Lifetime Reliability • Solutions

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The Lifetime Reliability Solutions
Certificate Course in Maintenance and Reliability
Module 2 – Machinery Vibration Analysis Fundamentals

Session 6
Vibration Measurement Applied To Condition Monitoring

1. Introduction

An essential part of the maintenance of plant is the identification of the need for work to be carried out before failure occurs with all its consequent costs. Remember, maintenance is more than just "fixing things up"; it is the appropriate management of an asset for its lifetime.

Typically, the detection of the need for maintenance has been by one or more of these methods:
- From a perceived change in observed condition or performance – Condition Checking
- Let it draw attention to itself – effectively Breakdown Maintenance
- From routine or periodic inspections – Planned Preventative Maintenance
- From a measured and trended change in the condition or performance – Condition Based Maintenance

This process contributes more fully to plant reliability when it is applied in conjunction with **Precision Skills** in maintenance. Precision Skills is the focus of Unit 2.

The principal focus of this session will be the application of vibration measurement to condition monitoring.

2. Condition Checking

This procedure offers enormous potential but is frequently neglected or not recognised for what it offers. This is where plant operators, or others who visit and are close to plant on a regular basis, observe and report upon what they **See, Hear and Feel** in relation to the plant. They may use some rudimentary instrumentation to assist in this. In this role the plant operator is seen to be the first line condition monitoring personnel.

On plants where this role is formally recognised and feedback is expected, and is acted upon, there is a very significant lift in the reliability of the plant. Note the three essential elements here;

- The role is formally recognised; this may involve some appropriate training
- Advise or feedback is expected and a process exists for this
- The information is acknowledged and is acted upon. The outcome is fed back.

Condition checking will not be effective if plant housekeeping is not good. It is not possible to observe fluid leaks, coupling or belt debris, or witness marks of machine movement if the machine is dirty. If a machine runs roughly or noisily it will not be possible to detect an increase in roughness – a relatively subtle change from smooth to rough is very readily identified with the human touch.

Some modification in guarding may be needed to permit safe access for feeling bearings or observing debris from couplings.

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Under maintenance regimes such as TPM, plant operators and maintainers are formed into teams and the operator is trained and expected to carry out the basic routines of preventative maintenance and inspections, with support from the maintenance staff. This concept of teamwork, or partnership, has been reported to work very effectively when all the elements given above are in place, and are used rather than given lip service. Increasingly this concept is being used more widely, although not necessarily under a TPM regime.

3. Breakdown Maintenance and Planned Preventative Maintenance

These strategies are essential parts of any maintenance programme and are not considered further for the sake of this discussion.

4. Condition Based Maintenance.

The principal techniques of Condition Based Maintenance, or Condition Monitoring, are;

- Vibration Measurement and Analysis
- Oil Condition and Wear Debris Analysis
- Thermography
- NDT, particularly thickness testing
- Performance, eg flow measurement

At most sites where vibration condition monitoring is routinely conducted there will usually be a thermography and an oil analysis programme operating as well. However, until recent times there has been little effort to correlate the findings of all methods into a combined condition report. This is now changing with more emphasis being given to 'integrated condition monitoring' where an alarm in one method gives cause to look for evidence of a fault in the other methods. Better quality forecasts of remaining life are the result of good quality integrated programmes.

4. Vibration Measurement and Analysis

Vibration measurement and analysis has over many years been the most popular choice in Condition Monitoring of fixed plant because;

- It has been shown to be effective in detecting a wide range of machine defects,
- Detection is sufficiently early to allow remedial action to be taken,
- As a diagnostic tool it can be used to identify specific machine faults,
- The technique is essentially non-intrusive and can be performed whilst plant is in normal operation,
- Varying degrees of sophistication in instrumentation and technique can be applied,
- Relatively low cost of transducers makes installation for continuous monitoring attractive,
- In simplistic terms, 20% of the potential expenditure in instrumentation & skills can be used to detect 80% of the potential detectable faults,
- It is readily applied to in situ balancing.

5. The Vibration Condition Monitoring System

Typically in current times, most condition monitoring is performed with systems comprising;

- Transducer, either portable or installed

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- Data collection instrument
- Data Collector firmware
- Computer software

There are numerous simple hand held instruments for vibration and/or bearing testing available and these do have a place within a test programme but for condition monitoring purposes have limited value and depend upon manual archiving of data.

For the purposes of this paper the software driven system outlined above will be considered. These are available in varying degrees of sophistication and cost.

Choice of a system obviously depends upon the complexity of the machinery to be tested, the level of risk and the skills of the operators available. These factors are relevant to both in-house and contract services and aspects of this are considered more fully in Unit 2.

5.1 The Transducer

Transducers were considered in some detail in Session 3. All data collectors come with a portable transducer – normally an accelerometer – connected by a coiley cable and mounted by a magnet, probe or stud.

Because of issues of safety or accessibility transducers are sometimes permanently mounted on machines with a cable leading out to a connection point.

The industrial norm is to use accelerometers with an integrated amplifier (ICP) giving an output of 100mV/g. However, special applications, such as low speed machinery, will dictate transducers of different characteristics.

The mounting of the transducer is the weakest point in the whole measurement system. If the transducer is poorly mounted then all the sophistication and cost in the data collector and computer software is largely wasted.

Condition Monitoring depends upon minimising the errors in the repeatability of the data collected and great care must be taken to achieve this;

- Suitable preparation of the mounting point. This is often compromised in the interests of cutting costs – a bad choice!
- Repeatable plant operating conditions
- Integrity of cables and connectors – worn connectors or damaged cables can introduce spurious signals

Listening to the raw vibration signal through a headset allows the operator to identify when there is bad transducer mounting, damaged cables or connectors. This has been the standard practice for many years in the businesses run by both presenters. Sadly most data collector manufacturers have not embraced the concept.

Consider the diagram on the following page to see the uncertainty that can arise when changes are observed.

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Forces		Response	Observed
Balance Alignment Looseness Electrical Hydraulic etc	→ Bearings →	Structure Mass Stiffness Transducer Mounting etc	→ Analyser

What has changed?

The Force
or
The Response

We need to identify

the vibration characteristics
how the machine/structure moves
process changes
historical influences

↓

We analyse and diagnose

↓

Inspections and corrections are made

↓

Information on the condition found is fed back (↑ back to "We need to identify")

↓

Post repair tests are made

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5.2 The Data Collector

These tend to be state of the art portable electronic boxes that can be capable of performing most of the tricks that in the 1980s required a quite large mains powered instrument.

The simplest of these will collect broadband (or overall) measurement values only, for both lower frequency mechanical condition (vibration velocity) and higher frequency bearing condition (vibration acceleration). They can be quite effective for monitoring more basic machinery where there is not a high level of risk. But be aware of the limitations of broadband measurement.

The more sophisticated and commonly used boxes will collect broadband values, FFT data and Time Waveforms, as well as having circuits for proprietary bearing testing.

These instruments have the ICP power supply for accelerometer inbuilt amplifiers as well as having options for powering stroboscopes and other add-ons. Most have a screen for viewing the collected data and the capability for “massaging “ the data so that the instrument is then used more like a stand-alone diagnostic analyser.

Effectively these instruments can be regarded as frequency analysers; they will provide FFT and Time Waveform collection and analysis from any transducer providing a dynamic signal, eg pressure, noise, vibration, electric current, strain, laser. They are also capable of collecting and storing data from transducers providing only a DC signal.

Data collectors normally have onboard software (known as Firmware) which makes the instrument easily upgradable.

For data collection purposes the instrument is programmed by the computer software for the machinery to be tested and the measurement parameters to be used.

5.3 The Software

It is here that the data collection parameters and requirements are prepared, as well as the “massaging” of the collected data for analysis and reporting. Most systems offer levels of sophistication and cost. They have various types of Alarms and Reports which if correctly set up and used can remove a lot of the tedious data sifting that is involved.

With an appropriate “driver” most software packages can work with any data collector.

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6. Setting Up the System

The following are the steps to be considered in setting up a comprehensive vibration monitoring system. All steps are relevant to a simple broadband system but some of the detail would not be needed.

- Decide which machines are to be tested – review Session 2 with regard to choices of maintenance methods and the consideration of Risk.
- Identify the failure processes that are to be monitored and the most suitable monitoring method.
- Decide upon the measurement locations and planes (H,V,A) to be used.
- Determine the vibration measurement parameters which will show data relating to the failure processes – velocity or acceleration, frequency span, time of sampling (number of averages) for statistical confidence. Is the failure process going to be impactive (or spiky) such that Time Waveform should be used rather than, or as well as, FFT.
- Determine the plant operating conditions under which measurements will be taken.
- Decide upon the periodicity of measurement. Usually, as a guide, the period should be less than half of the time over which a defect will take from inception to failure. It has been found from many years of experience that in many industrial situations monthly testing is a good balance. However, there will be many situations where more frequent, or even continuous, monitoring is justified. Equally there are others where because of the duty cycle and criticality, less frequent – perhaps 3 monthly, is appropriate.
- Acquire the data which will assist in the diagnosis of the data – shaft speeds, gear ratios and number of teeth, pulley sizes, bearing number and manufacturer, motor details, number of impeller blades etc.
- Prepare the machines for testing; provide access to test points, decide upon mounting methods and provide/prepare these.
- Establish a reporting procedure to ensure the <u>information</u> that is derived is appropriately disseminated and acted upon.
- Establish Quality Procedures to ensure the system will do what it is supposed to when it is due, and that there is provision for review for effectiveness.

All of this can add up to a substantial amount of work but it is necessary to do it thoroughly for an effective programme.

A major conundrum is that the system is set up in the expectation that it will identify problems when they arise – unfortunately some vibration problems do not manifest in the way expected and it may be that the collection parameters chosen are not suitable for detecting the changes expected. Experience is a major factor here.
Perhaps more importantly, if there is any doubt, consider using collection parameters that are suitable for <u>detecting changes</u> rather than giving <u>diagnostic information</u>.

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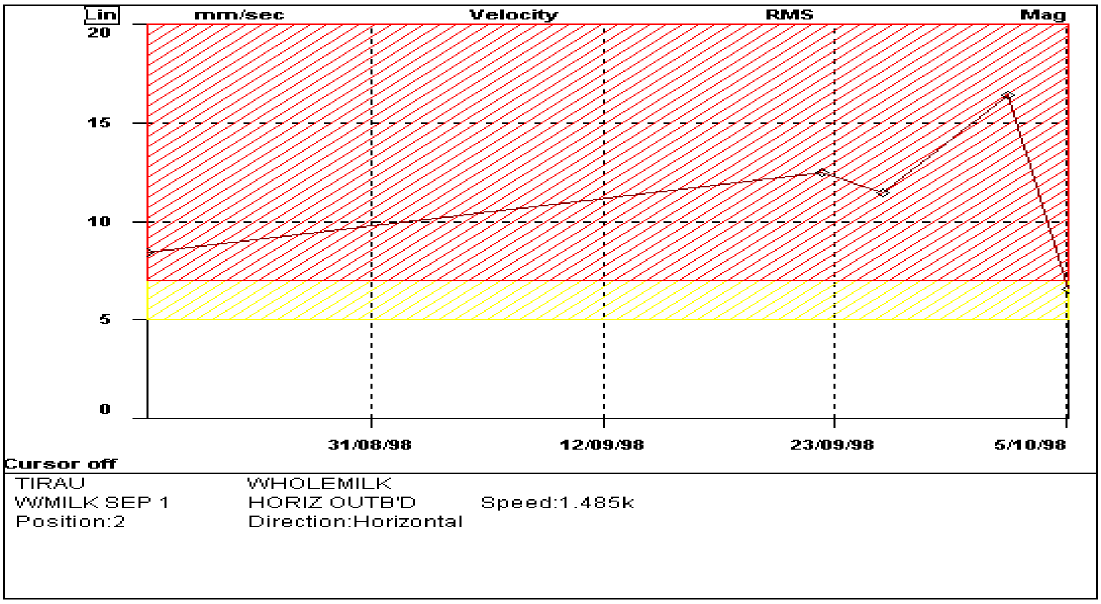
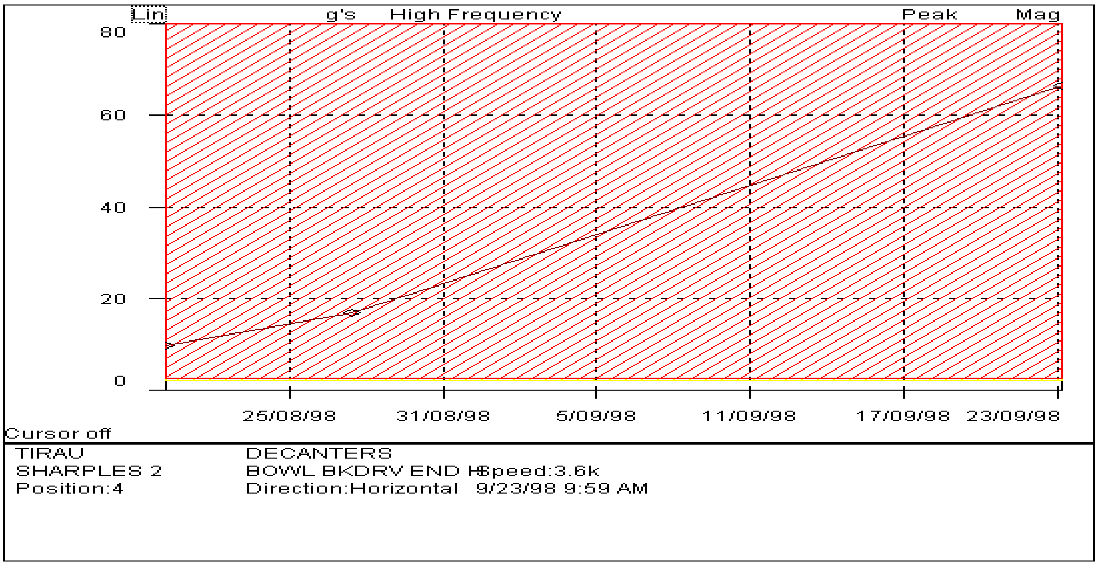
7. Presentation of Data

The Trend Plot

This the most commonly used plot and essentially forms the basis for condition monitoring. It is simply the graph of a parameter measured over a period of time. With vibration velocity it will be the overall vibration value measured between two filters, perhaps 10Hz to 1000Hz.



The **Trend** of a bearing condition parameter (Demodulated Acceleration) with time.



The Spectrum Plot

This is the most commonly used plot for diagnostic purposes and shows a range of vibration frequencies against the vibration severity. It is often simply a span of frequencies from zero (or near zero) to a maximum value and various computer techniques enable it to be "massaged" to reveal information. The quality of information is largely dependant upon the lines of resolution and the Fmax.

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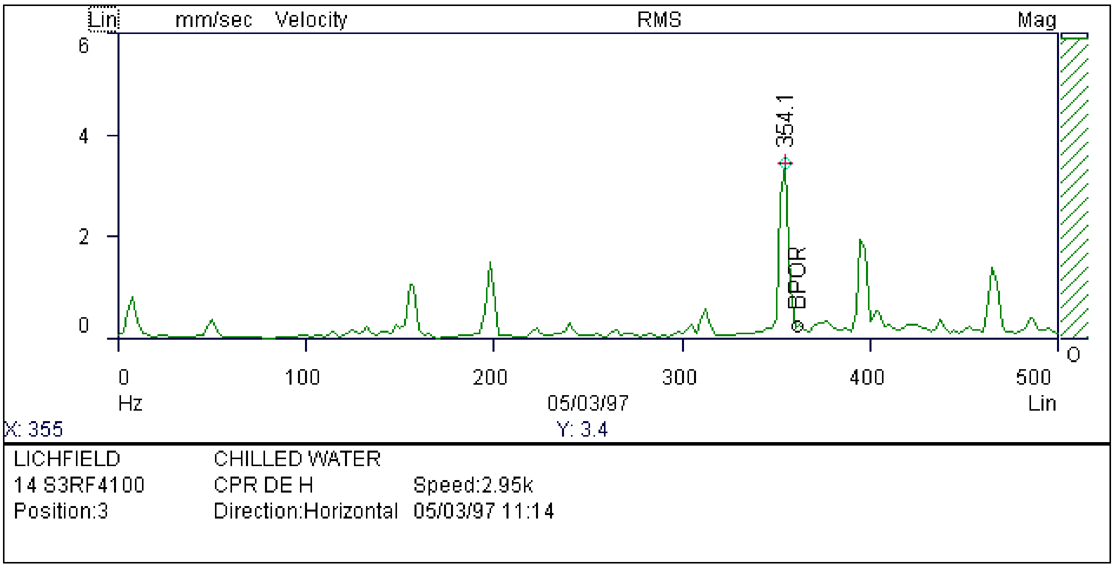
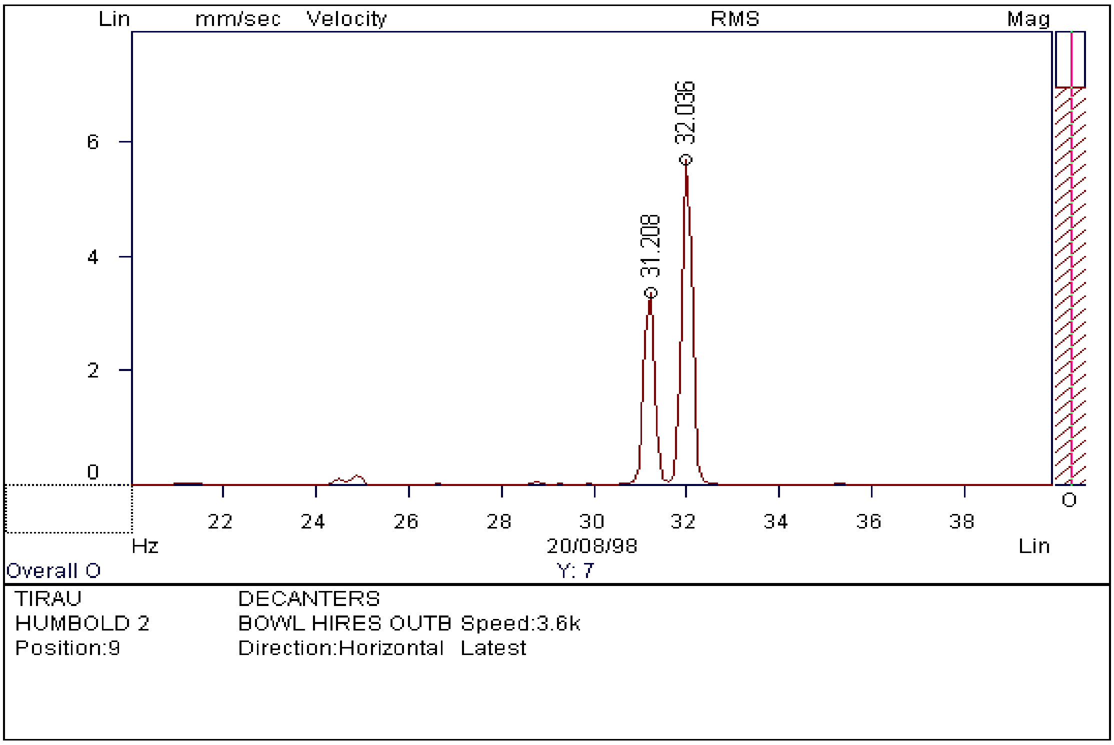
A typical Spectrum Plot from a screw type refrigeration compressor, with a frequency span of 0 – 500HZ and 400 lines of resolution.



A "zoom" spectrum from 20 – 40Hz with 400 lines giving a resolution of 0.05Hz which enables the separation of two peaks which would be seen as one with strong **beating** in the spectrum above which has a resolution of 1.25Hz.



The Waterfall or Map Plot

showing the development of bearing defect signals in a screw type refrigeration compressor.

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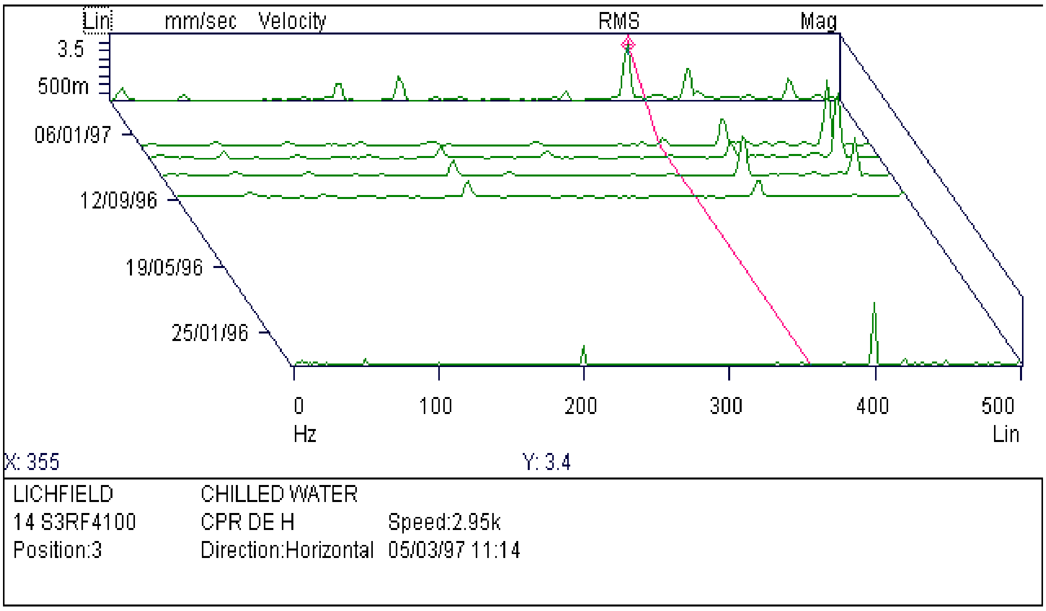
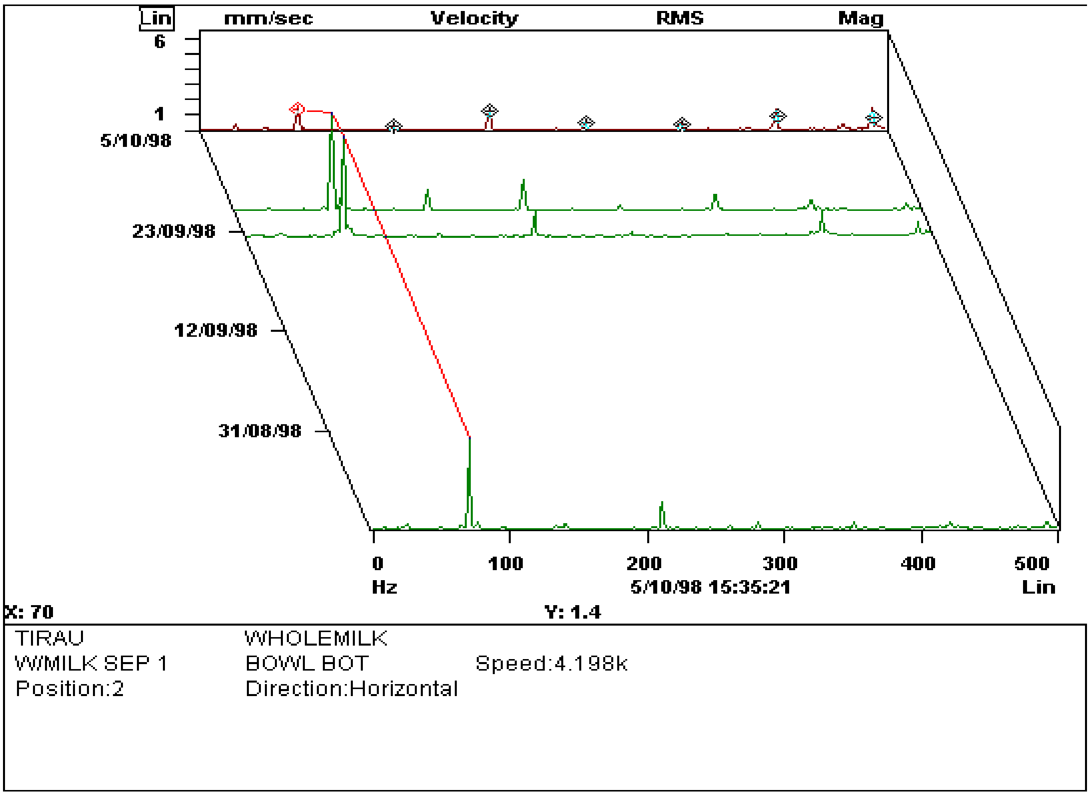


Showing the development of looseness in the bearing support system of a vertical bowl separator as a result of excessive unbalance. After balance correction the looseness remains.



The Waterfall Plot manipulated to show the trend of increasing severity of a specific frequency, indicating a deterioration of unbalance in a vertical bowl separator.

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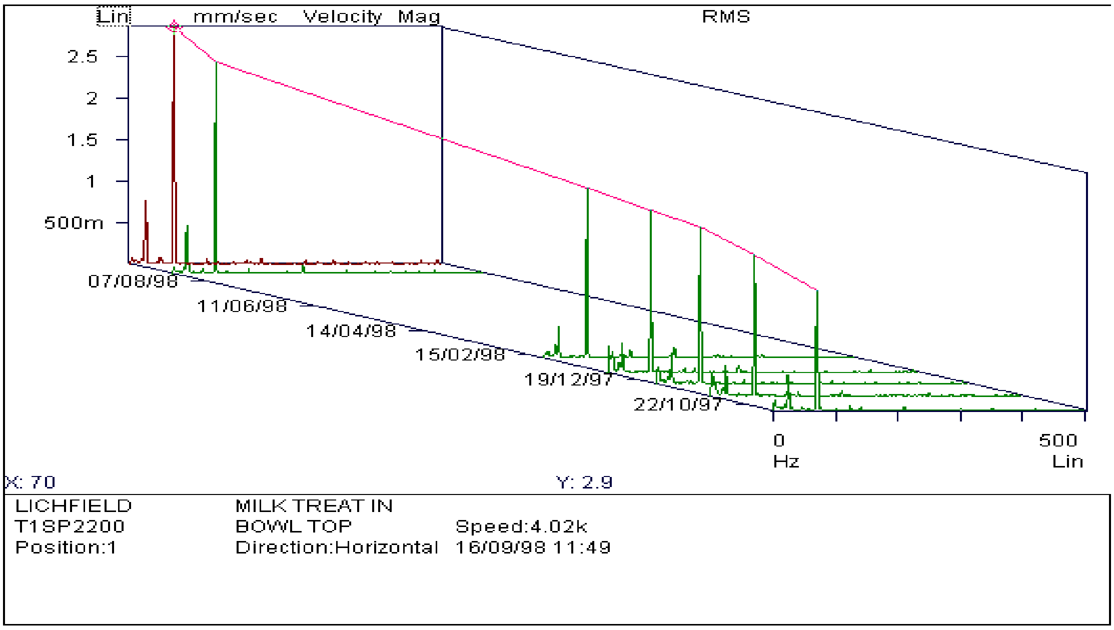
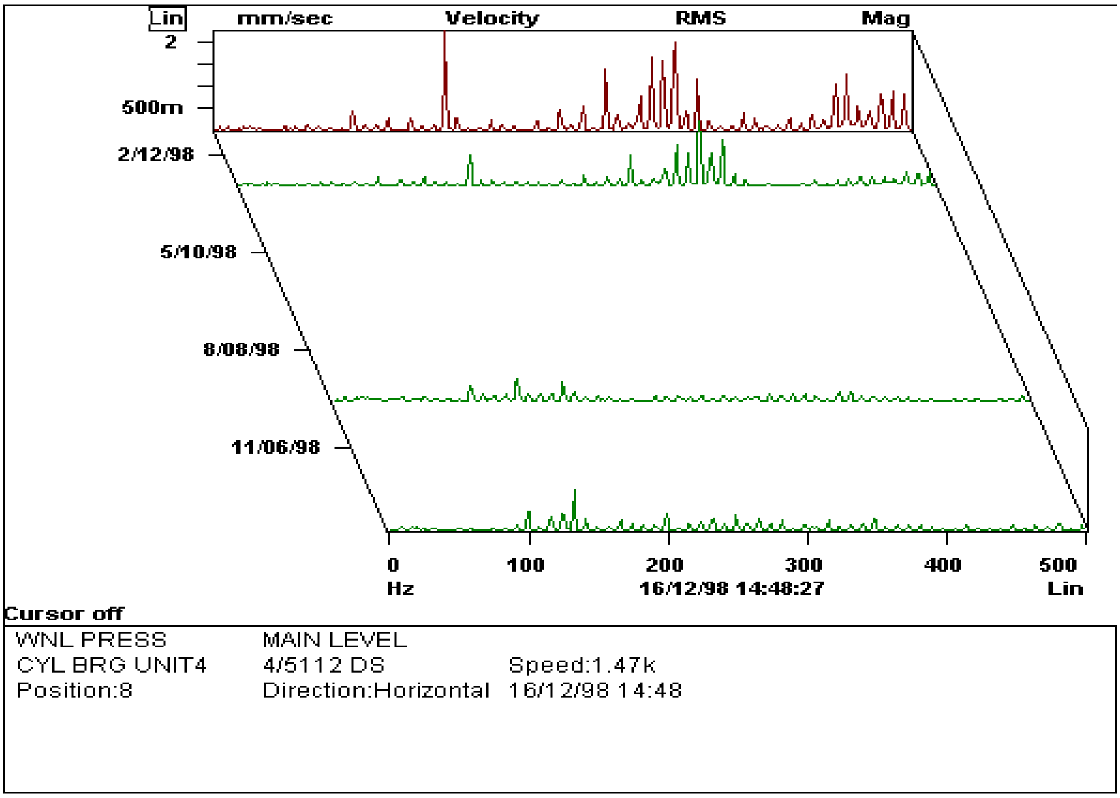


Showing the "changing condition" at a printing cylinder in a high speed printing press.



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8. The Effective Use of Vibration Condition Monitoring

One of the major and most obvious uses and benefits of vibration condition monitoring is the detection of incipient failures and planning in a repair/replacement with minimal disruption to production.

This is as far as many programmes go – simply a fault detection system. However, there are other benefits from vibration data that should be taken:

- Action upon minor defect at an early stage, eg correcting alignment before it initiates premature bearing failure.
- Use of diagnostic information to localise repair action to the defective components only.
- Use of diagnostic information for Root Cause Analysis and to design out problems.
- Achieve smoother running machinery and extended time between failures.

These are discussed more fully in Unit 2.

As the sophistication of a system increases so does the skill level required to operate it, and the need for experience in performing the higher level of diagnostics.

The simpler software based systems using only broadband measurements can be relatively effective without a high level of skill, but it is essential to have sound training and a good understanding of the technology. The provision and retention of staff with an adequate skills level is one of the major issues involved with operating an in-house vibration condition monitoring programme, but this is balanced to some degree by some of the benefits. This issue is a part of the subject of a paper in Unit 2.