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Ask Joe! Column

Adapting Acoustic Monitoring Technology to Detect Bulk Solids Flow

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ABSTRACT

Acoustic technology originally developed to detect wear on large turbines has been adapted to monitor solids flow in processing plants. The technology uses sensors that monitor high-frequency sounds or structure-born acoustics generated by friction and the impact of powders, granules and solids in motion.

Because the technology is non-intrusive, there is no need to interrupt material flow or shut down the process in order to install or maintain the sensor. Additionally, because the sensor never contacts material, wear and tear are significantly reduced. Low-frequency sounds generated by vibrations or machinery are ignored because the unique piezo-crystal in the sensor only responds to signals in the 75 kHz to 175 kHz range.

The sensor can operate in a stand-alone system or be interfaced to a facility's process control system. Typical applications include flow/no-flow or high-low/low-flow monitoring, plugged chute detection, and as a broken filter bag alarm in a dust collection system. Case histories illustrate how the technology can be employed to monitor critical areas in bulk solids processing.

INTRODUCTION

The reliable non-invasive detection of solids flow has many applications in the material handling industry. Downtime as a result of solids flow blockage or plugged chutes can result in both lost production and unnecessary maintenance. In the area of dust collection, the release of particulate matter into the environment by a faulty dust collection system can be costly, and undesirable for the facility and local community.

Over the years, many facilities tried to solve these problems using invasive technology. Devices used to detect the presence or absence of material have ranged from mechanical paddlewheels and tilt switches to opto-electric, proximity, vibrating, capacitive, and inductive electronic devices. Unfortunately, by it's very nature, any material that requires plugged chute detection typically displays enough adhesive qualities to fowl any invasive sensor, rendering it useless.

The plant engineer's ideal flow-monitoring technology does not contact the material being monitored. This eliminates the cost and hassle of cleaning the sensor on a regular basis. Furthermore, wear on the sensor is minimized because it is not subject to the abrasive properties of bulk solids flow.

PRINCIPLE OF OPERATION

Acoustic energy waves occur naturally when matter vibrates at a frequency usually between 0 Hz and 600 kHz. Sound is acoustic energy in the range of 20 Hz to 20kHz and may be detected by the human ear. Lower frequency acoustic energy has a relatively long wavelength and therefore takes a longer period of time to attenuate. For example, the low frequency sound of a foghorn can travel for miles through densely attenuating fog. Higher frequency acoustic energy has a relatively short wavelength, and thus dissipates rapidly. Consider that the low note struck on a piano carries for a significantly longer time than a high note, which lasts only an instant.

Originally adapted from a device used to monitor wear on large turbines, bulk solids acoustic monitoring technology uses a piezo-crystal, a type of crystal that generates electrical current when it is subjected to mechanical stress. Bulk solids acoustic monitoring uses a special type of piezo crystal that only responds to a designated high frequency bandwidth. Acoustic energy received by the sensor within a particular frequency range excites molecules in the piezo-crystal, producing a continuous electrical signal that can be measured and interpreted.

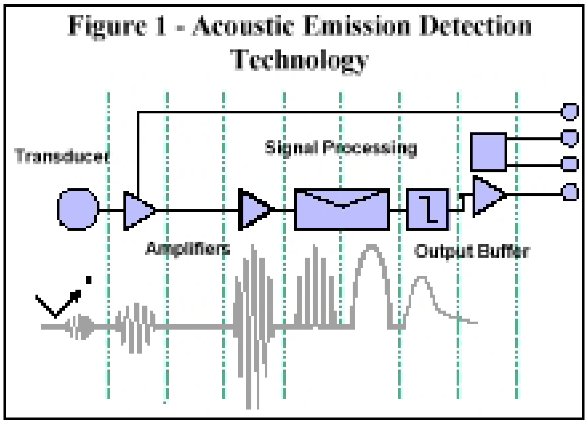
Figure 1 - Acoustic Emission Detection Technology

The electrical output from the piezo-crystal is in direct proportion to the level of acoustic energy received by the device. Additional amplification and processing by the sensor and associated electronics convert the piezo-crystal output into a electrical signal that is usable for indicating solids flow, 0 – 10 Vdc or 4 – 20 mA. The device is powered by 24 Vdc. Figure 1 briefly shows how the signal from the crystal is converted to a typical sensor output.

Most plant vibration is in the low-frequency range, typically well below 100 Hz. The sensor monitors a relatively narrow bandwidth, detecting acoustic energy between 75 kHz and 175 kHz, nearly a thousand times the frequency of normal plant noise. Typical sources in an industrial environment for high-frequency acoustic emission are friction or impacts of particulate matter against metal as illustrated in Figure 2.

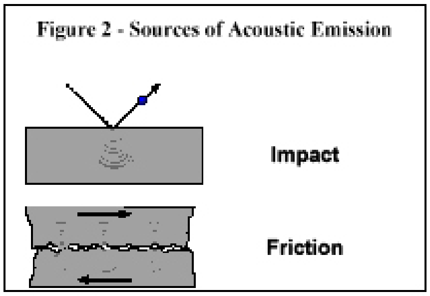
Figure 2 - Sources of Acoustic Emission

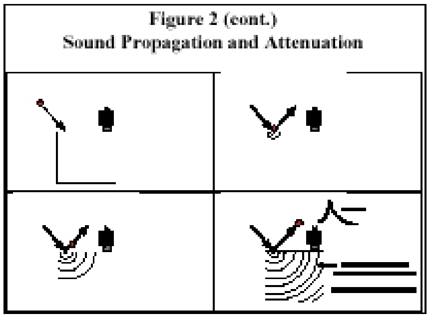
Figure 2 (cont.)
Sound Propagation and Attenuation

Another important property to consider is propagation, the transfer of acoustic energy at a molecular level. Acoustic energy easily propagates through dense materials such as metal, whereas it propagates poorly through less dense materials, such as air. This enables the technology to be immune to high frequency extraneous noise anywhere other than the designated monitoring area. Acoustic emission ranges are illustrated in Figure 3.

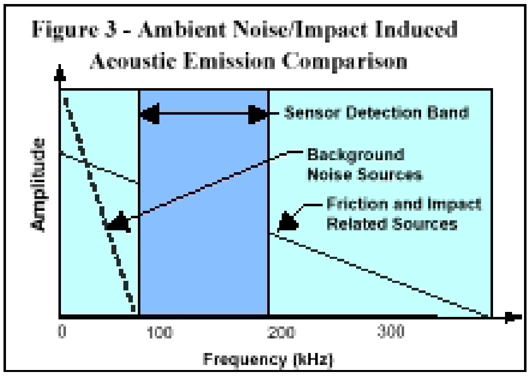
Figure 3 - Ambient Noise/Impact Induced Acoustic Emission Comparison

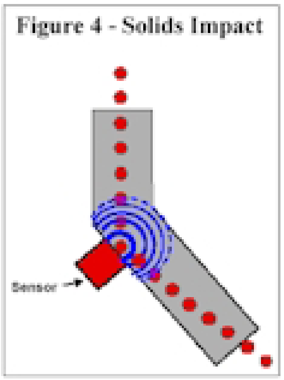
Figure 4 - Solids Impact

Summarily, as demonstrated in Figure 4, the sensor detects the high-frequency energy waves generated by the impact of solids against a metal surface, i.e. chute, pipe, or pneumatic line.

APPLICATION

Applying the sensor is relatively simple. It should be located where it can receive the most energy generated by the impacts or friction of the material. The technology requires that some amount of friction occur between the material being monitored and a metallic surface. Since a layer of paint or other protective coating can significantly attenuate the signal, any paint should be removed in order to facilitate metal to metal contact with the area monitored.

The technology requires that some amount of friction occur between the material being monitored and a metallic surface. The sensor may not work properly in the following instances:

- Where rubber or plastic chute liners are installed to guard against wear or as a flow aid.
- Very fine pneumatically conveyed particles that remain airborne in the flow stream and do not contact the sides of the pipe.
- Particle sizes over 600 mesh to 800 mesh may not generate enough friction in gravity flow conditions.

It is important to locate the sensor in areas with the greatest potential to prevent serious problems in solids flow processes caused by abnormal flow, sudden blockages, product absence, or equipment failure. Common applications include:

- Solids flow sensing
- Flow / no-flow detection
- High-flow / low-flow indication
- Filter monitoring and switching
- Broken filter bag detection
- Inflow blockage detection
- Cyclone blockage detection
- Screen damage detection
- Route verification

A typical application could be an alarm/control system feedback that indicates blockage, as illustrated in Figure 5. In this case, the control unit for the sensor utilizes a programmable start-delay timer to avoid activating an alarm during the period of time it would usually take for material to reach the hopper. The sensor can detect blockage in the chute below the hopper after the programmed start-up delay, thus energizing an alarm relay in the control unit to stop the feeder. With an appropriately sized hopper, the belt conveyor need not be stopped to avoid an overflow of product. This arrangement will also disengage the feeder if the belt conveyor unexpectedly stops, so material will not be spilled onto the conveyor.

INSTALLATION

The sensor weighs only about 1 lb. and can easily be installed without any special tools or procedures. A range of installation options are available to suite a particular application. Installation may be via a clearance hole and bolt, drilling and tapping, mounting disc, or extension tab. The unit may be screwed in, bolted on, or bonded in place. No special calibration is required after installation, except for setting the desired signal alarm level.

Because the sensor has several mounting options, it can be easily applied to various industrial processes. Choose the mounting option that will provide the optimum acoustic energy transfer to the sensor while maximizing the benefits of simple installation. For best performance, the sensor should be located near the greatest source of acoustic emissions (friction) from the pipe or chute work, typically near bends or elbows.

Do…

- Check various sensor locations for maximum acoustic signal strength.
- Use an acoustic bonding agent like silicon grease to provide maximum energy transfer.
- Isolate the sensor from extraneous high-frequency acoustic emission sources.
- Use the mounting tab option if the surface temperature slightly exceeds sensor specifications.

Don't…

- Locate the sensor on long straight chutes or pipes.
- Use the mounting tab if weak signals are anticipated.
- Apply to other solids flow processes in the plant without testing that particular application under all operating conditions beforehand.

CASE STUDIES

Faulty Dust Collection System Detection

The removal of dust from raw materials, grinding/milling processes, and finished products is required to maintain product quality and avoid discharging particulate into the environment. For maximum efficiency this dust is often recycled into the process or collected for other processes either within the plant or for sale as a byproduct. A faulty dust extraction system can result in material loss and excessive airborne particulate discharge. This can lead to excessive wear and premature breakdown of exhaust equipment, in addition to complaints from nearby residential areas.

Figure 6 - Faulty Filter System Detection

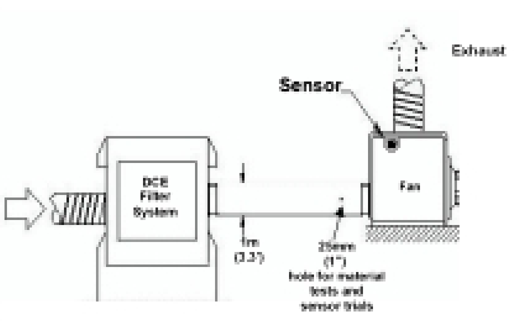

Figure 6 illustrates how an acoustic sensor can be used to detect a damaged filter in a DCE filter system. Particulate matter that passes through the filtration system impacts within the fan enclosure, generating significantly higher than normal acoustic emissions. Filter malfunction is immediately detected, prompting service and reducing undesirable particulate discharge.

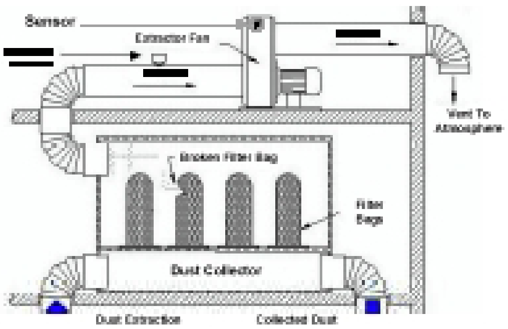

Figure 7 - Burst Filter Bag Detection

Many non-cyclonic, non-ionization dust extraction systems use replaceable filter bags. In operation, constant turbulence stresses and weakens the filter. Although regularly scheduled replacement of filter bags reduces the risk of failure, occasionally a premature breakage may unexpectedly occur. Figure 7 shows how the sensor can be mounted on the fan enclosure to detect increased acoustic emission caused by a broken filter bag, providing an alarm to prompt immediate replacement.

Plugged Chute Detection

Figure 8 illustrates an application in which screw conveyors are used to break up chocolate crumb that is manually loaded from bags into a hopper. Previously, a point level switch was used to detect a blockage in the chute between the screw conveyors. However, the sticky chocolate crumb often built up onto the switch, causing false alarms. An acoustic sensor was installed on the discharge of the second screw conveyor and adjusted to sound an alert during a no-flow condition. Consequently, frequent cleaning and downtime due to plugged chutes were eliminated.

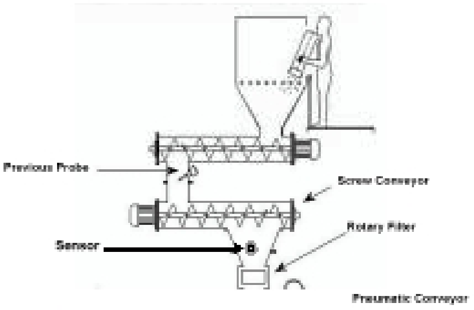

Figure 8 - Plugged Chute Detection

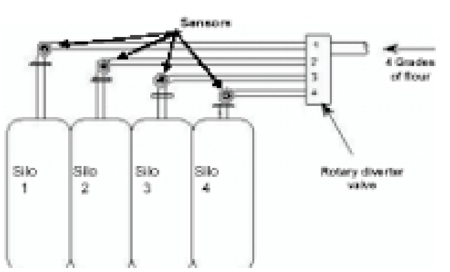

Figure 9 - Route Verification

Route Verification

Many milling processes are set up to batch various grades of milled product, particularly in the case of flour. Therefore, it is necessary to divert the milled flour to the appropriate storage silo(s) defined by the current batch grade. Accidental transport of milled flour to the wrong silo could result in a complete silo purge and significant product loss. As illustrated in Figure 9, a sensor was placed on each silo fill pipe to verify the diverter gate operation and avoid silo contamination in case of system failure.

Screen Damage Detection

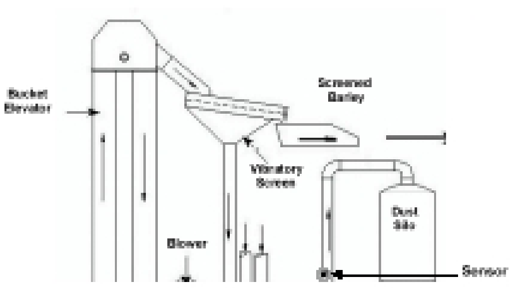
Figure 10 - Screen Damage Detection

The discharge from grain elevators is often screened to remove loose husk and dust. Grains tend to flow well in gravity-conveyed systems, however they can be quite abrasive, barley in particular. Over time, the high-velocity elevator discharge can wear a hole in the vibratory screen allowing full kernel grain to enter the dust collection system. This is a waste of valuable commodity and can cause additional problems downstream. In the barley application illustrated in Figure 10, a sensor set to detect an increase in acoustic emissions was mounted on the pipe just downstream from an elbow. The presence of full kernel grain in the system produced a significantly higher acoustic output than the husk and dust produced during normal operation. An alarm provided by the sensor control unit allows the operator to shut down the system and replace the screen before a significant amount of grain flows into the dust collection silo.

Conclusion

It is important to have the capability to indicate the presence or absence of material flows in many areas throughout a bulk-processing facility. A relatively low investment in monitoring can be significantly offset by material costs savings and increased plant efficiency and productivity.

Most bulk solids processors can accomplish these goals using low-cost acoustic emission monitoring technology. The sensor is non-invasive, so it does not contact the material and cannot become worn or fouled. An additional benefit of the non-invasive design is that the sensor can be installed without shutting down or upsetting the process. The acoustic emission monitoring sensor is an excellent example of how a technology developed for one type of equipment monitoring can be adapted for use in bulk solids processing.

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Welcome to Ask Joe!, a monthly column by our resident materials handling guru, Joe Marinelli of Solids Handling Technologies. Joe addresses the issues that bug you the most. And Joe knows!! Formerly with Jenike & Johanson, Solids Flow and Peabody TecTank, Joe is an expert on materials handling.

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