or on-line version of Automatic Diagnostic Expert Systems depends on the role of the equipment, played in the production.

We shortly summarize the major aspects of developing the on-line monitoring systems for the most important equipment. We review the main characteristics of the rule based expert system, the most important features of the on-line systems, and the information delivery using information technology our days. We present the architecture of two realized on-line systems, one at NPP Paks, and the others at MOL's Refinery Szazhalombatta.

AUTOMATIC VIBRATION ANALYSIS

The plant management in general accepts condition based maintenance principle, but has difficulties to handle the very large amount of data gathered by the new generation of portable vibration data collectors and/or on-line monitoring systems. The basic goal of plant

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management is the analysis of the data giving accurate, compact, reliable assessment of machine condition.

First we would like to clear up the difference between data and information. Data in our meaning are terms of numbers, RMS values, vibration spectra, waveform signals, as well as band and threshold exceptions. Information is result of analysis and interpretation of data, a statement on the machine's condition. Data is useful for vibration expert, but the information is useful for operational and maintenance experts and managers. The information is the name and severity of the fault, the repair recommendation, the expected time to failure.

The number of regularly tested machines in a monitoring program may grow so large in many plants that the quantity of machines picked up in the exception reports could overwhelm the human experts capable for detailed condition analysis. In this case, the success of the PdM program will hardly depend on the manpower available to manage the data and convert it to information about the machine condition and not on the instrumentation used to collect the data.

The resolution of this problem is the automation of the analysis process of measured vibration data using expert system and computer.

The expert system in the field of rotating machinery diagnostic means a computerized application of the knowledge of vibration analysts and expertise of maintenance specialists. The most expert systems for machine condition diagnostics are "forward chaining". This is the most commonly used method, wherein the expert software proceeds step by step interactively between the computer and the analyst from the measured vibration data and symptoms to a diagnostic conclusion about the machine's mechanical fault. This way of the vibration analysis is slow, not effective, and not appropriate to handle and analyze a large amount of vibration data.

The ExpertALERT vibration diagnostic expert system, developed by DLI Engineering (www.DLIengineering.com, www.delta3n.hu), operates automatically without the need for human interaction. It is a "backward chaining" rule-based expert system, which can work without human interaction in the process of vibration analysis, therefore this type of system is able operate on-line to continuously monitor and trend machinery health.

The ExpertALERT automated vibration diagnostic system uses the same method of data analysis what a human analyst do. The actual rotational rate of the machine is identified by an automated process. It serves for the normalization of the spectra, what makes possible to compare them with the reference data. The important peaks are extracted from the spectra using "fault files", they are compared to the base-line and the absolute values of peaks and the differences between currant and reference values (average plus one standard deviation) are arranged to the screening sheet, what is the input matrix to the analysis. The non-synchronous peaks, that may be bearing tones, automatically searched in the spectra by ExpertALERT. Cepstrum analysis is used to determine if non-synchronous peaks are part of harmonic series or have side-bands confirming that, they are really bearing tones. The screening sheet serves as the input for diagnostic analysis and it processed through the rule-base.

ExpertALERT use a component-based approach to automated analysis that means, the system treats the whole machine as the sum of its components. Analysis is realized by considering each component (electric motor, turbine, gear box, coupling, compressor, etc.) as a partially

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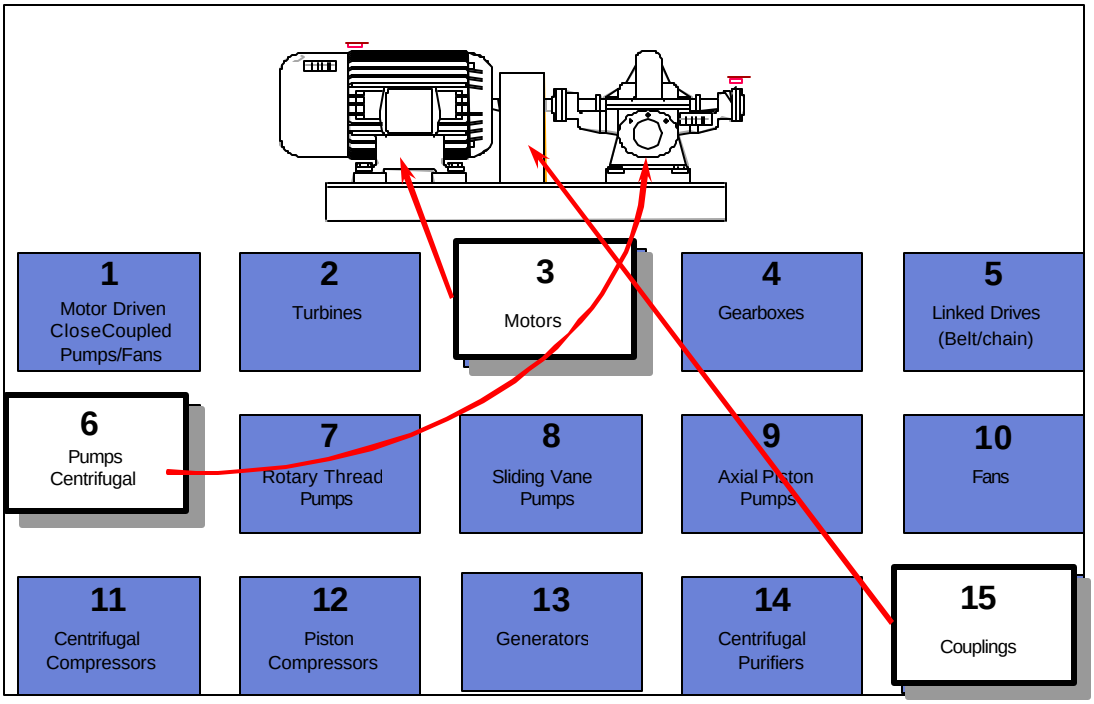
isolated machine and applying of rules that are referred to each component. This component oriented approach makes ExpertALERT extraordinarily powerful and flexible to handle a wide variety of machine constructions.

Figure 1 illustrates the component oriented analysis technique:



The severity of the determined faults computed on the base of the margin by which the different test amplitudes and exceedances of average plus sigma compare to the threshold values required for the specific faults. Fault severities are designated “slight”, “moderate”, “serious” and “extreme”.

Figure 2 shows the flow diagram of the automatic vibration analysis process:

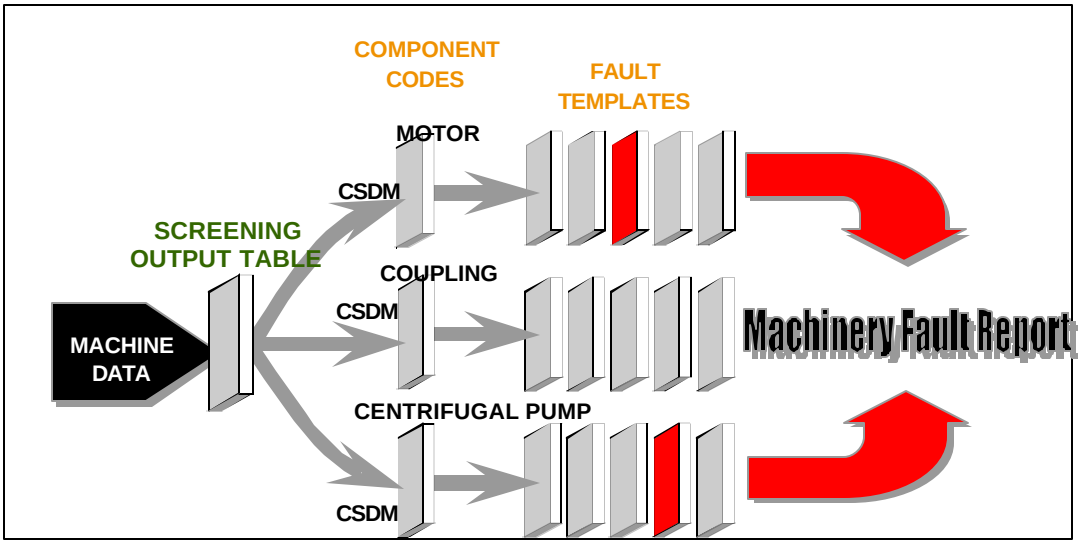


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Figure 3 demonstrates an example for the fault report produced by automatic analysis of ExpertALERT expert system:

F DMSA E315-6

Report generated on: 4/6/2004 09:33 PM
Acquired: 10/1/2003 03:55 PM 1x = 584 RPM Averages: 1

Figure of Merit = 984.

Maximum level: 5.6237 (+3.3849) mm/s at 1x on 1R in low range

RECOMMENDATIONS:

IMPORTANT: REPLACE BEARINGS
DESIRABLE: INSPECT FAN WHEEL; REPAIR OR REPLACE FAN WHEEL

DIAGNOSES:

SERIOUS DRIVE END LOOSENESS
SERIOUS FREE END LOOSENESS
MODERATE FAN IMBALANCE
SLIGHT FREE END BALL BEARING WEAR
SLIGHT DRIVE END BALL BEARING WEAR

POSITION LEGEND:
POSITION 1 IS: BEARING, BEARING 1
POSITION 2 IS: BEARING, BEARING 2

OVERALL LEVEL READINGS

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ALERT: 4.81 (+0.31) mm/s at 1A
   OK: 2.30 mm/s at 1R Alarm level: 4.50 mm/s
ALERT: 6.11 (+1.61) mm/s at 1T
   OK: 2.66 mm/s at 2A Alarm level: 4.50 mm/s
   OK: 2.90 mm/s at 2R Alarm level: 4.50 mm/s
   OK: 3.14 mm/s at 2T Alarm level: 4.50 mm/s
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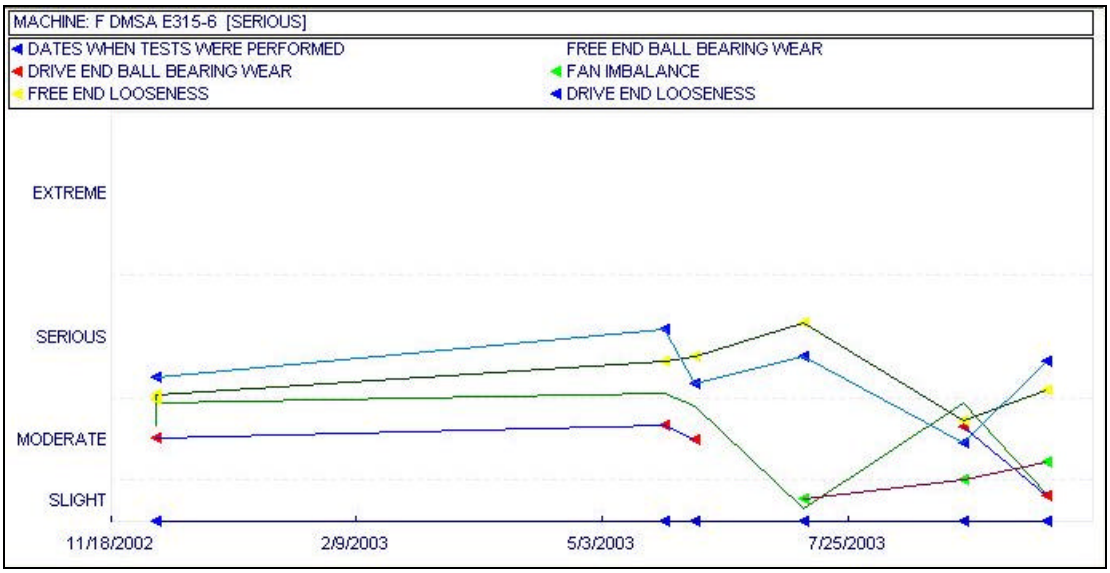
The backward chaining vibration diagnostic expert systems empower their users to make accurate repeatable condition assessments, fault diagnoses and repair recommendations about machinery, and to solve problems giving a strong support for the vibration analyst experts of the plant.

Figure 4 displays a fault severity trend plot:



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ON-LINE VIBRATION DIAGNOSTIC EXPERT SYSTEM

The most cost-effective approach to maintenance management is to go online and have all of the analysis functions conducted by off-site experts or in some central location within the organization. On-line vibration diagnostic systems, with remote monitoring capabilities, facilitate this type of work and spare the cost of sending technicians to the plant to collect data. It also saves the plant from being reliant on its own in-house predictive maintenance experts or provides the option of consolidating this knowledge in one office.

Reliable expert system technology also assists the move to the online analysis as the system can be left to itself to monitor the machinery. The analyst only needs to get involved when a fault has been detected. Modern communication technologies allow the monitoring system to alert anyone and everyone as soon as a problem has been detected, via email, text pagers or by popping up a live message on a computer screen at a remote monitoring station. The system can also close relays to cause alarms to sound, lights to flash or a control system to be signaled. Expert diagnostics are accurate enough to inform interested parties of the specific type of fault the machine has and the severity of that fault.

The Functions of the On-line System

Other changes in software technology are also facilitating the move into the on-line world. These include open architecture databases (like SQL Anywhere) and standards such as OPC (OLE for Process Control) which assists sharing and integration of information across different system platforms.

The DCXO on-line vibration diagnostic system has several software modules realizing different functions of the system. We shortly describe the most important ones.

The ExpertALERT software is responsible for setting up the database. The MID (Machine IDentification – the model of the analysis), which describes each unique type of machine being monitored, and then the individual machines are created. A survey is then built with the machines to be monitored by each DCX Online system. It is also used to perform detailed spectral analysis and long term trending. Notes can be added and expert system results can be reviewed in detail.

The DCX Online constantly evaluates vibration, process and performance inputs to determine machine condition with a high level of accuracy:

- No fault accuracy 99%
- Correct fault "type" accuracy 96%
- Correct faulty "severity" accuracy 89%

OnlineEngine is the main software component. It does all the hard work of collecting the data, analyzing it using ExpertALERT's rule-base for possible machine faults, then storing it in the database. It tests one machine after another, over and over.

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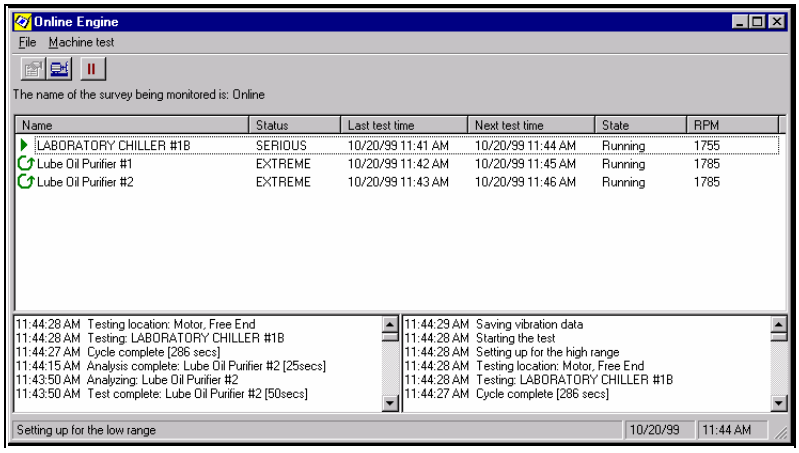
Figure 5 shows the screen of OnlineEngine:



InfoServer is responsible for getting all of the information to all of those users who need it – wherever they are. InfoServer is in constant communication with OnlineEngine. It is usually run on the same computer as OnlineEngine, but can actually operate on a separate networked computer via DCOM (Distributed Component Object Model). OnlineEngine has a user interface, listing the machines being tested, but this display is only can be seen on the DCX Online system collecting data. We can use OnlineMimic anywhere on the network.

The user will be informed when a machine changes status, from moderate to serious for example. She or he may not check every e-mail as it comes in this case PersonalAdviser can help. The DCX Online system is capable of collecting a huge amount of data, but the storage capacity of computers is limited. The DataManager program is used to thin out this data. In the OnlineEngine configuration section we may nominate how much data we wish to keep (all of the data for the past 24 hours, hourly data for the past week, etc.).

OnlineStartup software module starts each software component, and OnlineMinder watches them to ensure they keep running. OnlineStartup is configured to run each software components of the on-line system in right order, with appropriate delays, to ensure that after a power failure or other system shut down the entire system will recover gracefully and continue monitoring.

The DCX Online vibration diagnostic system was designed to be able to close a contact or utilize a relay switch based on user defined criteria. The idea of this is to allow the system to sound an alarm, flash a light or cause some other event to occur if a machine status changes. The ADAM-4060 relay is one hardware option that can be connected to a computer via the serial port. The Relay Manager software can cause that relay to switch if a machine status changes. The Relay Manager software can be installed on any computer on the network.

Distribution of Information

ExpertALERT Enterprise and DCX Online™ include NetCast™ HTML Server and InfoServer™ respectively. These servers generate dynamic web sites that include web pages for any or all of a plant's machinery. The next information is available on the web site:

- machine status,
- date/time of test,
- diagnostic results, and analyst comments,
- repair recommendations.

The site available on the company's network, or can be transferred automatically to a safe location on the Internet. Index pages include plant, area, and machine as well as user specific lists of machines.

Figure 6 shows the Netcast's screen. Clicking on a link, the appropriate web page will come up:

The InfoServer also provides an ASD (Active Server Documents) interface, so web browsers can be used to view information and near real time data generated by the DCX Online system.

ExpertALERT Enterprise and DCX Online's InfoServer can be configured to automatically generate an e-mail message to specific users when the status of a machine changes (such as Moderate to Serious), when there was any activity on a specific machine, such as a note or an analyst comment added or when any new test is performed. This is especially useful to keep personal well informed of activities that take place on a piece of equipment within their area of responsibility.

When the condition status changes, the DCX Online will contact the plant's operational and maintenance personal, technicians, managers and describe the problem machine's mechanical condition.

The DCX Online communicates in plain language. Alert emails, pagers and dynamic web pages are easily accessed and understood by the common plant professional. When connected to a network, the DCX Online will alert any workstation or control room display that a machine requires attention.

MCP's On-line Monitoring at NPP Paks

The Main Coolant Pumps in the primary circuit at NPP Paks are very important machines in aspect of energy production. The management of maintenance decided to install DCXO automatic vibration diagnostic systems for continuous surveying of MCPs of the four reactor units. There are six pumps on each reactor blocks. The installation of the first system is realized in two steps. The first step was finished for two MCPs, in February this year, and the test operation of the system was finalized in May. The next step is the expansion of the system to the rest four MCPs on the 1st RU. The project will be continued for the next three reactor units next year.

The MCP is a vertical centrifugal pump with a 1.5 MW power electric motor. We placed triaxial accelerometers onto three pickups.

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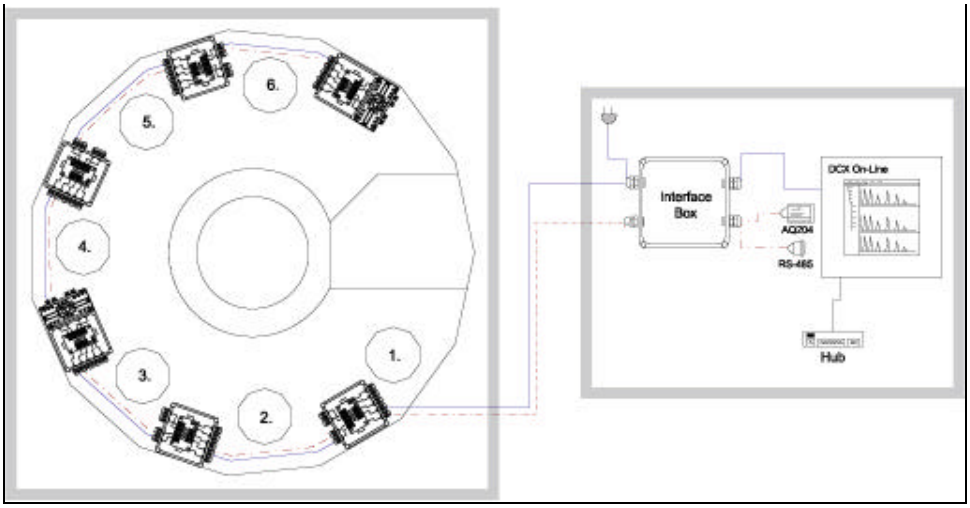
Figure 7 shows the schema of the system for one reactor unit:

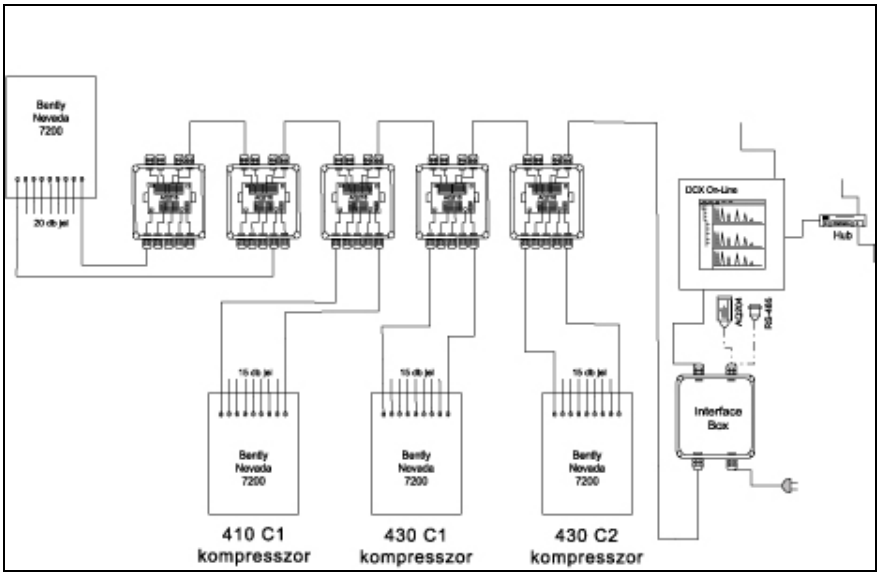


On-line Monitoring Systems at MOL's Refinery

MOL's refinery has an off-line vibration diagnostic system developed and installed by Delta-3N Ltd (www.delta3n.hu) for 1750 rotating machinery.

We have installed three DCXO on-line vibration diagnostic systems in MOL's (Hungarian Oil and Gas Company) Refinery Szazhalombatta, which use the proximity probe signals taken from Bently Nevada vibration protection systems. The DCXO systems make automatic diagnostic analysis of signals giving continuous information about the condition of most important machines of three plants of choice.

Figure 8 shows the schema one of the three systems:



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