MACHINERY LUBRICATION: January-February 2006
TITLE: Acoustic Analysis for the Rest of Us
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If a plant has ever experienced a bearing or electric motor failure and lubrication was suspected or confirmed as the culprit, then perhaps the lubrication personnel should look into acoustic analysis for solutions. If one has ever asked, "How much lubricant should I use and how often should I lubricate?" then acoustic analysis may help solve these common questions.

What is Acoustic Analysis?

Acoustic or sonic analysis is the measurement of sound waves caused by component contacts inside equipment. It is a term that is commonly used in the music recording industry, sound wave generation and human speech arena, but its application in industry with respect to monitoring bearing lubrication is relatively new. This is not to say that primitive derivatives have not been used for many years; most everyone involved in industrial maintenance is familiar with the screwdriver-to-ear/temple method of listening to rotating equipment. For safety reasons, this should never be attempted. It is, however, a simple and fairly effective method of diagnostics. This method works well because sound is created when a medium vibrates, which occurs when rolling elements inside a bearing are allowed to touch one another or the element raceway .

Acoustic analysis is similar to vibration analysis; however, its focus is not to detect causes for rotating equipment failure by measuring and monitoring vibrations at discrete frequencies and recording data for trending purposes. Acoustic bearing analysis is intended for the lubrication technician and focuses on proactive lubrication measures.

Devices that detect sound frequency use input transducers. Input transducers convert sound into audio signals. The following are various types of input transducers:

1. Air pressure or velocity microphones - convert sound waves traveling through air into an audio signal traveling in the microphone cable.

2. Contact pickups - convert sound waves in a dense medium (wood, metal, skin) into an audio signal. These are sometimes used on acoustic stringed instruments such as guitars, mandolins, violins, etc.

3. Magnetic pickups - convert fluctuating waves of induced magnetism into an audio signal. These are found on electric stringed instruments (electric guitars, etc.) and displacement meters on rotating shafts.

4. Tape heads - convert fluctuating magnetic fields (imprinted on magnetic recording tape cassette) into an audio signal.

An input transducer designed for bearing monitoring and lubrication utilizes a contact pickup and senses the vibrations (sound waves) generating in the bearing. Applying lubricant to a dry bearing softens the bumping metallic contacts and dampens the vibration of the rolling elements, therefore altering the strength of the vibration signal. This can easily be heard and recorded using equipment created for this purpose. Input transducers are extremely sensitive and it is extremely important to note that **the smallest amount of pressure of the contact pickup to the vibration source can yield varying results.**

Where It Began

The idea to monitor bearings using transducers originally stemmed from the use of ultrasonic devices designed to detect pressure leaks and bearing faults. These devices detect vibrations in the ultrasonic (above 20,000 Hz) frequency range. It was not uncommon for two people to determine the lubrication needs for a bearing at the same time. One technician would use an ultrasonic device to listen to the bearing and the other person, a lubrication technician, would inject grease using a manual grease gun. Once the ultrasonic technician felt satisfied that lubrication had reached the bearing, he would signal the lubrication technician to stop greasing. There are two inherent problems with using ultrasonic detection this way:

1. Allocating resources and equipment for two maintenance personnel to lubricate a bearing is not cost-effective.

2. Determining the optimum point at which a bearing has been lubricated can be difficult using only ultrasonic detectors.

Therefore, industry continued to lubricate bearings in the traditional manner by using time- and volume-based lubrication schedules. As bearings continued to be over and under-lubricated, the need for a better method remained.

In the late 1980s, Douglas Gribble, founder of UVLM Inc, invented a device and method for bearing lubrication utilizing an input transducer that measured in the sonic (20 Hz to 20,000 Hz) frequency range and attached directly onto the grease gun. This device allowed a single lubrication technician to lubricate bearings based on the quality of sound generated by the bearing, reducing labor costs. Properly lubricated bearings and those needing lubrication have distinct sound characteristics, both of which are sensed and interpreted by the human ear.

Recently, other manufacturers have introduced equipment into the marketplace designed with the lubrication technician in mind. Many of these tools operate in the ultrasonic frequency range. While they are designed for a single user, they also rely upon additional technologies for signal interpretation. Some include decibel gauges and meters; others record or monitor a signal and use software to interpret the sound signature. The true effectiveness of any equipment depends heavily upon the ability to interpret data presented from a bearing. There exists a great deal of discussion and debate over which technology, device or method is best. To understand this, it helps to understand a bit about what sound actually is and how the human ear works.

What is Sound?

Sound is the effect of causing a medium to vibrate. The initial vibration of a sound source is called the fundamental, and the initial frequency is known as the fundamental frequency. The subsequent vibrations, which are exact multiples of the fundamental frequency, are called the harmonics. It is the strength of the harmonics that distinguishes the quality (or timbre) of musical instruments, and making it possible for humans to identify two different instruments playing the same note.

When a person listens to sounds, in the audible or sonic range, sounds such as music or a bearing, the brains response involves a number of regions outside the auditory cortex, including areas normally involved in other kinds of thinking. A person's visual, tactile, and emotional experience all affect where the brain processes these sounds. This ability is called the brain-ear reasoning method. Thus, the reasoning for source of sound or its quality is determined by more than just the sound heard and the level of decibels noted.

The primary auditory cortex of the brain is retuned by experience so that more cells become maximally responsive to important sounds, such as the correct amount of grease to add to a bearing to achieve a sufficient lubrication level. This happens naturally in the sonic frequency range. Retuning the brain to identify the sound qualities that are important in diagnosing a bearing's proper lubrication level is done automatically with the brain-ear reasoning method.

A human cannot hear a heterodyned (digitally altered) signal from the ultrasonic range and make any natural assumptions about that sound. This renders a decision about lubrication requirements difficult. Worthy of discussion is not whether the sonic frequency or the ultrasonic frequency is a better frequency for identifying relubrication requirements, but whether the human involved in making the decision can more accurately discern the condition using one method over another.

Additionally, because sound depends upon vibration, it can travel through anything except a vacuum. Sound travels through some materials faster than others; traveling about four times faster in water than in air, and about ten times slower in rubber. The speed of sound is virtually constant at all frequencies, but sound will travel faster in humid air rather than in dry air. Humid air also absorbs more high frequencies than low frequencies. Imagine a bearing expanding, under load and running hot. As it cools, it shrinks, potentially causing condensation to build up. When that bearing is running again and a reading is taken from a transducer, the vibration signal might actually fluctuate due to moisture content and humidity. If this potential situation is not considered, trended data may yield inaccurate results.

Acoustic: Sonic, Ultrasonic or Both?

Acoustic by definition relates to the range of human hearing or naturally audible. In other words, acoustic signals are measured in the sonic frequency range. Another term for the sonic frequency range is bioacoustics. Defining terms may help to categorize differences between technologies and their effectiveness for industrial lubrication. As humans are ultimately responsible for the decision to lubricate or not, it is important to understand how the methods used may affect those decisions. It may be splitting scientific hairs when trying to determine whether or not the definition of acoustic should include frequencies outside of the human hearing range that have been digitally altered or heterodyned in order to be audible to the human ear.

However, the human ear is unique in that it can process and naturally filter through several aspects of analog sonic sound. Sound is not a single item of physics, rather a myriad of tones, harmonics, pitch, phase, intensity, speed of sound, etc. Individual brain cells respond optimally to a particular pitch or frequency. These cells shift their original tuning when a person learns the specific tone that is important. This cellular adjustment edits the frequency map stored in the brain. The important tones and contours of sound made by a bearing that requires lubrication are modified when the proper amount of lubricant is added. This optimal level is easily achieved using the brain-ear reasoning method alone.

Interpretation of an ultrasonic signal can be difficult to manage, depending upon the goal. While it may be simple to discover and interpret a, damaged bearing using ultrasonic instruments, determining what that damage is can be difficult. If the goal is to simply locate bad bearings, then that goal may be easily accomplished. If the goal is to determine, at the point of discovery what the damage actually is, then the success of that goal is diminished. Applying this to bearing lubrication, lubrication technicians must be able to accurately access and determine a course of action at the point in time of lubrication. Allowing any length of time to pass between collection of data, data interpretation and action increases the opportunity for error. Time is one of the major destroyers of bearings and rotating equipment. Industry wrestles with time on a daily basis. Tools that shorten the delay in responding to a failure condition will save industry billions of dollars in waste and costly downtime.

Conclusion

Acoustic or sonic analysis is a useful tool in judging the volume and frequency effectiveness of bearing relubrication work orders and PM's. When used consistently, acoustic analysis reduces the amount of labor and materials involved in relubrication. It reduces the number and degree of bearing failures in all kinds of rotating equipment and allows a technician the ability to properly lubricate bearings, WITHOUT increasing their work load. This is critical in implementing an effective acoustic monitoring and lubrication schedule. When a technician's job becomes harder, more time consuming or stressful, stiff resistance to change follows. Experience teaches us that making a person's job easier, more interesting or rewarding is the only acceptable method of encouraging changes to work habits, willingly!