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Exceptional Condition Monitoring®

The Way Forward For Outsourced Services

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Contents:	Page
Executive Summary.....	2
1 Introduction	3
2 Is Predictive Maintenance Past its Prime?.....	3
3 Machinery Duties	4
4 The VBCM Management Challenge.....	5
5 Managing VBCM by Exception.....	6
6 Summary.....	7
References	8

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condition management solutions

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Exceptional Condition Monitoring® The Way Forward For Outsourced Services

Executive Summary

Machinery Condition Monitoring practice of the 20th Century has now further progressed with a combination of traditional vibration and acoustic emission measurement techniques. For outsourced services, where the interval between measurements is likely to exceed 4 weeks or more, the traditional vibration data collection method is not appropriate. Overall and frequency band vibration measurements rely on long-term trending, that although excellent, can take time to produce results. A more practical approach is 'Condition Monitoring by Exception'. This process of **Detection, Analysis** and **Correction** returns predictive maintenance programmes (PMP) to its original roots for outsource services.

The tool, that now enhances traditional vibration techniques, is Acoustic Emission (AE). It produces a consistent bearing condition measurement due to its ability to ignore all extraneous plant signals. AE is not affected by process or machine speed variation or indeed specific sensor locations. The early indication of lubrication starvation or developing bearing damage is the consequence of other factors that the maintenance manager can plan remedial action. More in depth root cause analysis, aided by powerful FFT portable vibration analysers and software, can then guide maintenance engineers.

The benefits of **Condition Monitoring by Exception** are as follows.

- AE is a Go/No Go reading for immediate bearing fault detection
- No need for a plant machinery asset register or bearing details
- Taking bearing Distress® measurements requires almost no training
- Expert analysis is undertaken when ascertaining machine service extension
- Production is able to enjoy faster assurance of maintenance priorities
- Acoustic emission brings down the cost of condition monitoring

The application of AE offers on the spot machinery condition without having to build machinery condition trends that can take several months of data collection. Set up time is minimal and expertise for taking routine measurements is less important. At the Analysis stage, if the cause needs to be ascertained or the machine cannot be halted for remedial work, then the detailed non-invasive vibration analysis will prove its worth.

Condition monitoring by exception brings immediate results with assurance of plant life expectancy. Managing CM of rotating machinery is no longer the domain of specialists since the AE tool has made it mainstream and effective. Exceptional Condition Monitoring® is CM by Exception making the process practical and cost effective, especially where Outsourced Services are concerned.

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1 Introduction

Largely due to staff turnover, especially those proficient in vibration based condition monitoring, companies are increasingly experiencing difficulty in operating their programmes. As such, there is a growing trend to outsource such specialist services. Although the benefits of maintaining machinery by condition are well proven, execution remains a challenge, largely due to the need for expert labour intensive practices.

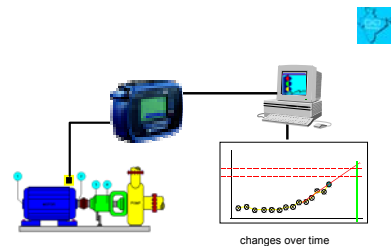
Successful VBCM is ensured with constant speed machinery, especially those above 600rpm. With the increased power and complexity of VBCM systems, the skill level and specialisation required has mitigated against its acceptance into mainstream engineering.

The range of variables for successful vibration based condition monitoring has also increased due to industry's progressive move to variable speed electric motors as a positive energy conservation programme. While 'normalising' vibration signals to variable speed rotors has been around for some time, it was primarily designed for on-line periodic surveillance systems.

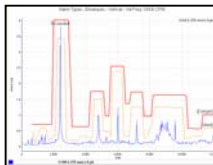
As machines became increasingly complex, so CM techniques were developed to make bearing condition assessment easier without the need for expert diagnostic skills. The need to simplify machinery fault detection with a higher degree of accuracy became more essential but this was not the direction of traditional VBCM product vendors. Fortunately, as with all technologies, something new comes along that makes a paradigm shift in established practice. Acoustic Emission (AE) is now recognised as the front line detection tool for detecting bearing Distress®. When used in tandem with powerful multi-channel FFT analysers with phase measurement, the process of **Detection, Analysis and Correction** has become practical again.

2 Is Predictive Maintenance Past its Prime?

Computerised in the 1980s, the corner stone of Vibration Based Condition Monitoring (VBCM) is based on trending of regular samples of vibration data. The more samples collected the greater the certainty of prediction. Those systems that produced excellent results employed either fixed or 'quick release' sensor pads at all measured points. This ensured quality and consistent data. Vibration readings taken with hand held prods or magnetic sensor holders have significant limitations, especially where high frequency transmissions are essential for consistent bearing condition analysis.



**Computerised Data
Collection & Trending**



Frequency Band Alarming

If the quality of data is unquestionable and machine frequency band alarms (see figure) are used, as designed, then the system gives an excellent return on investment. However, for a CM System to be fully effective it needs to be interfaced with a CMMS (computerised maintenance management system). When machinery faults are detected, work orders are generated; the system automatically verifies the effectiveness of subsequent corrective action.

Unfortunately, life is seldom perfect, even with the most advanced data processing systems the human element intervenes. Machines will be replaced in the middle of the night; often the new unit is not identical to the original. The VBCM database is not always updated until someone notices that the trends and vibration band alarms are illogical. Historical trend data, essential to the VBCM programme, will be inconsistent; thus it takes time before a new trend is established. Managing this data on large plants soon looms bigger than the process itself and the original objectives of optimising plant uptime can easily become blurred.

Often a contentious subject is the frequency of vibration data collection. The classification, duty and importance of machines to production and safety will be determining factors. The decision whether vibration sampling should be every 1, 2, 4, 6 weeks etc will also be influenced by the availability of standby plant. The author has seen databases where two samples per annum are proudly illustrated as a trend! This is clearly a huge waste of investment and a false sense of plant security by a supposed VBCM programme.

Certain organisations apply VBCM as a 'Breakdown CM Strategy' where someone notices that a machine is jumping around the shop floor! Only then is an Analyst deputed to establish the cause. This approach tends to defeat the concept of predictive maintenance.

Due to the difficulties of collecting quality data and at an acceptable frequency as well as the attrition of skilled engineers to predict machinery condition, companies are finding it increasingly difficult to manage their VBCM programmes. As a result, the move towards outsourcing VBCM services is becoming more widely accepted. VBCM rate contracts tend to specify sample collection periods of every two or more months. If the traditional measurement approach is applied the programme will not meet expectations. However, by operating **CM by Exception**, which is a combination of acoustic emission for **Detection** and vibration for **Analysis**, then the benefits will be quickly realised. First, an appreciation of plant processes, machine duty and electric motor development is necessary to illustrate how VBCM is changing with the needs of industry.

3 Machinery Duties

All Process Plants have similar objectives of productive outputs; they vary extensively in method. From continuous 24/7 operations to batch production or a hybrid of processes each requires an understanding and application of the appropriate condition monitoring technique. The situation is complicated for VBCM with a wide spread use of variable speed machinery and processes. (See figure below)

OPERATIONS	CONDITIONS
Continuous	Constant speed machines
Periodic Continuous	Runs at constant speeds as required
Periodic Intermittent	Short running speeds as required
Variable Speeds Broad Range	No fixed speed period, linked with process needs
Variable Speeds Narrow Range	Variable between say 200 RPM

Traditional vibration data collection is effective with continuous constant speed machinery but introduce any variables then the data becomes more complex and perhaps confusing. Unless an expert vibration analyst is available to recognise the inconsistent data, the wrong conclusions will be drawn. This leads to incorrect maintenance decisions that can impact on the confidence of a VBCM programme.

At the more basic overall vibration measurement method, specific findings according to the orientation of the sensor are generally understood. The table below illustrates that the low frequency high-energy signals dominate over the secondary signals. However, by applying acoustic emission measurements, it detects bearing condition irrespective of sensor orientation and ignores low frequency high-energy forces that interfere with detecting developing faults at higher frequencies.

Orientation / Plane	Primary Indication	Secondary Indication
Horizontal – 90°	Unbalance	Alignment, Looseness, Gear Meshing
Vertical – 0° or 180°	Looseness	Unbalance, Alignment
Axial	Alignment	Unbalance, Gear Meshing
Dual Sensors – 45° C/L	Unbalance, Shaft Position	Looseness, Alignment, Oil Whirl
Acoustic Emission – Any position, seek highest signal	Bearing & lubricant condition	None - Unbalance, miss alignment, looseness etc. impose stresses on bearings. - Distress® is the key indication

The AE system is fast replacing the lower frequency techniques such as spike energy, shock pulse, Kurtosis, Crest etc. These have a much lower signal to noise ratio and hence are also affected by none bearing faults. Since AE operates at 100 KHz it produces an extremely high signal to noise ratio that is used in the time domain for fault identification.

4 The VBCM Management Challenge

Often misunderstood, the best vibration measurements are from constant speed machinery, generally over 600 rpm. In fact the higher the speed the better and if anti-friction bearings are involved then readings taken from the outer bearing case are relatively easy to analyse. However, process plants will have a range of machinery types in use. With the realisation that energy savings and environmental benefits are available from variable speed motors the challenge of traditional VBCM with FFT band alarming becomes even more complex. Increasingly industries are employing variable speed motors across the globe.

Let us look at rotor speeds related to traditional vibration monitoring:

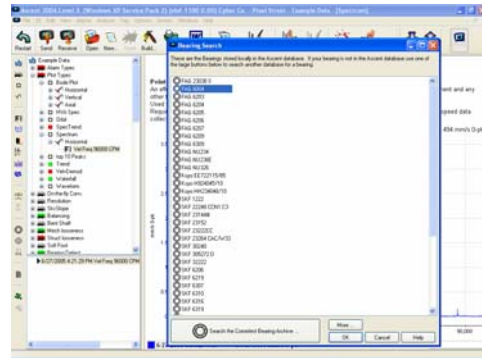
Rotor Speed RPM	Degree of Measurement Difficulty	Method / Solution
>600	Not difficult	Traditional vibration frequency domain for detailed analysis well established
<600	Becomes more difficult	Use low frequency sensor to measure in displacement
<100	Very difficult	Long data collection time with time synchronous averaging to get clear signal
<50	Special technique needed	Set up requires considerable care, data may be confusing
<5	Not practical	Use Acoustic emission, simple process and effective

Those process plants with slow speed machinery need to ensure that vendors of vibration measurement services are suitably equipped and have the expertise and tools to measure very low frequencies for condition analysis. The alternative is to use acoustic emission that covers virtually all speed ranges from 0.25 rpm and above.

5 Managing VBCM by Exception

Managing condition monitoring by exception is not a new way but a better route to effective and rapid results, especially for outsourced services. Where the interval exceeds 4 weeks between readings then a different approach to the accepted vibration trending is required. Often such services are established on a rate contract basis for one or two years.

The traditional computerised vibration data collection process requires setting up detailed database associated with the Plant Machinery Asset Register. All bearing details are required to set up machinery frequency band alarms. This is aided by most software systems that have as many as 30,000 bearing types in their database. The systems that produce the best results are those with a well-managed database, regular samples and prioritised machinery with a root cause analysis for practices such as Reliability Centred Maintenance (RCM).



To undertake a comprehensive machinery vibration analysis, measuring amplitude, frequency and phase is essential. Although the modern data collector has the facility to take phase readings this is seldom used due to the extra effort involved and time taken. Only the former two parameters are collected routinely. Unfortunately this reduces the analytical power of the system by 33%. As a result, when a suspect machine is ultimately identified, a full analysis is then undertaken applying all three parameters but by exception.

For Outsourced Services where regular sampling is undertaken, it is advisable that the Client has a licensed copy of the vibration database. Having all the history of machines electronically rather than hard copy reports of machinery is a safer option. Reports can be voluminous and mask the real information of fault development. Vendors should offload data at site for access by Engineering and Production staff. They should issue summary reports on the spot and then a formal report later. Software access keys and site licences are available from leading Consultancy Service Vendors. This approach protects the Client's machinery data history for the long term.

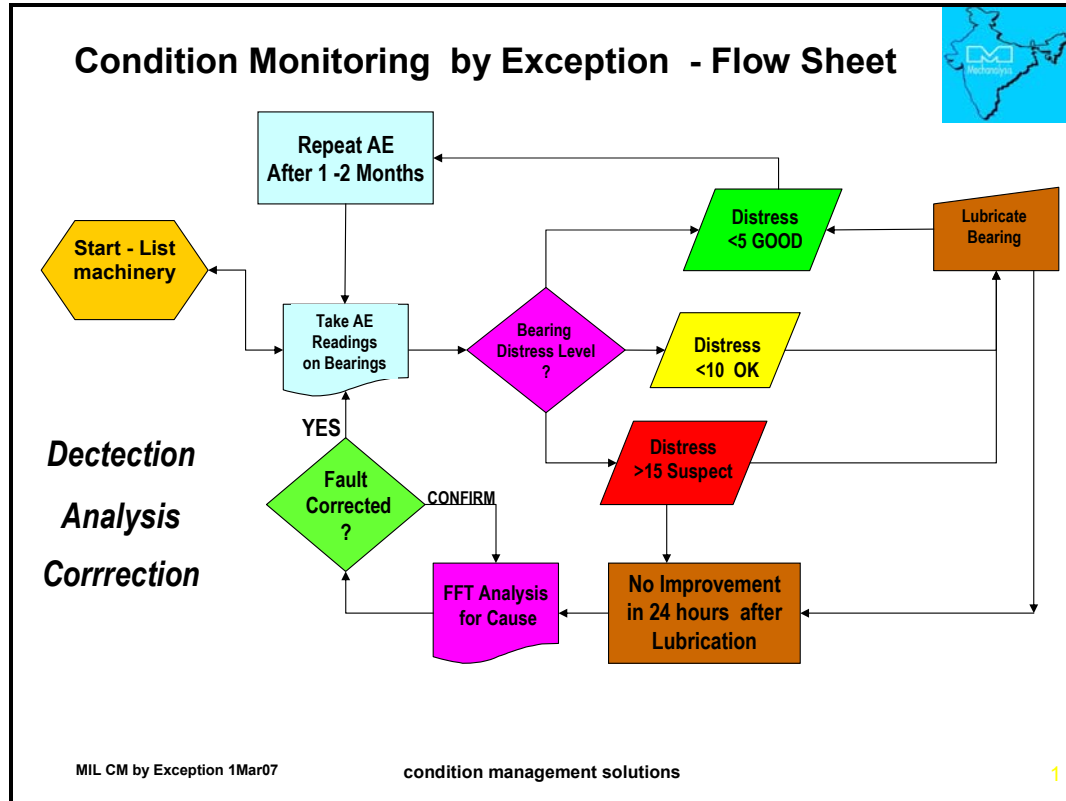
However, for Process Plants, who use infrequent Outsourced Services, the effort and reward of applying detailed machinery databases are questionable at best. A simpler and more effective approach is to apply a bearing Distress® measurement routine using acoustic emission meters and then undertake comprehensive vibration analysis to determine the root cause of the bearing's Distress®.

The chart below illustrates the process of Detection, Analysis and Correction. This simple but logical approach is undertaken as follows:

- Step 1:** Measure the bearings, if Distress® is below <5 then the bearing is in good condition and can be checked in a month or two later
- Step 2:** If the bearing Distress® is <10, the bearing is in satisfactory condition but attention to lubrication may be beneficial.
- Step 3:** If the bearing Distress® is >10-15 then lubrication must be checked. If after 24 hours, the Distress® level has returned to its original figure then detailed FFT analysis with phase should be done to identify the cause.

Step 4: Once the cause of the bearing Distress® has been corrected, this may include re-alignment, rotor balancing and replacement of the bearing etc. A further FFT analysis should be done to verify the effectiveness of the work done.

Step 5: Is a return to Step 1: measure the bearings, if Distress® is below 5 then the bearing is in good condition and can be checked in a month or two later.



It can be seen that Condition Monitoring by Exception is a simple process that focuses on the prime machine health indicator that is bearing Distress®. This approach avoids the use of a Plant Asset Register and maintenance of a detailed machinery database. The AE Tool is applied to all rotating machinery by plant personnel on a routine basis. When a detailed FFT Cause Analysis is required then an in-house or contract vibration consultant can be employed on a case-by-case basis.

6 Summary

Successful vibration based condition monitoring is a process of consistent data collection based on trending which is the easier stage. Data analysis and maintenance advisory notes credibility lies with the expert vibration analyst. However, these experts tend to move jobs to the highest payer and so VBCM programmes have difficulties of continuity.

In the case of those organisations that have decided that it is better for them to outsource VBCM services rather than continue to struggle managing an in-house CM Cell, the frequency of measurements will be an economic decision. Irrespective of the merits of more or less data collection, any series of measurements is better than none at all. However, if the traditional vibration data collector is applied with a database for managing the information then the readings must be more frequent than less to be beneficial.

An alternative to this approach is to undertake condition monitoring by exception. By taking bearing Distress® readings, which is a simpler and lower cost approach, machinery maintenance priorities can be easily established. An FFT 'Cause Analysis' investigation can then be applied by exception when the source of the problem is not obvious. In house skills for in-depth vibration analysis can be developed and enhanced with interactive training CDs. Such computerised training tools in vibration techniques will always be available to any employee when retained in-house.

The following points summarise the issues discussed.

1. **Turnover of Condition Monitoring staff is a growing concern. By simplifying the measurement process will reduce the reliance on full time expert analysts.**
2. **Vibration analysis skills can be retained in house through interactive CD training.**
3. **CM Service Vendors should supply the client with the VBCM machinery database**
4. **Vibration based condition monitoring gives excellent results, if measurements are taken frequently on continuous constant speed machinery.**
5. **For long-term intervals between measurements or variable machine speeds, an alternative strategy is required.**
6. **Acoustic Emission, used for bearing Distress® measurement, is simpler to use as a front line tool and is not affected by readings taken on variable or even slow speed machinery.**
7. **The cost of CM can be reduced by the application of acoustic emission.**
8. **Apply FFT vibration analysis to ascertain the fault cause by exception rather than routine.**
9. **Acoustic emission is ideal for those Condition Monitoring programmes that are outsourced with long intervals between measurements.**

Condition based maintenance is a proven method for reducing maintenance costs that will directly improve the bottom line. Outsourced services can be successfully provided if Condition Monitoring by Exception is based on bearing assessment by a process of acoustic emission measurements.

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The Mechanalysis Approach

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