Automation India

Enabling Global Competitiveness

Issue 10 – August 2007 A newsletter of the Automation Industry Association of India

Dear Friends,

In the three years since our inception, AIA as an apex body of all the leading automation companies in India has been successful in increasing awareness amongst users about the benefits of automation. Various ‘industry-specific’ seminars and user meets have been conducted that evinced keen interest from new users who were hitherto skeptical about investing in automation and deriving the benefits from a resultant reliable, safer and efficient production facility. AIA has been successful in educating new users about the benefits of automation and change the perception that enterprise level automation is not just the monopoly of large process industries. AIA continues to be a platform for users, integrators and academia to exchange ideas and disseminate information on latest technological developments.

This issue of our newsletter is dedicated to the theme of ‘Machinery Health Monitoring and Protection System’. The long term health of rotary equipments and plant machinery is vital to the reliability, availability as also the safety of any running plant. Traditionally, this has been achieved by stand-alone systems that are available to monitor the condition of machinery and generate alarms so that maintenance action could be initiated. However, the modern trend is towards predictive intelligence — the shift from abnormal situation management to abnormal situation prevention with emphasis on getting diagnostic data with direct access to all elements in a plant — motors, turbines, pumps, compressors etc. The trend is also towards integrating the data available from these stand-alone devices over a common bus and transmitting these to a Central control room to present a ‘holistic’ view of the plant. We have attempted to cover these concepts briefly in this edition of the newsletter and hope these ideas will prove equally beneficial both to the user and integrator fraternity.

With best regards,

Sunil Khanna
Member, Executive Council, AIA
& Guest Editor, Automation India

Automation Tech 2007

Sharing global vision and inspiring teams

Over 100 delegates from various industries attended AIA's AUTOMATION TECH 2007 symposium at Mumbai, on 12th April, 2007. The theme for the event was: Automation - The Next Enabler Of Global Competitiveness in Manufacturing & Infrastructure.

Dr K Kasturirangan, former Chairman of ISRO and currently Director, National Institute of Advanced Studies and also a Member of Parliament, inaugurated the event. Dr Kasturirangan spoke about the enabling role of Automation in India's progress. Sharing his vision of national excellence, he urged industry captains and AIA members to engage in collaborative resource sharing.

Eminent industry leaders from Automotive, Oil & Gas, Power, Engineering & Construction, Metals & Mining, Pharmaceutical, Warehousing & Supply Chain sectors spoke about their own experiences on how automation technologies have enabled them to raise Quality, Consistency, Speed, Productivity and Efficiency to global levels.

The symposium concluded with a CEO panel discussion, on ways and means to raise awareness levels about 'real-time' ability that differentiates Industrial Automation from traditional IT & Telecom technologies. Prominent CEOs who participated shared how global vision inspired their teams to adapt quickly to high levels of automation. Automation, they said, had clearly stepped up business capability, created new opportunities for higher value-addition and driven their companies growth, performance levels and customer satisfaction.

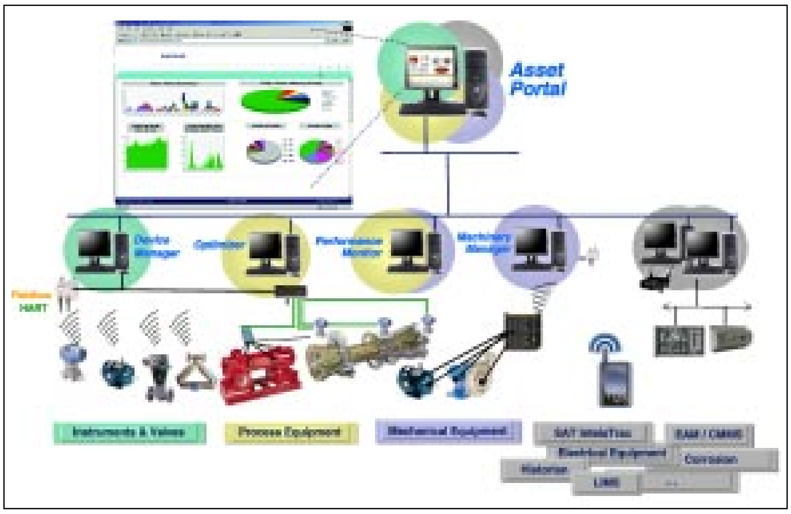
For complete event coverage, visit http://www.aia-india.org/EVE/evecurrent7.htm

Left: *Dr. K Kasturirangan, lighting the inaugural lamp, flanked by A Rajabahadur, ARC Advisory Group and Ravi Uppal, ABB.*

Below: *Panelists at the CEO Round Table — from left — JP Singh, AIA; Uday Bhansali, Accenture; Gerhard Klement, Reliance Biopharmaceuticals; Senthil Chengalvarayan, CNBC TV 18; Kuldip Kaura, Vedanta Resources Plc; K Venkataraman, Larsen & Toubro Limited; Anil Sardana, The Tata Power Company; Ravi Uppal, ABB.*

Enterprise-wide Plant Asset Information helps improve Plant Availability & Reliability

In ever changing business dynamics and ever increasing competition, industries are forced to cut that extra fat and are under constant pressure to increase the quality & throughput of the product with minimum work force, reduced capital and operational expenditures. In such a scenario the unplanned shutdown of the plant may even affect the bottom line of the Facility. Some times the cost & production loss due to single unplanned & unexpected shut down may exceed the annual maintenance budget that was sanctioned. Justification of unplanned & unexpected shutdown is becoming increasingly difficult.



To take the full advantage of the production assets & to maximize the value of the investment, the Full Asset availability to the plant is mission critical.

By combining the technology of predictive intelligence & the web we can predict the failure of the assets & take proactive actions to prevent the breakdown. We can identify the non-performing/under performing assets, analyze the problem & find out the root causes & solutions to prevent unpredicted failures. The asset portal, utilizes these technology to provide a one stop destination for diagnostic information from all critical plant assets across the Enterprise. The Asset Portal operates on open standard communication protocols such as XML/OPC & is a tool that allows users to capture asset information from a wide range of internal sources and customize how they use that data. Maintenance management personnel can obtain timely information to quickly identify critical equipment that is not performing and can predict unexpected failures or off specification product in time to take corrective action.

The Asset-Portal captures events, diagnostics, pre-alarm abnormal condition from disparate data sources such as Condition Monitoring Systems, Instrument Maintenance Management System, Equipment performance Monitoring Systems etc & displays into formats which aid in critical decision making & monitoring ASSET Condition in a facility. The Asset-Portal can communicate with these data sources on Open protocols like OPC or XML.

Asset Portal presents a clear & unified picture of the operating conditions & predictive maintenance information of mechanical equipment, process equipment, field instruments and valves. In addition, Asset Portal provides detailed help information on how to correct problems when they occur and helps in increasing the quality, throughput of the product and increases the availability of the Plant assets & tools.

Typically you can have the consolidated view of the following in the Asset Portal:

- View a snapshot of your enterprise's overall health to aid in determining availability and performance of critical Assets.
- Summarize the health of assets in a graphical format with an enhanced dashboard.
- Filter, save, and export data to create reports.
- Use categorized data to create asset reports and see

- **View all plant asset information in real-time from anywhere.**
- **Asset Portal leverages web technology to dramatically simplify the integration of all plant asset information.**
- **It provides information, to all levels of the organization, so people can work more efficiently and make better decisions.**
- **Asset Portal enables people to see opportunities for improvement and companies to excel.**

a clearer view of enterprise health.

- Poll data sources on demand instead of on a timed basis to get the most current information.
- Help the plant management in long-term performance monitoring and historical analysis.
- Improve the Maintenance Efficiency, capture powerful diagnostics and categorized data from your assets in the field and use this information to support decision-making. With the help of the Asset Portal, you can filter data to find the information that is important to you. Then you can export this information for analysis & to reporting tools such as Excel, to identify the assets that perpetually cause problems.

You can view the assets from different locations & can give the expert opinion on the problems.

To gain full value from the system you should ensure that

1) The System is based on Open standards such as XML/ OPC
2) The System is modular & expandable for the future plant requirements
3) The Assets are properly prioritized by the experts
4) The System should interface with the CMMS or ERP System
5) The System must provide the means of accessing secure plant asset information throughout the enterprise.

Instrument Maintenance Management System (IMMS)

The Instrument Maintenance Management System enables users to reduce the time required to troubleshoot, configure, and calibrate field devices through easy access to device diagnostics .

The IMMS enables Pro-active & Predictive Maintenance Practices & stream lines Maintenance & Calibration activities in the plant. This will drive towards excellence in maintenance & operational practices & will result in improved plant availability.

Instrument Maintenance System should be based on open communication standards. The System must be a single integrated S/W application to perform core functions of device configuration, Calibration Management, Automatic documentation for audit purpose. Predictive & advanced diagnosis of Foundation Field bus, HART & Conventional field instruments and valves.

The Instrument Maintenance System should have the following capabilities:

- Management & Configuration of data for Foundation Field bus, HART & Conventional field instruments and Values remotely
- Automatic recording of Configuration changes, Diagnostic Status Changes of Intelligent Devices & Values for the Audit & regulatory purposes.
- The Powerful diagnostics of the intelligent devices so as to conduct advanced analysis and generate alerts for Preventive & Predictive Maintenance.
- Calibration Management of HART, FF & Conventional devices like defining the Test Schemes, scheduling the calibration of the devices in the plant, downloading / uploading of calibration data to standard calibrators, generating calibration history of the instrument, generating calibration data report with "as left & as found data", test equipment, cross reference reports.
- Launch advanced valve performance diagnostics like valve signature, step response analysis, dynamic error band, step analysis, friction test, valve stroke test etc.
- Instrument Maintenance System should deliver a key value to the "Safety Instrumented System" by extending the time period between proof tests, preventing procedural errors through test automation and IMMS must provide automatic documentation of proof tests for regulatory / statutory requirement. This system can be effectively used to meet many of the requirements of IEC 61511 in safety instrumented system applications. The IMMS must be a non interfering application & should not be a part of safety function. IMMS must include individual login security, automatic audit trail and SNAP-ON diagnostics will allow the user to meet specific safety lifecycle requirements.
- The Instrument Maintenance Management s/w should have the capability to interface to the Asset-Portal.
- The IMMS must be based on international standards of inter operability like EDDL to get the long term support & benefits of the investment. EDDL (Electronic Device Description Language) is an international standard & is endorsed by IEC (IEC 61804-3). EDDL is endorsed by the three major digital busses, viz 1) Fieldbus Foundation 2) HART Communication Foundation & 3) Profibus Nutzerorganisation (PNO).

Adopting the above mentioned predictive intelligence tools & technologies will enable users to:

- Access real-time diagnostic
- Get early indication of equipment deterioration and take proactive maintenance to prevent costly breakdowns
- Have increased visibility on automation assets and detailed analysis to isolate the bad actors
- Simplification of Maintenance Processes
- Optimized use of the available Manpower and resources
- Improve the bottom line of the operating entity.

Madhusudan Golsangi

Simple solutions save maintenance cost — a case study

"Condition Monitoring System", short CMS, is more than just a buzzword in the maintenance business. It stands for **continuous condition monitoring**. The goal is to minimise downtime. If arising damage is predicted, maintenance can be optimally planned. A machine part is exchanged exactly when the wear margin is almost fully exhausted. Only in this way the efficiency of the system can be maximised. Experts agree: 90 to 95 percent of all failures are preceded by measurable damage behaviour. But the difficulty lies in detecting the exact moment.

CMS monitors minimal changes in the conditions of system parts, for example via vibration measurement on rolling element bearings. Due to the continuously measured data a comparison with predefined limit values is carried out. Any deviation is automatically signalled to the monitoring unit and actions can be planned.

The jam and confectionary manufacturer Zentis in Germany, is one of the first to use such condition monitoring systems. In the central cooling system a huge cooling fan with a diameter of nearly three and a half metres carries the heat away. The unit including motor and gear is mounted outside on a cooling tower. The rotor blades are exposed to extremely strong forces when they rush with 2,000 revolutions per minute through the air. Even tiny deposits and wear cause unbalance. An enormous stress for bearing and gear.

A fault would have fatal consequences: "Especially in the food industry we depend on specified temperatures. If the cooling fan failed the whole cooling system would break down and with this also the three-shift production for about a week", says Romeo Odak, responsible for technical equipment and installation at Zentis in . The financial impact is obvious. And due to the size of the plant the system cannot be designed redundantly.

Intuition

In the past the cooling fan was regularly inspected with a lot of manpower and material input involved. Bearing damage is mostly noticed acoustically, "five people and five opinions on what kind of irregular sounds are perceived", says Odak. 50 percent of the decisions whether something should be replaced were taken objectively, 50 percent subjectively. In case of doubt a piece was replaced rather than to risk a failure. However one barely reached the wear limit. It was "learning by doing", soon preventive maintenance became routine which meant regular replacing irrespective of the real stage of wear.

Continuous monitoring via CMS

At the heart of this system is a small and compact sensor for rolling element bearing diagnosis. It permanently monitors the acoustic emission and calculates thereof the frequency spectrum from this. This allows to reliably evaluate the condition of the bearing.

The sensor was directly mounted at the gear of the fan. After quick parameter setting and teach-in the unit was ready for use. The sensor displays the condition of the bearing via a 9-digit row of LEDs in traffic light colours. "We were surprised about how precisely the sensor indicated the increasing wear of the gear over months", says Odak. "When the indicator of the unit had reached the yellow zone we could calmly plan the replacement of the system." When the system eventually indicated the "red phase" the manufacturer was asked to replace the cooling fan. "We were able to calculate exactly when the replacement should take place and worked in advance in the production. In this way the replacement did not cause any production loss."

Precise diagnosis

"We were keen to know how far the wear margin of the gear was consistent with the indication of the sensor. That is why the old gear was transported with a flat bed truck to the manufacturer where it was disassembled. The examination showed: around 90 to 95 percent of the wear margin was used - exactly the value that also the sensor had indicated."

By now Zentis uses more than 40 sensor units. "Also for other systems the bearing conditions were exactly indicated. This allowed us to replace the worn out components at their maximum life-span without ever having to worry about a standstill", confirms Odak. "Correct maintenance using CMS strategies allows a reduction of 25 to 40 percent in maintenance costs."

Sensor features

The sensor is a vibration sensor with integrated rolling element bearing and machine diagnosis based on frequency analysis. It allows permanent monitoring of small machines and components while featuring the same diagnostic quality as expensive systems. A small unit typically monitors up to two different rolling element bearings. A larger unit monitors up to twenty different frequencies.

Damage to rolling element bearings is detected as early as it arises. The bearing monitor sets the switching output 1 and indicates damage progress with yellow LEDs. The **operator can take preventive action**. Progressive damage to rolling element bearings is signalled via the second switching output 2 and is indicated via the bearing monitor's red LEDs. **The operator should react at once**. The basic parameters are set on a PC. Data such as type of bearing, rotational speed and input / output function are transmitted to the sensor via the RS 232 interface. The reference conditions of the machine are taught after mounting by pressing a pushbutton on the sensor.

Bipin Jirge

Rotating Machine Life is in the oil analysis

Industrial machines are generally supposed to have 40,000 hour (about 5 years) mean time between failures (MTBF). This only happens if you have "good lubrication". If you have "poor lubrication" or "no lubrication" you get far shorter operating life.

How do you know when the lubrication is good or poor? There are four parts to this answer.

1. Keep the oil clean
2. Keep the oil dry
3. Keep the oil fit for use
4. Monitor the wear debris in the oil

First, keep the oil clean. "Cleanliness is next to godliness" is an old saying related to personal hygiene. Cleanliness is also very important when it comes to your lubrication systems. Graham Fogel reports that 46% of the abnormal wear debris is abrasive wear resulting from oil contaminated with dust and other hard particles. Many industry experts say that dirt-in-oil is public enemy number one. This root cause leads to many later problems when load-bearing steel is milled away by tiny quartz particles trapped between moving surfaces of bearings and gears. Be sure to monitor the particle counts and particle size distributions to validate target cleanliness levels (TCLs). If TCLs are not met, then corrective measures such as these should be implemented:

- keep oil supplies covered,
- install desiccating breathers on oil supplies and oil compartments,
- use appropriate filtration in-line, off-line, and when transferring oils.

Second, keep the oil dry. Corrosion is another major cause of early machine failure. An MIT study generalizes that 20% of all machines are taken out of service as a result of corrosion. What causes that corrosion? The most common cause is water. Other causes are coolant and process media. Lubricants are supposed to provide a sealed barrier preventing surface oxidation. Unfortunately this is ineffective when the lubricant is loaded with moisture and other corrosive materials.

Third, keep the oil fit for use. Do you have the right oil in each application? If so, has it become deteriorated? Lubricants perform a variety of functions, some of which are unique to specific applications. Following the recommendation of the original equipment manufacturers and your lubricant supplier each application is identified to receive one specific brand or mil-spec oil designation. Be sure to mark the oil supplies and oil fill points clearly and correctly. Also be sure to test viscosity and dielectric to validate correct lubricants are in use and that they remain fit for continued service.

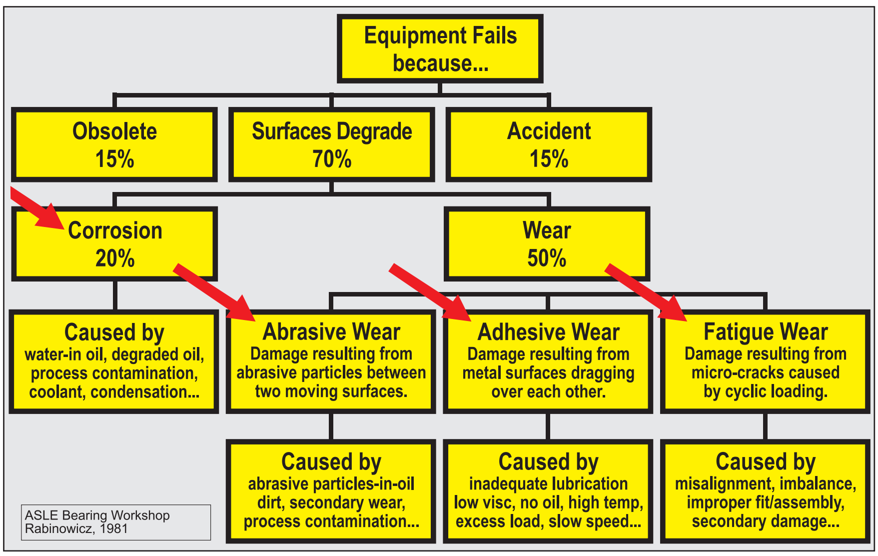
Fourth, monitor the wear debris in the oil. Wear debris is your indication that surface damage is taking place within your machinery. Dust contamination, water contamination, and deteriorated oil are three root causes of damage to load-bearing surfaces. Misalignment, imbalance, excessive load, extreme temperatures, and many other roots also lead to internal damage that might be revealed through wear debris analysis. Wear debris analysis really is the referee you should rely upon to establish both severity and cause of problems revealed through used oil analysis.

Although blood does not actually lubricate your joints, you can imagine a variety of functional similarities between the blood in your body and oil in your plant machinery:

- Mixing different fluid "types" can be dangerous
- Systems carry fluid to all parts
- Systems transport heat
- Systems carry away solid and liquid impurities
- Fluids carry diagnostic information
- Fluid sampling is relatively non-intrusive and nearly painless
- Fluid change-out is intrusive and can introduce new problems

This analogy is intended to highlight the important fact that operational life of your machinery is largely determined by the good lubrication practices you employ. These good practices include keeping the oil clean, dry, and fit for use. In addition, you should periodically take a look at wear debris in the oil to see the nature and severity of developing problems.

Ray Garvey



Integrating vibration and oil analysis with Condition Monitoring Programs

Today's condition monitoring programs that wish to advance towards true "Reliability Centered Maintenance" (RCM) must incorporate more than one technology into their diagnostic tool kits. No longer can an organization expect to do this while "putting all their eggs into one basket".

At one time, most industrial condition monitoring programs included only vibration analysis. And, in so doing, these programs were typically at least moderately successful, particularly if their condition monitoring teams received professional training which is vitally needed in order to truly become proficient in the application of vibration analysis technology. Many engineers and managers of that era felt that vibration analysis alone was sufficient to achieve their reliability objectives and every machine type could be effectively evaluated and faults reliably detected on components within these machines by vibration analysis alone. Vibration analysis was eventually proven effective for certain machine types in its capability of evaluating the condition of some of the more complex machinery types including centrifugal air compressors, rotary screw air compressors, roots blowers, multi-stage gearboxes, AC and DC motors, turbine/generators, boiler feed pumps, low-speed agitators, rolling mills, machine tools, etc. However, now it has become conclusive that an integrated approach employing more than one condition monitoring technology has proven to be noticeably more effective.

However, despite the determined efforts by numerous people in the vibration analysis field, certain machine types for the most part still cannot be adequately evaluated by vibration analysis alone (at least to the depth desired). These machines include reciprocating air compressors, diesel engines, internal combustion engines, greased motor operated valves, presses, piston type hydraulic pumps, etc. And, even in the case where vibration analysis can effectively evaluate the condition of the machinery mentioned above, adding oil analysis to condition monitoring programs has given us a much more complete picture. Oil analysis has actually detected certain problems within these machines before they are evident in vibration analysis data - particularly on multi-stage gearboxes, plain bearings, rotary screw air compressors, roots blowers and on certain rolling element bearings which might be located distant from an accelerometer mounting location.

Figure 1 is an important illustration developed by specialists at Noria Corp. (ref. 8). This illustration correlates Oil Analysis observations with the 4 rolling element bearing failure stages detected by vibration analysis. Note that several factors can be observed in the oil analysis photos as the bearing transitions from Failure Stage 1 through Failure Stage 4. First, there is an increase in particle count; likewise

	OIL ANALYSIS OBSERVATIONS	
Initial Stage	• Slightly increasing particle count, especially at the small particle range. • Slightly increasing ferrous density (WPC), but no major change in the percent large particles (PLP). • Slight increase in elemental iron might be seen, especially if the sample is acid / microwave digested. • Photomicrograph shows presence of small (<30 microns) platelet shaped, contact fatigue particles.	
Second Stage	• Increasing particle count. • Increasing wear density (WPC) and increasing percent large particles (PLP). • Elemental iron may remain stable unless the sample is acid or microwave digested. • Presence of platelet-shaped contact fatigue particles with increasing size (say 30-50 microns, depending on filtration) and density. • Possible presence of spherical particles.	
Third Stage	• Substantial increase in particle count • Substantial increase in ferrous density (WPC) and in present large particles (PLP) • Minor increase in elemental iron unless the sample is acid or microwave digested. • Photomicrograph image reveals large particles (above 30 microns) are appearing in great numbers, both platelets and cutting wear. More and more particles are appearing to have three dimensional shape.	
Final Stage	• Further increasing particle count. • Very high ferrous density (WPC), especially the percent large particles (PLP). • Minor increase in elemental iron unless the sample is acid or microwave digested. • Photo image reveals large chunky and fatigue particles, some in excess of 75 microns depending on filtration. Low alloy steel particles may appear blue due to the high heat associated with failure in the final stage of the bearing's life. Some particles may become visible to the naked eye just prior to failure. Particles generated from cage material, primarily cutting wear, will begin to appear.	

Figure 1: Correlation of oil analysis observations with the 4 bearing failure stages detected by vibration analysis (Ref. 8)

in ferrous density and in percent large particles; and a corresponding increase in contact fatigue particles (see Figure 2). Importantly, note that while vibration data alone cannot detect problems during Failure Stage 1, Oil Analysis can do so as shown by the text and photos in Figure 1.

Building the case for technology integration

The focus of this paper is on how integration of just one of these tools with vibration analysis has greatly enhanced the reliability and effectiveness of condition monitoring programs - oil analysis. Actually, the oil analysis technology has been around for many years. The problem was that numerous condition monitoring teams were either not aware of oil analysis; or, if plants did have personnel assigned to perform oil analysis, these persons in most cases did not interface with the vibration analysis condition monitoring teams on the same plant site. The decade of the 1990's has fortunately seen a great shift in this trend. At least some plants have seen the wisdom in adding oil analysis to vibration monitoring to enhance their machine condition monitoring programs. Likewise, several vibration condition monitoring vendors have begun to expand their offerings to incorporate oil analysis products, services and data management. Some vendors have upgraded their software to incorporate oil analysis data into their databases to provide the analyst with a much more complete picture of the operating condition of machinery under his watchcare using these combined detection tools. With the combined offering, they are better positioned to make more effective decisions and recommendations.

In fact, one comprehensive study at a nuclear plant beginning in 1994 clearly showed how the integration of oil analysis with vibration analysis could widen the depth and breadth of a plant condition monitoring program (refs. 2 & 3). Table-1 is a meaningful comparison of the relative strengths and weaknesses of oil analysis and vibration analysis. Likewise, it provides insight into how the results of one technology can complement those of the other.

Importantly, please note from Table-1 that when oil analysis and vibration analysis are "married" within a program, the weaknesses in one technology can be overcome by the strengths in the other. For example, while oil analysis cannot detect resonance, vibration analysis is very adept at doing so. Conversely, while vibration analysis has only mixed success in detecting wear of oil lubricated journal bearings, oil analysis is very adept at detecting the wear debris in the lube and assessing the severity, thereby helping the plant make the important decision on whether or not they should continue to operate the machine. Also, when both technologies pinpoint the same problem, the diagnosis and follow-up recommendations are rarely inaccurate. The authors of ref. 2 made the statement: "Our experience shows that a strong, up-to-date vibration program can be improved by closely integrating it with a strong oil analysis program. The combined program becomes more than the sum of the parts".

The complement between the two technologies continues. For example, note from Table-1 that while vibration analysis can pinpoint which gear might have a problem, oil analysis can predict the type of failure mode. Also, Table-1 shows that oil analysis will detect defects on rolling element bearings during Stage 1 as previously discussed whereas vibration analysis typically cannot see the problem until Failure Stage 2.

Having this information in hand from both technologies facilitates the process of determining the root cause of a problem. In doing so, the program is elevated to a more proactive capability. In fact, a condition monitoring program is not truly effective until it has put into place a "Root Cause of Failure" analysis process to continually identify the failure/problem source(s), allowing proper corrective actions to be taken which can prevent the problem(s) from repeatedly occurring.

A review of some of the data available today reveals several important facts about the need to integrate oil analysis and vibration analysis:

- Early Detection of Rolling Element Bearing Problems — Oil analysis is typically more adept in detecting early bearing failure conditions. When both technologies detect faults, problem diagnosis and its assessment is rarely incorrect (ref. 2).
- Effect of Integrating Oil and Vibration Analysis — Integrating oil and vibration analysis can allow early detection and trending of numerous problems to which a machine can be subjected. Ref. 5 states: "Detecting the faults is the first step in the diagnostic process. Early fault detection yields benefits in diagnostic time, avoidance of unplanned down-time, elimination of chain reaction failures, and improved precision of maintenance actions." Often, stopping a machine and repairing a single component can prevent this problem component from adversely impacting adjacent machine parts, thereby avoiding costly (and potentially catastrophic) failure (ref. 5).
- Root Cause Failure Analysis - Ref. 5 states "Both oil analysis and vibration analysis are required to effectively determine root cause failure. Confidence in maintenance and operations decisions is substantially improved when both methods are employed".
- Condition of Lubricating Fluid - Ref. 4 states "The life of the machinery is in the lube". Oil analysis is required to assess the quality of this "life blood", no matter what the type of machine it might be.

Our experience has led us to make the following conclusions about oil analysis:

TABLE I: CORRELATION AND INTEGRATION OF LUBRICATION AND VIBRATION DATA

Condition	Lube Program	Vibe Program	Correlation
Oil Lubricated Anti-friction Bearings	Strength	Strength	Lubrication analysis will detect /can detect an infant failure condition. Vibration provides strong later failure stage information
Oil Lubricated	Strength	Mixed	Wear debris will generate in the oil prior to a rub or looseness condition
Machine Unbalance	Not applicable	Strength	Vibration program can detect an unbalance condition. Lube analyses will eventually see the effect of increased bearing load.
Water in Oil	Strength	Not Applicable	Water can lead to a rapid failure. It is unlikely that a random monthly vibe scan would detect the anomaly.
Greased Bearings	Mixed	Strength	It makes economic sense to rely on vibration monitoring for routine greased bearing analysis. Many lube labs do not have enough experience with greased bearings to provide reliable information.
Greased Motor Operated Valves	Mixed	Weakness	Actuators are important machine components in the nuclear industry. Grease samples can be readily tested; it can be difficult to obtain a representative sample. It can be hard to find these valves operating, making it difficult to monitor them with vibration techniques.
Shaft Cracks	Not Applicable	Strength	Vibration analysis can be very effective in monitoring a cracked shaft.
Gear Wear	Strength	Strength	Vibration techniques can predict which gear. Lube analysis can predict the type of failure mode.
Alignment	Not Applicable	Strength	Vibration program can detect a misalignment condition. Lube analysis will eventually see the effect of increased/improper bearing load.
Lubricant Condition Monitoring	Strength	Not Applicable	The lubricant can be a significant cause of failure.
Resonance	Not Applicable	Strength	Vibration program can detect
Root Cause Analysis	Strength	Strength	Best when both programs work together

* Source: Integration of Lubrication and Vibration Analysis Techniques by Bryan Johnson and Howard Maxwell; Pale Verde Nuclear Generating Station (Ref. 2)

1) The leading indicator of gear problems is oil analysis. In fact, in one case, a wear problem initially detected and trended by lube analysis was not detected by vibration analysis for approximately 6 months; it then trended in both technologies for approximately another 18 months until it was decided corrective actions were necessary.

2) Oil analysis is effective on large motors outfitted with plain bearings (particularly on motors greater than approximately 1000 HP). Oil analysis has proven a better and more reliable tool at detecting problems with wear of sleeve bearings on many machine types than has vibration analysis (on the other hand, vibration analysis is still the tool of choice to detect other plain bearing problems including oil whirl and oil whip).

Since adding oil analysis to our "condition monitoring arsenal", we have attempted to employ the following policy with condition monitoring clients: if a gearbox is considered critical whatsoever, oil analysis should be considered mandatory since it is often difficult with vibration analysis to clearly differentiate between actual gear wear versus gear tooth shape (profile) or tooth orientation problems (i.e., tooth misalignment, eccentricity and/or excessive backlash). Plus, in some gearboxes, oil analysis is able to differentiate wear from gears versus wear coming from bearings within the same machine. Research performed at Monash University in Victoria, Australia unveiled some important findings on condition monitoring evaluation of gears (ref. 6).

Building an Integrated Condition Monitoring Program

The plant can incorporate oil analysis into its program in several ways by collecting oil samples and sending them off-site for analysis, by employing on-site instruments for oil analysis, or by a combination of both strategies.

Certain "in-shop" oil analysis equipment can now provide very rapid answers (in less than one hour) in confirming wear problems (ref. 4). However, on-site analysis does require some investment in hardware, software, and in training. Management should review its options carefully before proceeding. Following is suggested:-

1. The entire condition monitoring team performing all technologies has been brought together in one common area allowing much information transfer and improving the accuracy/reliability of diagnostic calls as well as root cause analysis;

2. All condition monitoring personnel report to a single plant program manager who himself directly reports to plant management (providing him the ear of both maintenance and production plant management);

3. All condition monitoring personnel are "cross trained" in at least one other condition monitoring technology giving them greater confidence and understanding of the other technology;

4. All condition monitoring personnel work full time in their field (they may occasionally assist in performing certain corrective actions, but are not expected to do this on a regular basis);

5. All condition monitoring personnel receive formal training in their areas of expertise at least one week per year in order to keep them up to date and to further advance their knowledge which is of immediate benefit to the plant. Audits through the years have proven there is a direct correlation of program effectiveness to the quantity and quality of continuing training condition monitoring team members receive.

Conclusions

- Is vibration analysis a powerful condition monitoring tool? You'd better believe it!
- Is oil analysis likewise a powerful condition monitoring tool? Ditto.
- Does one technology "fill the gaps" left open by the other? Yes, they do.
- In other cases, does it improve the confidence and credibility of the analyst if both tools diagnose problems on a critical machine? Absolutely.
- Only one question remains - If you have only employed one of these powerful tools in your own program to date, why not significantly enhance the effectiveness of your program by adding its "complementary cousin" to your program? You and your plant management will be glad you did.

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Shashank Singhal
S Pola

Online transient analysis optimises asset utilisation

Traditional condition monitoring systems are designed for "steady state" operation of the turbine. But a turbine is rarely operating under these conditions. Loads, pressures, temperatures and vibration are changing rapidly, especially during startups, shutdowns and "bumps" in the night.

During these "transient" events, rapidly changing conditions within the machinery should be watched carefully.

All bearings need to be monitored continuously with ongoing comparison to a baseline so that changing conditions can be recognized. This technically challenging mode of operation generally requires advanced collection methods, high level processing, and the services of a turbine specialist to keep a close watch during a startup or shutdown operation, which might take from 24 to 48 hours.

The danger of rapid degradation of machine health is greatest at this time, yet it is the most technologically challenging period to monitor due to the large volumes of data generated and the speed with which changes can occur. New transient analysis technology meets that challenge by automating the process throughout the critical period. Live views give analysts a decision-making tool that can be accessed from another location by dialing into the system. Any machine that is being monitored by protection systems can be upgraded to transient analysis technology.

Extracting data

Since the turbine's operating parameters are constantly changing, it is important to monitor overall machine health and not just changes in vibration. In transient analysis, turbine engineers and operators have easy access to continuous, real-time vibration information, allowing them to closely monitor the condition of turbines during critical startup and shutdown periods.

Several different plots of live data are available on control room monitors, giving decision-makers an exact picture of what is happening within the machinery. Characteristics of this new transient analysis technology include:

- A live turbine dashboard (monitors) that produces new information five times every second and enables immediate action
- Up to 40 hours of complete data recorded before, during, and after an event
- Easy navigator for improved operator efficiency and a simple setup
- A smart data search system that extracts necessary information from voluminous data

Through the "live turbine dashboard" in the control room, users have dual monitors to view the development of seven different plot types: Orbit, Shaft Centerline Bode, Nyquist, waveform, spectrum, and cascade — on up to eight bearings. The data are updated up to five times per second.

A spectral measurement system processes vibration waveforms into frequency and amplitude content (FFT spectral data). Many factors can influence the overall vibration value, but they may not be recognized specifically unless the FFT spectral data are captured, analyzed, and published — real time. Trends of specific defects, such as oil-whirl, rubbing, unbalance and looseness are displayed on the monitors.

A data recorder stores continuous data, not just snapshots. Should it become necessary to carefully examine any critical period during a turbine startup or shutdown — or a

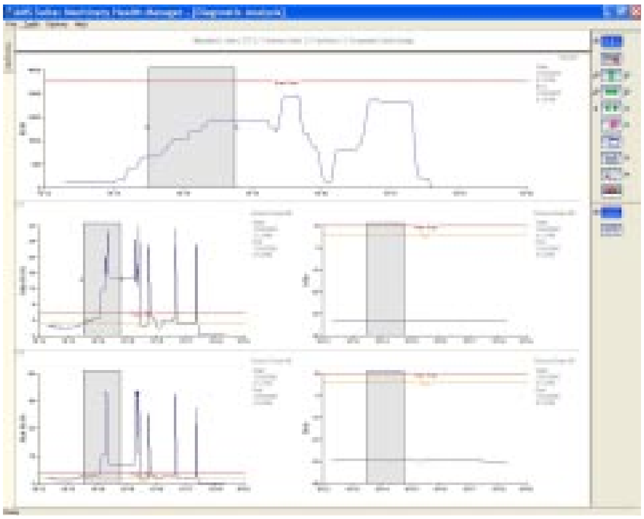


FIG 1 The turbine goes from heat soak to running speed in the top plot. In the second plot left the user has moved the "region of interest "rectangle to a slight "bump" he wants to investigate, and clicked extract.

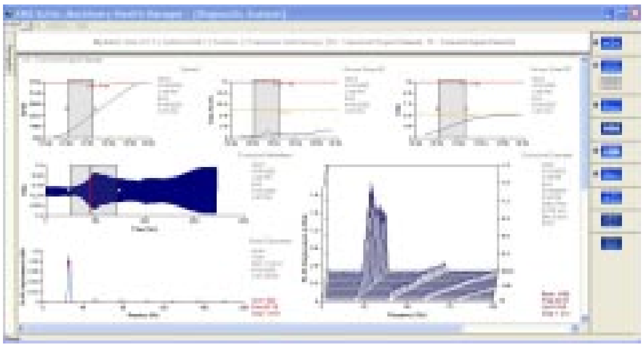


FIG 2 The analyst now has detailed information called for in Fig 1. Top left is RPM Vs time. The turbine has come upto running speed , and the operator has performed the overspeed check in the "region of interest" rectangle.The turbine was tripped offline and no fault was detected.

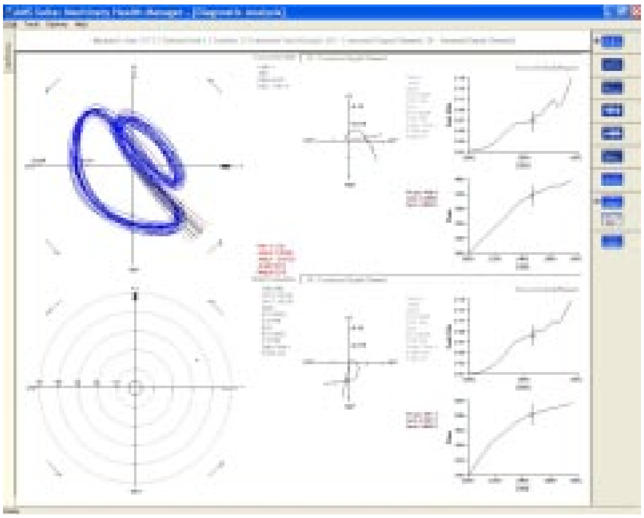


FIG 3 Stored data that were extracted show that vibration amplitude did not reduce after the first critical speed.

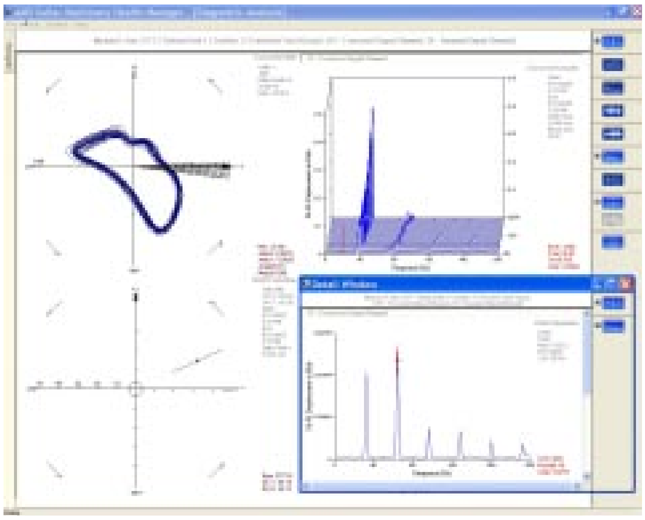


FIG 4 Orbits, Shaft centreline and spectrum plots show that shaft misalignment may have caused high vibration.

bump in the night — key data are available. If an operation must be left unattended, auto archiving can be initiated to cover any 40-hour period.

In the past, it was necessary to have a vibration collection strategy for monitoring turbines because of the large volume of data generated. But those collection strategies sometimes missed critical data. Today, setting up data-capture simply requires checking a box on the "configuration" screen. If that box is checked, transient data are collected. A "region of interest" selector enables turbine engineers and operators to pick the window where they want to extract detailed information (Figures 1, 2). No time is wasted searching through megabytes of data.

Aiding turbine analysts

Transient data help analysts to zoom in on any anomaly in turbine operation in the last 60 hours. The following case study highlights how this detailed data can benefit turbine analysts. When starting up, a turbine is attempting to pass through the critical resonance. Vibration should have begun to decrease at that point. Instead, it took an abrupt turn and vibration began increasing greatly with speed (Figure 3).

The Bode plot (upper right) shows that the critical resonance speed of the machine was changing — it was shifting to the right. For the critical to shift, damping, stiffness or mass must be changing . It is reasonable to assume that mass did not change, but that damping or stiffness of the system has changed . The operator noticed that the turbine did not pass through the critical speed. (In some cases the anomaly is not too great and the operator could continue to increase speed, passing through the critical speed). In this case, the operator was not getting past the critical resonance. Vibration continued to increase, so a decision was made to shutdown the turbine.

Simply re-starting this turbine, with no remedial action, will cause the same result.

Other plots will reveal what action must be taken for a successful startup. The orbit shows that the normal dynamic shaft motion has abruptly detoured (Figures 3, 4). A normal orbit would follow the green path. The shaft was not moving freely in an elliptical path as we would normally expect.

Loading or misalignment could explain the shift in critical resonance speed shown in the Bode plot. When the shaft is misaligned or improperly loaded, stiffening of the system can increase. This increases the critical resonance speed.

The shaft centerline plot in the lower left should not be one dot, as the turbine came up to speed (Figure 4). Ideally the shaft centerline position within the bearing should move up and to the right. However, if the shaft is misaligned or improperly loaded, it would be forced and held in an abnormal position. The shaft centerline plot helps confirm misalignment. The spectrum plot shows a high 2x turning speed peak — another indication of misalignment or improper loading. All the above show that the turbine needs to be re-aligned and checked for binding and improper loading.

The above technology provides the user a powerful tool for predicting the future health of machines and developing an optimization strategy to reduce maintenance, thus enhancing their plant's return on assets (ROA).

Shailesh Naik
Sudip Das

Secure Condition Monitoring via the Web

Internet based Condition Monitoring forms the basis for condition-oriented maintenance services, and is thus an important component of many maintenance and service strategies. The system also manages data and information about the machines if the customer so desires. A vital part of any Internet-based teleservices platform involves embedding the concept into the current communications and process requirements. Precondition for utilization is a secure Internet connection. Adopting load related, condition-oriented maintenance of machine tools, it is possible to improve the servicing processes and thereby to reduce the risk of an unscheduled system downtime. To enhance technical availability, an attempt is made to design the typical wear components to withstand longer load times. In all areas that cannot be protected with robustness, the machine user should be supported and notified well in advance through proactive diagnosis.

Condition monitoring via an internet platform

The user benefits in situ from this platform solution, which requires relatively little logic (thin client) as compared to a locally installed solution (fat client). For example, the machine can send an SMS or e-mail over the server and does not need a local provider or a local server. In addition, the burden on the machine control is reduced because the communications mechanism is largely installed right on the machine.

Furthermore, the service provider only requires an up-to-date Internet provider and secure access to the Internet. For the user, this eliminates all of the expenditures for the operation of a server (availability, redundancy and data security). Moreover, the system is available worldwide and enables electronic cooperation between partners. With such condition monitoring, the fact that the complex analysis algorithms need not be installed on every machine plays a very important role. These are always available on the server in the most up-to-date form. In other words, all machines immediately benefit from algorithm improvements. Yet another advantage of the platform solution: defined trends are recorded and still available even after the exchange of control components such as the local hard drive.

To arrive at an effective overall concept, it is essential that various services such as remote access, workflow, control monitors, condition monitors and administrative services are linked with one another as part of a complete work sequence. The condition monitor then generates a trigger for the following effective sequence. After all, an incoming message is only useful if it is processed correctly. The integration of condition monitoring into the overall process is particularly important — especially if it concerns the cooperation between machine manufacturer and user.

The concept of condition monitoring for machine tools encompasses two different processes, namely monitoring and test series. With monitoring, data are automatically recorded and generated without the need to do anything on the end customer's side. While they are important indicators, these data are not sufficient for a valid condition monitoring evaluation. That is why the user has access to test series which have to be executed by the operator at the end customer's location. As a result, the algorithms placed on the server do not only provide information about the recorded values, but also about the quality of the measurement data. The measured parameters, for example, tolerances, inversion range or friction values, are then displayed in trend curves as measurement series. Detailed information on transgressive values can be viewed and retrieved by double clicking.

Condition monitoring on complex machine tools involves a multitude of individual activities, during which data from the controller, the NC core, the drive system and the operator panel are generated, interlinked and analyzed. Internet based services offer a mobile, worldwide "tool chest" for both the end customer and the manufacturer.

Condition Monitoring as a toolbox for individual requirements

Based on standard services, individual customers, manufacturers of milling machines, have developed enhanced concepts for condition monitoring of certain TCO components.

Tool changers
Company A locally developed a tool of its own which records tool changes in real time according to its specific requirements, and then documents the results in a file. All of the files are automatically loaded onto the server and analyzed by Company A service in compliance with the respective end customer agreement.

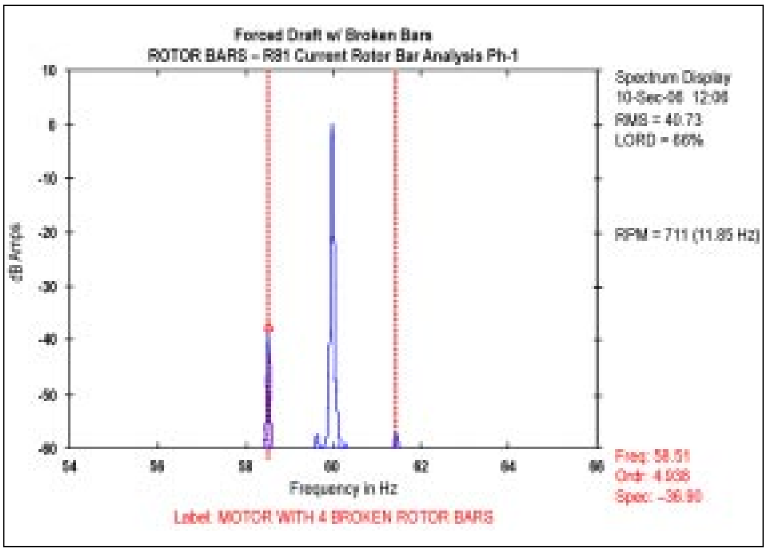
Servo axes
Based on the standard synchronous axis test (for servo axes with ball screw), the Company B has expanded the function to allow the rigidity of an axis to be assessed via trends. As part of the service package, they conduct this analysis for end customers, making an important assessment criterion available without the need for external sensor technology.

Main spindles
Company C has developed a process for spindle testing. Here, the measurement program is loaded and started by the server via maintenance contract. The measurement data are generated with the help of vibration sensor technology in the motor spindle and appropriate evaluation electronics, and the SW made available by the central service company, thus creating a spindle or inventory analysis. Depending on the result, further (service) measures are initiated.

Nitin Nair

Machinery Health Monitoring and Fault Diagnostics — adding Motor Analysis to a Vibration Program

Motor current and magnetic flux measurements are very important parameters to determine motor health. Motor current signature analysis program detects motor broken/ cracked bars as well as problem with the high resistance joints on any Induction motors. Flux analysis is used to detect stator related shorts, broken rotor bars and changes in voltage balance. Motor current and flux analysis technology, with embedded analysis expertise, helps complete a total Machinery Health Management program by diagnosing electrical problems that may be missed with a vibration monitoring program.



Detecting Broken Rotor Bars

Heat and fatigue, especially with excessive motor starts or overloading, can lead to broken rotor bars in electric motors. Broken rotor bars eventually lead to motor failure, and can cause secondary damage to stator windings. Rotor bar damage can be difficult to detect in a vibration signature. Therefore motor current analysis is a valuable additional technology to apply as part of a complete Machinery Health Management program. Motor current analysis provides a conclusive indication of broken rotor bars by identifying the "slip times number of poles" sidebands around line frequency (50 Hz), and comparing the sideband amplitude to the amplitude of the line frequency peak. If the sideband amplitude rises to within 45 dB of the line frequency peak, a problem is indicated, 35 dB indicates severe damage. In the plot below, the 60 Hz line frequency peak is shown in the center. The software has calculated and drawn dotted lines to identify the sideband peaks. Notice that the amplitude of the peak on the left is within 36.9 dB of line frequency amplitude. This indicates significant rotor bar damage.

Motor current analysis usually requires opening up Motor Control Cabinets in order to access electrical wiring with a current clamp. This can be dangerous, and requires an Electrician to be involved, and may even require suiting up in special gear. To avoid the risk and inconvenience of opening up MCC's, the flux coil can be used. The flux coil allows you to trend motor electrical condition using magnetic flux measurements taken directly off the end bell of the motor.

The flux measurement shows the same information as the current measurement, though the amplitudes depend on where the flux coil is placed in the magnetic field. Therefore, the flux data is used to look for changes in the trend on a monthly basis. When amplitudes start to rise, a current clamp is then used to confirm the absolute severity. In addition to the convenience flux analysis provides, it also provides additional diagnostic information not found in the current signature. In addition to rotor bar condition, flux analysis gives indications of changes in stator winding condition.

Adding Motor Analysis to a Vibration Program

If you already have a Vibration monitoring program in place, it is easy to add motor analysis by simply adding the required software and flux and current coil. It is possible to have the database wizard, which can will automatically configure the measurement points for proper analysis, and the Expert System can automatically screen through large amounts of data, analyze, and report on motor condition, so you don't have to be an expert at reading the plots.

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Designed and printed by stetdelhi@gmail.com