WHITE PAPER

Predicting Bearing Failures with Acoustic Vibration Sensing

BostonDynamics

Conveyor systems and rotating equipment are ubiquitous within manufacturing plants and logistics centers. They are essential for transporting materials through the production process. Hidden inside this equipment are thousands of bearings designed to reduce mechanical friction. If one or more of these bearings fail, production can come to a grinding halt and lead to unplanned downtime costing thousands of dollars per minute. Companies that can identify and fix bearings before they degrade will have a competitive edge.

> **“**Now we’re using Spot to detect air pressure leakages in our warehouses, but some use cases for the future could be that we detect vibrations on our conveyance [systems], which would help us reduce downtime.**”**
>
> - **Tomek Pauer**
> Project Manager, Otto Group

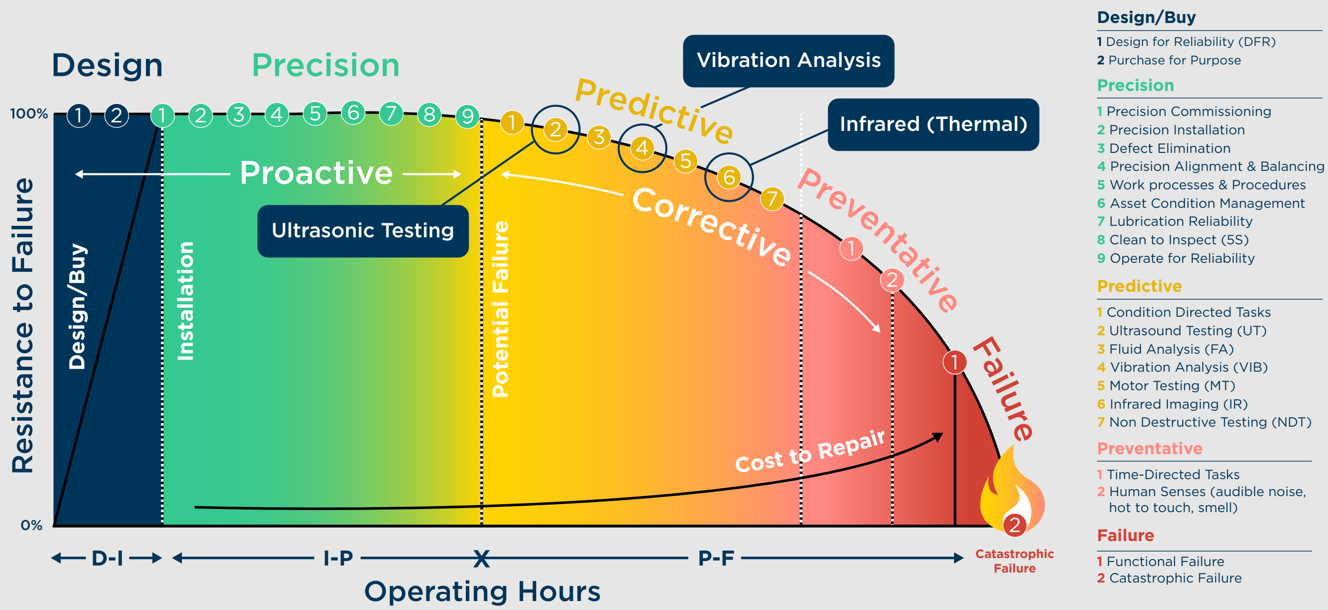
Predictive Maintenance for Rotating Equipment

Predictive maintenance is a proactive strategy in which maintenance teams monitor equipment in real-time, looking for signs of deterioration long before they reach failure. By leveraging modern sensors, data analytics, and machine learning, predictive maintenance can extend the lifespan of equipment, minimizing the risk of costly disruptions to production.

Predictive maintenance programs must focus on a wide range of inspection targets, including overheating components, electrical faults, air leaks, gas emissions, and oil levels.

When it comes to bearings, one way technicians can stay ahead of failures is by monitoring vibrations. For example, electric motors drive conveyor belts, while gearboxes adjust their speed and torque. The bearings they contain generate different sound frequencies (or vibrations) as they wear. Tracking these changes is essential for keeping the system running smoothly.

D-I-P-F Curve (Design-Installation-Potential-Failure)



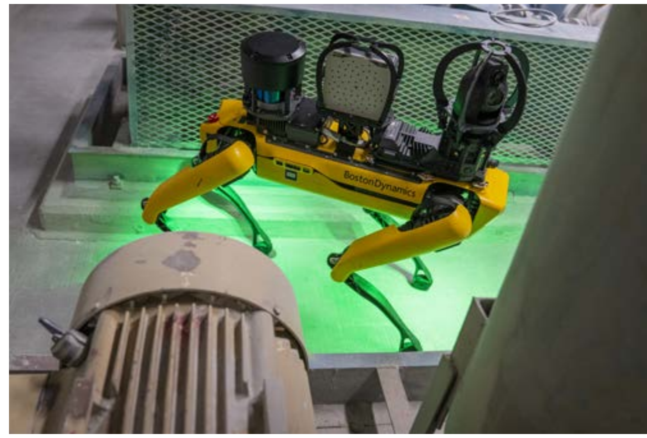
Attribution/Inspiration: The D-I-P-F curve was originally developed by Doug Plucknette, Certified Reliability Leader, Author, RCM Blitz (ISBN:978-0-9838741-6-4) and further modified/evolved by Brian Heinsius, Certified Reliability Leader

The P-F (probability of failure to functional failure) curve summarizes the value quite well. This curve describes the lifecycle of equipment inside of a plant, between when it was specified for installation in the plant to when it can fail.

- Cost of repair increases as it gets closer to failure
- Taking action after a failure incurs costs much more to fix
- It is difficult to predict the time between identification of issues and functional failure
- There are a variety of strategies and inspection methods that can be used to identify issues at different stages of the equipment's lifecycle

As you can see, vibration analysis and ultrasonic sensing are two common sensor-based inspection methods that can be used to understand machine condition earlier in its lifecycle.

What are vibration analysis and ultrasound testing?



Changes in vibrations are often the first signs of trouble in machinery with rotating parts, such as motors, pumps, and turbines. Traditionally, technicians measure vibration levels by attaching a small portable contact sensor or installing a permanent inline sensor—typically an accelerometer—to a motor's housing. These generally detect vibrations in the 0 to 10,000 Hz range. Similarly, ultrasound testing is performed by placing a contact probe placed on the machine to capture a broad range of frequencies.

However, these sensors are sensitive to frequencies beyond human hearing (>20kHz). A well-functioning motor will have steady, predictable vibration levels. If issues develop—such as imbalance or a misalignment due to wear—the motor will produce unusual or stronger vibrations. This principle applies to any kind of bearing.

Modern accelerometers can integrate with IoT platforms and software used to estimate the functional lifespan of machine parts based on trending data. This enables maintenance teams to schedule repairs at times that are least disruptive to production, such as off-hours or shift changes.

Acoustic vibration (ultrasonic) sensing

While analyzing vibrations through direct physical contact has been a common method for decades, measuring vibrations based on sound waves is a more recent development. Acoustic imagers are devices that use specially-engineered microphones to measure ultrasonic sound frequencies emitted by machinery while in operation. Even in noisy industrial environments, acoustic imagers can filter out background noise and hone in on specific frequency bands that are beyond the realm of human hearing.

One way to measure sound is amplitude, which denotes intensity in decibels (dB). Sound can also be measured as frequency, denoted in Hz or kHz. Sound frequency refers to the number of vibrations—or cycles—a sound wave undergoes each second, measured in Hertz (Hz). Healthy human ears can generally perceive sound frequencies in the range of 20 Hz to 20,000 Hz, or 20 kHz for short.[1] For perspective, low bass sounds fall between 20 Hz and 250 Hz, human speech between 250 Hz and 4 kHz, and high-pitched sounds in the range of 4 kHz to 20 kHz). Sound frequencies above 20 kHz are generally considered ultrasonic and generally beyond human perception.

Basics of Acoustics - Amplitude

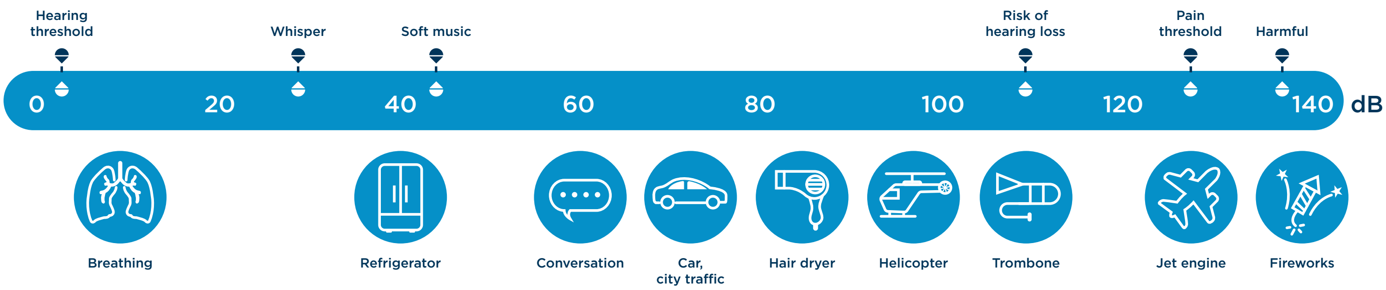


Illustration derived from Fluke Process Instruments

Not only do acoustic imagers detect these ultrasonic frequencies, they get their name from being able to superimpose graphics over live video detailing the exact location of detected sounds. These "acoustic images" provide a visual sound map of machinery.

[1] Cutnell, John D. and Kenneth W. Johnson. Physics. 4th ed. New York: Wiley, 1998: 466.

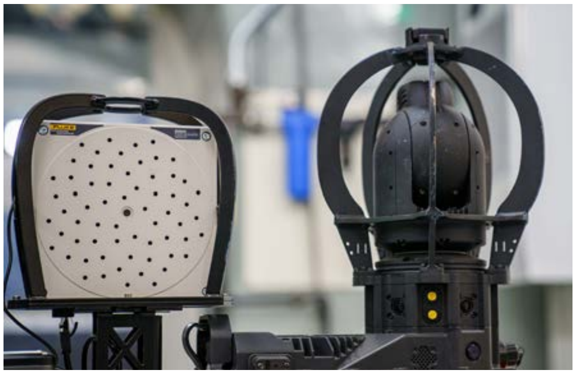
Acoustic Imaging Applications

Acoustic imagers are best known for detecting industrial gas leaks in pressurized systems. Air compressors, pneumatic tools, and HVAC systems are particularly prone to leaks, which typically generate sound frequencies in the range of 20 kHz to 100 kHz. However, as acoustic imaging technology has become more sensitive, it has become a viable, non-contact option for vibration testing.

First line of defense

While acoustic vibration sensing is less precise than contact vibration analysis, it is effective as a non-contact "first line of defense" in identifying potential mechanical issues where inline sensors are not present. Acoustic imagers can alert technicians there may be a concern that warrants more thorough inspection using an accelerometer. As a result, acoustic imaging represents an effective tool, especially in hazardous areas or when equipment is hard to reach.

An example of an industrial-grade acoustic imager is the Fluke SV600, which uses 64 digital microphones to detect ultrasonic sound frequencies. The SV600 can continuously monitor equipment from a fixed position, making it ideal for permanent installations within factories or along production lines. It can also be mounted to the agile mobile robot Spot to conduct pre-scheduled inspections completely autonomously.



If the SV600 reveals an anomaly, technicians can conduct a closer inspection and look for deviations from normal operating conditions. These visualizations show the intensity and location of sound anomalies, guiding teams to the exact source of the issue. For example, a worn bearing will appear as a bright sound signature on a video monitor that trained technicians can interpret.

Handheld acoustic imagers like the Fluke ii910 complement the SV600. These devices are more compact and have fewer microphones, but they are a good option for manual inspections on an ad hoc basis because operators can position the device for a more precise reading.

Introducing Spot®

Spot is a walking quadruped robot that can navigate dynamic industrial facilities. Spot can walk in any direction, climb stairs, maneuver around still or moving obstacles, and traverse uneven terrain without human intervention. Today, Spot is used to autonomously monitor equipment and conduct safety checks in complex environments like manufacturing facilities, logistics centers, power plants, construction sites, and underground mines.

A mobile IoT device

Various sensors and cameras can be mounted on Spot. This includes the SV600 as well as a PTZ camera and a thermal camera. With these devices, Spot captures real-time, detailed assessments of equipment health and site conditions.

The SV600 is fully integrated as a payload on Spot, allowing for ultrasonic inspections of rotating equipment on a regular schedule. By using Spot with the SV600, companies can reduce the need for tedious manual inspections in potentially dangerous or hard-to-reach areas. Spot autonomously navigates pre-programmed routes on a routine schedule to conduct inspections without variation.

Orbit integration

Spot feeds data directly into Boston Dynamics' Orbit software, a web-based application used to analyze inspection data, manage your Spot fleet, and remotely operate Spot. Orbit provides a user-friendly interface where operators can plan missions, monitor real-time data, and review inspection results. Orbit enables detailed comparisons over time, automated alerts, and immediate response to detected issues. It can also be integrated with existing business systems.

Technicians can analyze acoustic images in Orbit to identify indicators of wear and tear on equipment and prepare long-term strategies to extend its life. This centralized early warning system optimizes equipment performance so facilities can continue to operate smoothly.

Benefits of Robotic Inspections of Rotating Equipment

Cost savings

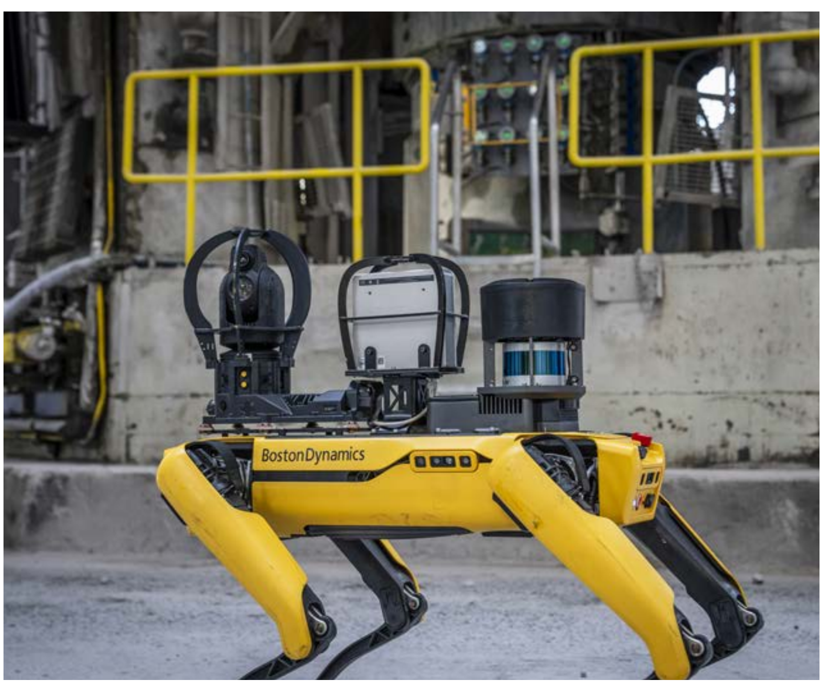
The SV600 gives Spot ears that can hear beyond human perception and provide greater insight into the operations of critical assets. Placing a fixed sensor on each motor within a conveyor system may be impractical or cost-prohibitive. Additionally, relying on employees to conduct manual inspections using handheld sensors is difficult to scale. Spot and the SV600 are a tremendous advantage for covering more ground and increasing inspection frequency.

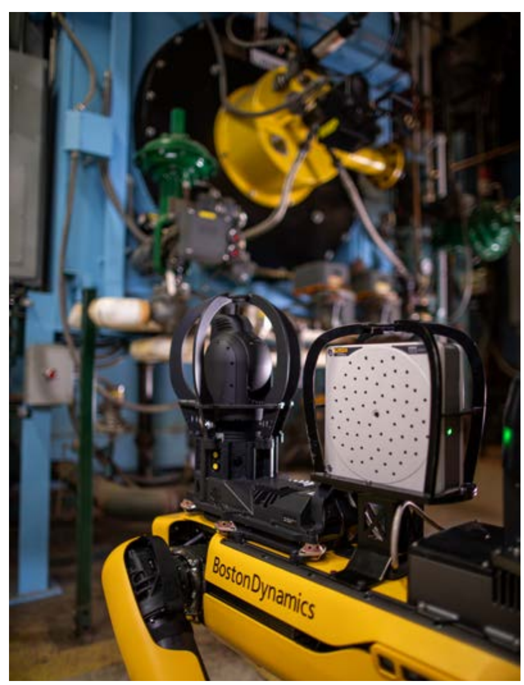
Autonomy

Spot's true value is autonomous missions. Maintenance teams plan routes for Spot to inspect key equipment and Spot does the rest, creating of its environment to navigate complex industrial environments without assistance Spot will follow the same routes and repeat the same inspections, day in and day out. The benefit of Spot and SV600 working in tandem is that they can conduct ultrasonic inspections quickly, from a distance. Maintenance teams can simply monitor the collected data and respond when anomalies arise, or when trends suggest a particular part is approaching end-of-life.

Consistency

Consistent measurements are key to identifying trends over long periods of time. And unlike technicians who might vary in their methods using manual sensors, Spot collects data in the exact same way every single time.





The ROI of Industrial Inspection with Spot

Beyond acoustic vibration sensing, Spot and the SV600 remain a powerful duo for detecting air and gas leaks within industrial settings. Leaks can have significant and costly impacts, including reduced energy efficiency, higher operating costs, and mechanical failures.

Leaks are often symptoms of larger problems. Machines must run more frequently or at higher rates due to lower air pressure, which shortens their lifespan. When a machine starts to falter due to a leak, it's no longer able to do its job. This can lead to condensation or corrosion within other equipment—even contamination of finished products. Spot and the SV600 can identify the sound frequencies associated with leaks so maintenance teams can intervene early.

Image courtesy of ST Engineering

In addition to acoustic imaging, Spot can use visible-light cameras to read analog gauges and circular sight glasses displaying pressure and fluid levels that require regular monitoring. Spot can also utilize thermal cameras to identify changes in surface temperatures of machines and equipment that might indicate overheating components.

The potential return on investment of robotic inspections is clear. Spot and the SV600 can help companies dramatically scale their inspection operations, starting in only a matter of weeks. By identifying more mechanical issues early, maintenance teams can avoid the critical breakdowns that would otherwise disrupt production or even bring it to a standstill.

In this way, robotic inspections make maintenance teams more productive. Employees can spend less time conducting manual checks and, instead, focus on more high-value tasks, such as analyzing data trends and performing repairs. Because Spot can venture into hazardous areas and scan hard-to-reach equipment from a distance, employees are further kept out of harm's way.

By detecting leaks, malfunctions, or inefficiencies in equipment with Spot and the Fluke SV600 companies can also reduce energy consumption and operational costs. As a result, robotic inspections offer a compelling combination of labor savings, increased operational uptime, and improved energy efficiency. By combining mobile robotics with precision measurement and diagnostics, Boston Dynamics and Fluke continue to enhance the capabilities of industries around the world.

Image courtesy of ST Engineering

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