Operational Challenges of Today

‘Our target is zero unplanned downtime’
  • Maximize Equipment Availability & Reliability
    • Plan ALL Maintenance - HOW?

‘We are trying to be competitive today with a plant that is typically more than 40 years old - and so are our competitors.’
  • Extend Machinery Life & Rebuilds

‘We are running our equipment beyond its design capacity to handle the variety of materials that we must process’
  • Increased throughput without RISK of machine failure?
Answer These Tough Questions...

What maintenance does the machine need during the next planned shutdown?
  • Do I have the parts, do I have the people?

Can the equipment run beyond the next scheduled outage?
  • What work can I safely schedule out until the next shutdown?
What is Vibration?

- Vibration – The motion of a body about a reference point
- At its simplest, vibration is displayed as displacement over time
Why Use Vibration Analysis?

"Of all the parameters that can be measured non-intrusively in industry today, the one containing the most information on machinery health is the vibration signature."

Art Crawford
Acknowledged expert in the field of vibration analysis
Overall Versus Spectrum

- Overall can let you know that there is a problem
  - “Hey Fred, something is wrong with your car!”

- Spectrums can tell you what the problem is
  - “Hey Fred, your water pump is bad!”
The Units

**Displacement** accentuates the low frequencies - Mils

**Acceleration** accentuates the higher frequencies (g’s)

**Velocity** is consistent across a larger range of frequencies

Most vibration is analyzed in Velocity since the energy level is consistent throughout the frequency range.
How do we measure vibration?

- Three types of sensors
  - Displacement, Velocity, Acceleration
- Signal processor of some type (CSI 2130)
  - Local or portable display for field analysis
  - Remote
- Software for viewing and storing collected vibration data
Displacement Probes

Typical Applications

- Sleeve bearings
- Most turbine and large motor driven machinery
  - Main turbine generators
  - Boiler feed water pumps
- Applications in which ‘X-Y’ data is required for measurements such as
  - Shaft centerline from DC gap data
  - Orbits from vibration data
- Not practical for bearing or gear analysis
Electromagnetic Induction
Velocity Pickup

- Velocity Sensor Application
  - Mounted on case of machine or shaft riders
  - Used on sleeve and roller bearings depending on the application
  - When integration to displacement is required
  - Hi-temperature
    - Up to 900°F or higher
Theory of Operation – Velocity Pickups

- Mechanical
  - Moving coil
  - Self-powered
Accelerometer

- Accelerometer Applications
  - Case mounted or magnet mounted
  - Primarily Roller-element Bearings and Gears
  - When analysis and diagnostics are important
Accelerometer
FFT Signal Processing
Signal Processing – The Mystery

Turning Speed Time Waveform
Signal Processing

Add twice turning speed vibration
Signal Processing

Add blade pass vibration
Signal Processing

Add Bearing Vibration
Signal Processing

Total Vibration
Signal Processing – break down complex waveform in to waveform components

The Fast Fourier Transform (FFT) takes the complex waveform and breaks it down into the component sine waves

The amplitudes for each sine wave is then plotted at the frequency of the sine wave, creating the Spectrum
Signal Processing – The FFT or Spectrum

Spectrum (FFT)

- Twice Turning Speed
- Turning Speed
- Blade Pass
- Bearing Frequency

Vibration Basics (Miller) 22
So What can Vibration Analysis Detect?

- Detect and Track progressing stages of **Bearing Failure**
- Identify **Imbalance** and **Misalignment**
  - Vibration Analysis is used to correct Imbalance
- Identify/correct **Resonance**
- Identify **Mechanical Wear** in couplings, bearings, support structures, etc.
- Detect other defects such as:
  - Lube failure / soft foot / broken rotor bars
  - Pump cavitation, and many more...
What is a Vibration Program?

- Expertise, Technology, and Work Processes that
  - **Prevent Unexpected Downtime**
    - By assuring machines do not fail catastrophically
  - **Extend Machine Life and Optimize Performance**
    - By detecting & correcting root cause conditions that cause excessive wear
  - **Allow You To Work Efficiently**
    - By trending progressing faults and...
    - Coordinating repairs to occur at planned outages

Do the right work…
At the right time…
With the right methods…
A Few Case Histories to Get You Thinking

• **Paper Mill:**
  - On-line vibration monitoring detected a cracked shaft
    - Press section
    - Trend increased drastically over 36 hour period
    - Would have otherwise failed catastrophically

• **Offshore Oil Platform:**
  - On-line vibration monitoring saves compressor twice!
    - Bearing problem detected through vibration analysis.
    - Bearing was replaced.
    - New fault detected 6 hours later
      - *Thermal expansion created bearing misalignment*
A Few Case Histories to Get You Thinking

- **Cement Mill:**
  - On-line vibration monitoring solves mystery
  - Air handler with intermittent high vibration
    - Resonance occurs when baffle open at ~61%.

- **Power Plant:**
  - On-line vibration extends maintenance intervals
    - Preventive turbine maintenance every 5 years
      - Unnecessary maintenance can induce faults!
    - Extend from 6 – 10 years with on-line monitoring
      - Average repair cost around $1 million
Where Should Vibration Analysis be Used?

- Predictive
  - Critical to production
- Preventive
  - Support equipment
- Reactive
  - Easy/Inexpensive to replace
Establishing a Vibration Program

- Define program focus / resources
- Determine collection method(s)
- Create database
- Collect data
- Detect developing faults
- Diagnose nature and extent of fault
- Document business and maintenance implications
1) Define Program Focus

- Identify Critical Machines
  - Effect on production
  - Availability of back-up machine
  - Cost to repair
  - Time to repair

- Determine Resources
  - Fully in-house staffed
  - Fully out-sourced
  - Combination: Startup, Initial contract service, etc.
2) Determine Collection Method(s)

- Route-based periodic
  - General plant equipment
  - Walk around survey
  - Manual measurement
  - Monthly reading typical
  - Readily accessible

- Online monitoring
  - Critical equipment
  - Installed sensors
  - Automatic monitoring
  - Define measurement interval
  - Inaccessible or hazardous areas
3) Create Database

- Enter machine configuration information
  - Machine ID (asset code) and Description
  - Machine Design info, Operating Speed, etc.

- Define measurement points
  - Point ID (identification) and Description
  - Sensor Type (accelerometer)
  - Analysis Parameters (how to analyze signal)
  - Alarm Limits (allowable amount of vibration)
Data Collection Points - Nomenclature

Standard: 2 vibration directions per bearing + 1 axial per shaft
Add 1 PeakVue® point per anti-friction bearing

MOH = Motor Outboard Horizontal
Collect Data (Survey)

1) Periodic survey with walk-around Portable Analyzer

2) Continuous survey with online monitoring
5) Detect Developing Faults

Visual detection using color and shape

Entire machine train on one screen

Vibration divided into frequency bands

Motor  Gearbox  Pump
6) Diagnose Nature of Fault

- Each machine fault generates a specific vibration pattern (Bearings, Belts, etc.)
- A single vibration measurement provides information about multiple components
- The frequency of the vibration is determined by the machine design and operating speed
6) Diagnose Nature of Fault

Knowing the accurate machine speed and phase is *important* for vibration analysis.

A tachometer is required to determine machine speed and phase.
6) Diagnose Nature of Fault

Trend shows rate of advancement for fault in question

Individual trend parameter covers suspect frequency range
Frequency Band Alarming

Alert and Fault alarms for each parameter
6) Diagnose Nature of Fault

Imbalance typically appears at the turning speed of the machine.
6) Diagnose Nature of Fault

Misalignment typically shows up at either 1 or 2 x turning speed
6) Diagnose Nature of Fault

Looseness shows up as multiples of turning speed

Looseness
6) Diagnose Nature of Fault

Bearing wear shows up at specific peaks related to the geometry of the bearing and the speed of the shaft.
Roller Bearing Faults

Four different bearing frequencies

- Ball Spin Frequency (BSF)
- Fundamental Train Frequency (FTF)
- Ball Pass Frequency Inner Race (BPFI)
- Ball Pass Frequency Outer Race (BPFO)
A Typical FFT Spectrum

Specific peaks typically correlate to specific machine faults related to machine speed.

Need Spectrum Analyzer for diagnostics, not just Overall vibration meter.
Actual Outer Race Defect

Advanced bearing wear shows up clearly in spectrum
Early bearing wear frequently sometimes can’t be detected with standard vibration measurements.
Gear Mesh Fault

Many distinct peaks increase with gear wear.

Sidebands increase with gear wear.

Gear Wear
Examples of Orbits

- Misalignment, Resonance, Wear
  - Ellipse
  - Truncation
- Misalignment
  - “Banana”
  - Inside ellipse
- Misalignment and other problems
  - “Figure Eight”
  - Inner loop

Mi-higher, Resonance, Wear

- Misalignment
- Shaft rub or mechanical looseness
- Sub-synchronous whirl
7) Document Business & Maintenance Implications

- Document:
  - Diagnoses
  - Recommendations
  - Accuracy
  - Reoccurring faults
  - Production gains
  - Cost savings
  - Financial impact
Summary: Key Points in a Vibration Program

- Expertise, Technology, and Work Processes that
  - Prevent Unexpected Downtime
    - By assuring machines do not fail catastrophically
  - Extend Machine Life and Optimize Performance
    - By detecting & correcting root cause conditions that cause excessive wear
  - Allow You to Work Efficiently
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