VTBNet™ – Low Cost and Practical approach to Vibration Monitoring of Conveyor Belt Systems

A conveyor belt is the carrying medium of a belt conveyor system. A belt conveyor system consists of two or more pulleys (sometimes referred to as drums), with an endless loop of carrying medium - the conveyor belt - that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler pulley. See figure 1 below. There are two main industrial classes of belt conveyors: 1. general material handling, e.g., moving boxes along inside a factory; and, 2. bulk material handling or transportation used to move large volumes of material goods, e.g., coal, ore, lignite, grain, salt, sand, and other resources.

The use of steel-belt conveyors has spread throughout the processing industries. Applications of steel-belt conveyors include cooling/solidification, drying, pressing, freezing, baking, and materials conveying.

A belt conveyor is an important system component of production in many processing and mining industries. Their failure can cause expensive repairs and reduced loads during peak demand. The efficiency and reliability of this system is an important concern to all operators.
It is ultimately up to the plant owner to decide what levels of vibration monitoring is adequate for protecting and monitoring their conveyor belt system. The table below is intended to point out the commonly used vibration devices and their application disadvantages for the protection of the drive pulley and the idler pulley. The table is for informational purposes only and the specific empirical evaluation of your product and application is recommended.

<table>
<thead>
<tr>
<th>Vibration Device</th>
<th>Application Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Vibration Switches</td>
<td>Manufacturers generally do not list the accuracy or repeatability of their mechanical vibration device. It is important to note that this device has no useful signal outputs, no trending capabilities, no analysis capabilities for condition monitoring, and no advance warnings for a deteriorating machine.</td>
</tr>
<tr>
<td></td>
<td>Mechanical switches which are basically inertia activated devices that require large changes in g forces to trip. There are process equipment operated at low RPMs and they will not create large changes in g forces to trip a mechanical vibration switch set to 1 g or greater. Note that for trip setting under 0.5 g, the mechanical switch is unstable and will trip due to mild bursts of wind or the closing of nearby plant doors.</td>
</tr>
<tr>
<td></td>
<td>The normally closed (NC) and normally open (NO) contacts on the internal microswitch (SPDT) can become erratic during the mechanical resonance (high g levels) encountered during process equipment start-up.</td>
</tr>
<tr>
<td></td>
<td>Operators prefer to test the functionality of the mechanical switch while it is still mounted on the machine. The typical approach is to impact the machine casing at or around the location of the switch with a hammer. The operator then repeats this act until the switch trips. Unfortunately, repeating this test over time can dislodge the internal adjustable spring, armature, or some mechanical part or component. The switch may work partially, but, the switch is basically not reliable. Another possible reason that the switch did not trip initially to the hammer impacts because the internal mechanical components may have become corroded due to ingress of moisture or corrosives. Therefore, with corroded internal components, lowering the g level setpoint for test purposes will not allow your mechanical switch to trip.</td>
</tr>
<tr>
<td></td>
<td>Basically, there are many non-functional mechanical switches in the field and your process equipment investments are not properly protected against excessive machine forces.</td>
</tr>
</tbody>
</table>

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Conveyor Belt Drives - Vibration Monitoring

Within the product processing and mining industries, it is common for machinery such as pumps, fans, screens, crushers, and conveyor belt systems to be running around the clock. The rotating components need to be continuously monitored to warn of low frequency imbalance, misalignment, roller bearing wear and impeding bearing failure. As these machines are frequently installed in areas which are difficult to access and it is dangerous work for operators to climb up on the conveyor structures to take vibration measurements. Today, with the latest innovations from Machine Saver, Inc., a new technology can be coupled to a practical approach to reliably detect, monitor, analyze, and protect conveyor belt systems with digital transmitters formed with integral cable assemblies, sensor to sensor instrumentation wiring, and an industrial sensor computer. Instrumentation wiring from the sensor interface computer to the control room can be avoided by simply using the wireless option.

Advantages of Wireless Vibration Monitoring

Wireless vibration monitoring can provide early alarms for remote locations so that effective measures and machine reliability can be improved. One advantage of wireless vibration monitoring is that it uses the latest technologies from Machine Saver, Inc., to move vibration and temperature data rather than people. Online vibration analysis can be obtained at any time from any location, thereby minimizing...
installation related costs. Plant personnel can avoid climbing on top of the air cooler fans to take vibration measurements and making trips to hazardous plant locations.

Trended overall vibration levels can be kept on the cloud for future reference. Early alarms can be set up to provide sufficient time for management to plan for the scheduling and purchasing of parts and tower downtime. Another advantage is the accessibility of many digital protocols and the ease to make our vibration monitoring system all wireless with any third party wireless transmitter and receiver system.

VTB Sensor

VTB Sensor is 3-axis (X,Y, and Z) digital and temperature transmitter with integral 18 foot (6 meter) cable can detect rotational and structural problems (low frequency), e.g., imbalance, misalignment, bent shaft, and mechanical looseness; and, can detect rolling element bearing problems (high frequency) in their early stages. The sensor can simultaneously detect in three measurement planes (X,Y, and Z) and in all three vibration measurands- acceleration, velocity, and displacement. The embedded temperature sensor has a service range of -40°F to 221°F (-40°C to 105°C). By integrating 3-axis vibration detection and temperature into one digital transmitter, one transmitter can take the place of seven sensors. Figure 2. illustrates the vibration measurement planes detected by VTB Sensor.

![Figure 2. Roller Bearing - Shaft Measurement Planes](image)

VTBCom™

VTB Com is an industrial communications computer designed to interface and monitor the digital signals coming from VTB Sensor. VTB Com can log the digital signals from several VTB Sensors and communicate the data to other computers using a variety of digital communications such as: Ethernet, USB, GSM and wireless systems. VTB Com has 4 independent CAN bus channels that can each power and communicate up to 24 daisy-chained VTB Sensors- for a total of 100 VTB Sensors with a cable range of 329 feet (100 meters).
VTBNet™ Protection System and/or Condition Machine Monitor

By using VTB Sensor and VTB Com, sensor computer together, VTBNet becomes a cost-effective online, vibration system that can be easily installed to detect and protect fan assets. By integrating VTB Sensor, VTB Com, sensor computer, and the CBMvision® machine condition monitoring software, an enhanced VTB Net can take a snapshot of the dynamic signals and to upload the dynamic vibration and temperature data to the cloud where its is automatically analyzed to detect trends and predict future problems with the cooling tower.

More plant maintenance departments, instrumentation personnel and reliability managers are adding VTB sensor to their machines. It no longer requires a capital expenditure since you can add the VTB sensors one at a time and after the first VTBNet is installed you only have to run the communication link back to the closest VTB sensor. With so many digital protocols available on the VTBNet system, it is also very easy to make this VTBNet system all wireless with any third party wireless transmitter and receiver system so it lends itself well to integration with the very latest technology.

VTB Net system advantages: (1) Low cost; (2) Easy installation; (3) Less parts to fail; (4) Less wire to install; (5) wireless option; (5) Smaller footprint; (6) More information from one sensor; (7) Lower cost on the computer I/O module; (8) Unique universal sensor mounting feature; (9) Dynamic capture and signal analysis; (10) Zone 1 / Div. 2 certified or only one intrinsic safety barrier is required for many of VTB Net sensors in Zone 0 / Div. 1 hazardous areas; (11) Dependable with a limited warranty.

VTBNet™ Product Application

VTB Sensors with an integrated cable assembly designed for wet and corrosive environments can be used to detect and monitor the vibration levels of the conveyor belt systems (motor, coupler, gearbox, drive pulley, and idler pulley). See figure 2 below. By measuring vibration continuously, machine degradation can be monitored and impending failures can be prevented to avoid unscheduled shutdowns.

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VTBSensor™ Mounting Locations

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Product Processing and Mining Plants – Application Considerations

1) Access to components of a conveyor belt system may be difficult as the motor, gearbox, and roller bearings can be integrated into a drum which allows physical contact only to the pulley drive. Once the vibration sensors are placed on the conveyor belt system, there is the added concern of the product falling (iron ore) on top of the digital sensor and cable assemblies. Therefore, it is important that the VTB-Sensors are mounted in a way to minimize interaction with the moving product.

2) The drive unit consists of the following: electric motor, damping coupler, gearbox and the coupler that connects the output shaft to the drive pulley. The frequency of component failures in this group is from the highest to the lowest – gearbox, pulleys, motor, and couplers respectively. As illustrated above, two (2) VTB-Sensors are recommended to monitor the gearbox and the motor. At a minimal, you can use one (1) VTB-Sensor to monitor the gearbox for gear teeth problems and roller bearing faults.

3) The VTB-Sensor has a built-in temperature sensor that can be used to detect an overheating motor, coupler, gearbox and drive pulley.

4) Roller bearing failures of large pulleys under conveyor belt tension can cause considerable damage to the drive unit or the conveyor belt structure. Overheated roller bearings can also start fires, fueled by dust, grease or paint. The VTB-Sensor, 3-axis digital transmitter also has a built-in temperature sensor to monitor the overheating of roller bearings.

5) Although idler pulleys are not as critical as drive pulleys, the roller bearings in the idler pulleys can overheat and become a fire hazard. It is normal practice for conveyor belts to be inspected on a
regular basis by operators who visually check and use a microphone device to listen for idler pulley problems. Recently, operators have successfully measured the surface temperature of idler pulleys from a safe distance.

6) AC motors can fail and shutdown due to excessive bearing temperature or roller bearing defects. While many AC motors incorporate temperature sensors into the motor windings, the VTB-Sensor digital transmitter has a built-in temperature sensor to provide additional over temperature protection to prevent AC motor damage and subsequent failure.

7) Obtain technical expertise from Machine Savers, Inc., with applications involving the use of band pass filters for the diagnosis of machine vibration levels; or, the use of vibration devices in a hazardous locations, underground mining, or corrosive environments, e.g., sour gas, salt-spray, high or low pH levels.

8) Verify that the machine rotating shafts are supported by rolling element bearings. VTB-Sensor is a digital sensor that was designed to detect and monitor low frequency vibrations, e.g., imbalance, misalignment, high frequency roller bearing condition, and temperature. Mount the VTB-Sensor in the radial position at or around the roller bearing cap. Do not mount the digital transmitter on a flimsy bracket, or the sheet metal part of the machine. The integral cable should be clamped to the body of the sensor with a cable tie to prevent strain and excessive movement of the cable as both these could produce false signals. The integral cable should also be fixed at suitable intervals to cable trays or other suitable supports.

9) A mining plant is one of the harshest environments where sensors are to be installed. In order to protect VTB-Sensor’s integral cable, we recommend using stainless steel armored braiding or equivalent.

10) Within the mining industry there may be instances where the sensors are used in potentially explosive gas atmospheres, for example, an underground coal mine (methane atmospheres). This means any products used in this environment must be ATEX (IECEx) certified for an intrinsically safe area, in this case specifically Group I (mining).

11) Review the machine’s maintenance records. Mount the VTB-Sensor as close as possible to source of vibration. Based on the records, this area will have the most wear and is most likely to have problems.Recall that down time on a conveyor belt system is down time for the mine.

12) Overtime, a higher than normal overall vibration level indicates that some force is causing the machine to vibrate more. As you increase the speed of the machine that vibration energy becomes more destructive. The enhanced overall vibration levels provided by VTB-Sensor will indicate continuously what your overall vibration levels are and this provides time for operators to create a standard baseline vibration level for each machine asset. Once the baseline vibration levels are reached, you can plan and schedule an inspection of the machine components and the roller

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bearings. **Note:** In mining applications, trending of bearing temperatures, CO, CH4 and air flows can prevent potential dangerous conditions such as fires or explosive atmospheres.

### Suggested Vibration Trip Levels

For machine protection, the typical vibration trip levels are shown in the chart below for different types of equipment commonly used in the processing and mining industries.

These suggested trip levels are starting points and the recommendations provided by the equipment manufacture should be followed. Preliminary references for suggested vibration limits are the Vibration Institute, Hydraulic Institute (pumps), ISO-2372, and ISO-10816-3.

<table>
<thead>
<tr>
<th>Type of Machinery</th>
<th>AC Motors Gearboxes</th>
<th>Conveyors</th>
<th>Gear Centrifugal Pumps</th>
<th>Packaging Machinery</th>
<th>Crushers</th>
<th>Fans/Blowers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Vibration Trip Level (196.8g)</td>
<td>0.1 to 0.3</td>
<td>0.3 to 0.5</td>
<td>0.1 to 0.3</td>
<td>0.5 to 0.8</td>
<td>0.6 to 0.8</td>
<td>0.2 to 0.4</td>
</tr>
</tbody>
</table>

### Product Processing and Mining Plants - Common Vibration and Temperature Faults

Since excessive vibration is a machine’s reaction to internal and external forces, vibration and temperature monitoring and analysis can be utilized as an indication of a tower’s mechanical condition.

Certain machine faults, e.g., imbalance, occur at certain frequencies. By determining the frequency of the machine fault and by measuring the amplitude of the vibration signal, we can find out what internal or external forces are causing the vibration.

The expected frequency faults in the vibration spectra are called frequency orders (1X, 2X, 70X). They coincide at or around the normal running speed (1/4X, 1/3X, 1/2X, 1X, 2X) or can extend to many times the speed of the running machine (X10, X25, X50). Imbalance or misalignment, for example, occurs at the speed of the rotating shaft (X1) and overheating in motors and right angle speed reducers can be caused by increased bearing loads due to machine imbalance or misalignment.
The damaging forces encountered in Processing and Mining Plants are listed in the table below by each system component. The format is machine component/fault, frequency order, typical measurement plane, and comments. Figure 4, shown below has basic calculations that can be used to approximate the roller bearing faults encountered during the life of the bearing.

<table>
<thead>
<tr>
<th>Machine Component/Fault</th>
<th>Frequency Order</th>
<th>Measurement Plane</th>
<th>Vibration Measureand</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive Pulley System/Worn or Improper Belt tensions</td>
<td>1X,2X,3X,4X RPM of Belt</td>
<td>Radial</td>
<td>Velocity, in/sec, pk</td>
<td>Worn, loose, or mismatched belts between the drive pulley and idler pulley can cause dominant vibration peaks at 1X, 2X, 3X, and 4X RPM of Belt. Small amplitudes of axial vibration can occur.</td>
</tr>
<tr>
<td>Drive Pulley System/Misaligned Pulley/Eccentric Pulley/Belt Resonance</td>
<td>1X,2X RPM of Belt</td>
<td>Axial</td>
<td>Velocity, in/sec, pk</td>
<td>Excessive driver pulley and driven idler pulley misalignment or extreme sheave wear may appear as imbalance.</td>
</tr>
<tr>
<td>Drive Pulley System/Roller Bearings and Shells</td>
<td>1X to 15X Gearbox Output RPM</td>
<td>Radial</td>
<td>Velocity, in/sec, pk</td>
<td>The most frequent failures for pulleys are: bearings and shells</td>
</tr>
<tr>
<td>Motor/Imbalance</td>
<td>1X, 2X Motor RPM</td>
<td>Radial</td>
<td>Velocity, in/sec, pk</td>
<td>Small amplitudes of axial vibration can occur. Imbalance can be intensified by mechanical resonance. 1X Motor RPM vibration can also be caused by Soft Foot.</td>
</tr>
<tr>
<td>Motor/Bent Shaft</td>
<td>1X, 2X Motor RPM</td>
<td>Axial</td>
<td>Velocity, in/sec, pk</td>
<td>Bent shaft can cause roller bearings misalignment.</td>
</tr>
<tr>
<td>Motor/Mechanical Looseness</td>
<td>1/2X, 1/3X, 1/4X, 1X, 2X, Motor RPM</td>
<td>Radial (Vertical)</td>
<td>Velocity, in/sec, pk</td>
<td>There may be some vibration levels on the horizontal plane, but, the amplitudes will be highest near the mechanical fault. Excessive coupling wear can lead to mechanical looseness.</td>
</tr>
<tr>
<td>Motor/Rotor Bar and Stator Defects</td>
<td>1X,2X,3X Motor RPM</td>
<td>Radial</td>
<td>Velocity, in/sec, pk</td>
<td>Rotor Bar Passing Frequency (F_{RBPF}) = Motor RPM X No. of Rotor Bars. Broken rotor bars are common faults that cause electrical imbalance. Small amplitudes of axial vibration can occur.</td>
</tr>
<tr>
<td>Motor/Shaft/Coupling Misalignment</td>
<td>1X,2X,3X 4X,5X,6X, Low Level Harmonics</td>
<td>Axial and/or Radial</td>
<td>Velocity, in/sec, pk</td>
<td>Shaft/Coupling Misalignment may involve both Angular (Axial) and Parallel Offset (Radial) Misalignment. Misalignment can occur under the following conditions: 1. Machine alignment and installations errors; 2. worn roller bearings; 3. settling of bases, foundations, and tower structure; 4. shift of relative position of machines after installation. Excessive vibrations can lead to ACHE damage and possible shutdown.</td>
</tr>
</tbody>
</table>
### Motor/Resonance

<table>
<thead>
<tr>
<th>Condition</th>
<th>Frequency Range</th>
<th>Mode</th>
<th>Velocity Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less Than, Equal to, or Greater Than Motor RPM</td>
<td>Radial, Axial</td>
<td>Velocity, in/sec, pk</td>
<td></td>
</tr>
</tbody>
</table>

Resonance appears when a source frequency coincides with the natural frequency of the support structure, base foundation, piping, or mechanical component, e.g., rotor, gearbox, or belt driven systems. If the fans are driven by variable frequency drives, the fan speeds may cause resonant frequency vibrations that can affect the air cooler structure. Resonance can be confirmed by verifying that a small change in speed causes the 1X Motor RPM or Blade Pass Frequency vibration levels to change greatly.

### Rolling Bearing Defects with Visible Damage to the Bearings

<table>
<thead>
<tr>
<th>Condition</th>
<th>Frequency Range</th>
<th>Mode</th>
<th>Velocity Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1X to 15X RPM</td>
<td>Radial</td>
<td>Velocity, in/sec, pk</td>
<td></td>
</tr>
</tbody>
</table>

The vibration frequencies begin to manifest themselves in the 5 KHz to 15 KHz range. As the roller bearing wear increases and approaches failure, there will be an increase in overall vibration levels in the 500 Hz to 2500 Hz range.

For bearing defects within 1X to 15X Machine RPM, schedule a machine repair as soon as possible and inspect the roller bearings. If required, replace the roller bearings and find the fault(s) causing the bearing defects, e.g., imbalance, misalignment, improper bearing loads, excessive bearing temperature, contaminated lubrication, or insufficient bearing lubrication.

### Motor and Gearbox/Roller Element Bearings/Overheating

<table>
<thead>
<tr>
<th>Condition</th>
<th>Frequency Range</th>
<th>Mode</th>
<th>Velocity Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1X Motor RPM</td>
<td>Radial</td>
<td>Velocity, in/sec, pk</td>
<td></td>
</tr>
<tr>
<td>1X Fan RPM</td>
<td>Axial</td>
<td>Velocity, in/sec, pk</td>
<td></td>
</tr>
</tbody>
</table>

Overheating in electric motor bearings is generally lubricant-related. The ball bearings used in most electric motors are pre-greased, shielded ball bearings. Normal motor bearing operating temperatures range from 140°F (60°C) to 160°F (71°C). Normal motor roller bearing operating temperatures range from 140°F (60°C) to 160°F (71°C). Roller bearings in gear drives normally operate at 160° (71°C)-180°F (82°C)

Overheating in motors and gearboxes can be caused by increased bearing loads due to machine imbalance or misalignment.

Overheating can also be caused by bearing misalignment or ball skidding within the bearing.

Contamination of the roller bearings lubricant by solid particles, water, and other fluids can reduce the life of the bearings.

Improper lubrication generally causes overheating or excessive wear in the roller bearings. These conditions can result from insufficient or excessive lubrication, improper lubricants, e.g., viscosity is the load bearing component of the lubricant. Too thin, then the bearings cannot properly carry the load; and too thick, then the amount of friction will generate heat. Packing the space around the roller bearings with grease can also cause excessive heat. Avoid the use high pressure grease guns since they may rupture the bearing seals.

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**Figure 3.**

Bearing Faults can be approximated (+/-20%) using the following formulas:

- Outer Race Fault Frequency (BPFO) = 0.45 X Number of Rolling Elements x RPM
- Inner Race Fault Frequency (BPFI) = 0.55 X Number of Rolling Elements x RPM
- Rolling Element Fault Frequency (BSF) = 3.5 X RPM
- Cage Fault Frequency (FTF) = 0.4 X RPM

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Conclusion

With a combination of best practice techniques, correct setting of vibration and temperature alarm settings, and interpretation of vibration spectra, equipment used in the Processing and Mining Plants can be protected against rising vibration and bearing temperatures, e.g., motors, gearboxes, drive and idler pulleys.

This technical note has practical suggestions to assist you in your vibration monitoring application. While our product will not detect every vibration and temperature fault, we understand what others don’t- that every application requires practical machinery vibration expertise and involvement so that we can provide a customer focused solution to your vibration monitoring requirements. We want to support you with a reliable vibration and temperature product that successfully and consistently detects, monitors, analyzes, and protects your process equipment investment. Let us know about your application by consulting with the Machine Saver team at service@machinesaver.net. Our team can provide vibration monitoring solutions and benefits for your present application and extend their vibration expertise to your entire balance of plant equipment. Product and application information is available at www.machinesaver.com

References

2. Bruce M. Basaraba and James A. Archer, "IPT’s Rotating Equipment Handbook", 2000, Quebecor Jasper Printing