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Acoustic Lubrication Guidelines for Rolling Element Bearings in Electric Motors

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Introduction

Acoustic lubrication is the method of using a bearing's ultrasound signal to determine if a bearing requires lubrication or if the lubrication is sufficient. An under lubricated bearing will generate a greater signal than a properly lubricated bearing. The signals are measured in decibels (dB or db μ v)¹.

The general human hearing range is 20 to 20,000 Hz. Ultrasound is generally described as sounds with a frequency greater than human hearing range. Ultrasonic sound detection equipment may range in ultrasound frequencies of 20 to 200 kHz. Various vendors recommend different peak frequencies for optimum use with their equipment. Ultrasound measurement performs well at the manufacturer's recommended frequencies, the key being to maintain consistency within your ultrasonic lubrication program. Changing the peak frequency used on your equipment will alter your results and hamper your ability to recognize trends.

With the sound generated being well beyond human hearing, it is necessary to use an ultrasound receiver to detect the bearing's sound signals. The ultrasound device converts the inaudible ultrasonic noise into the sonic hearing range, making it possible for you to easily listen to the sound being generated by your equipment. The person performing acoustic lubrication (i.e., practitioner) should have a thorough understanding of the principles of ultrasound. It is recommended that this person attend a certified Level 1 ultrasound for predictive maintenance course.

Once lubrication of a specific piece of equipment is managed with an acoustic lubrication program, it is recommended that you put policies in place that prevent inadvertent lubrication by others not working within the acoustic lubrication program.

Rolling element bearings are designated as ball bearings, roller bearings and needle bearings, hereafter referred to as "bearing" or "bearings" in this article. They are also known as anti-friction bearings.

¹Decibels displayed by an ultrasonic instrument used for acoustic lubrication may be referenced as dB or db μ v. Check with your equipment manufacturer for an explanation of decibels.



The amount of grease suitable for a bearing is that which is necessary to provide replenishment of the oil through capillary action as the grease heats and cools. Generally, a minimum of one third of the open free space of the bearing should be filled with grease. Adding more grease results in no better lubrication, however in some, it can fill the void space, thereby reducing the space for moisture and dirt to accumulate. Over greasing, or too much grease in the cavity, can cause heat buildup due to pressurizing the cavity or collapsing the shield/seal. This heat buildup can result in heat-related bearing damage and early failure.

Acoustic Lubrication Guidelines

The following guidelines will help the practitioner obtain the best results with acoustic lubrication.

Setup

The recommended means of introducing grease is with a pistol type grease gun that has been cleaned, tested and has a known output capacity. Powered grease guns (e.g., air, battery, etc.) can pump as much as one-half ounce per second and are not recommended due to their ability to quickly pump excessive amounts of grease. A hand or pistol type grease gun can pump one ounce of grease for every 10 to 40 strokes based on the manufacturer. The exact output should be determined prior to using the grease gun. The grease gun should be connected to the fitting adapter using a flexible hose to reduce self-induced noise.

Basic Connection

Attach the grease gun to the grease fitting and attach/touch the ultrasonic sensor to the closest point on the housing to the bearing.

Advanced Connection

Attach the ultrasonic unit and the grease gun together on the grease fitting using one combined adapter. The grease tube on most equipment attaches close to the bearing and is a repeatable location. A custom adapter allows for the sensor and grease gun to attach to the grease tube and provides a dB level to the practitioner greasing the bearing. Better repeatability also can be accomplished with a button head grease fitting that applies constant probe contact pressure than a zerk² grease fitting, which relies on the practitioner to supply the probe's contact pressure.

The practitioner must be trained and knowledgeable in the operation of the selected ultrasound receiver. To accurately measure the ultrasound signal of a bearing, an ultrasound device is mechanically attached as close as possible to the bearing or source of the signal

² Although named for the inventor Oscar U. Zerk, the word zerk is used to describe a variety of grease fittings or check valves mounted on motors or bearing housings.

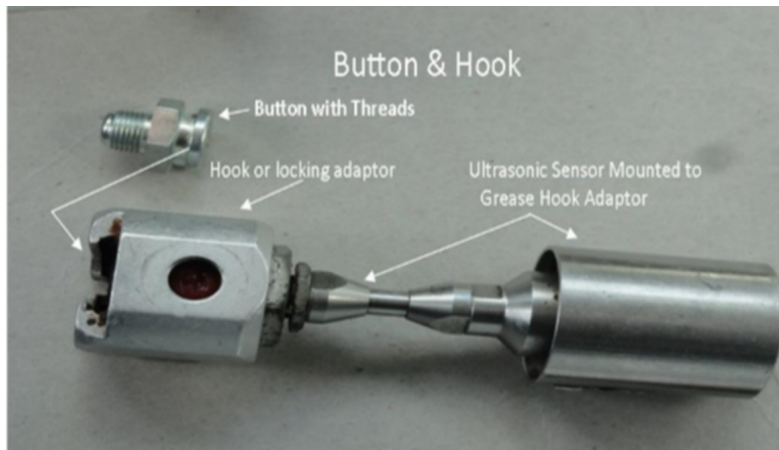


Figure 1: Modified button and hook style grease fitting, top, and an ultrasonic sensor.

and in exactly the same location for future readings. The configuration of the equipment to be lubricated must be accurately known. A sealed bearing cannot be lubricated. A single or double shielded bearing may be lubricated with great care given to slowly introduce grease. There must be somewhere for excess grease to go whether by use of a pressure relief or by removing a grease cavity plug.

The preferred bearing configuration is to have a single shielded bearing. The shielded side will be towards the inside of the cavity of the motor. The open side will be towards the rotor. Care should be taken so as not to change the bearing type without understanding the lubrication path.

Note:

The grease type must be known and only the same or a compatible grease type should be introduced into the bearing.

Cleanliness is of extreme importance for the grease and anything that comes in contact with it. Introducing abrasive material or other contamination to the process defeats the purpose of a quality lubrication program. Grease fittings used to introduce grease must be kept clean. It is recommended that you use a covered zerk (e.g., plastic dust cap) or button head fittings. Caution should be used when applying grease in contaminated atmospheres. Do not switch greases in a grease gun, rather, dedicate a grease gun and accessories for specific greases and stick with them to avoid cross contamination.

See the section, “How to Use a Grease Gun” for standards for grease gun use and management (see page 12).

New bearings should be run in the equipment for one to two days before taking an ultrasonic reading. When a new bearing is first installed, it requires run time in order to manifest an ultrasonic signature.



It is useful to compare signals from identical motors driving identical equipment under the same speed, load and temperature conditions. This will give the practitioner a reference for what constitutes a bearing going into failure or one in need of lubrication.

It is recommended to compare the current ultrasonic reading to the previous reading. This will help indicate the condition of the equipment and assist in determining the amount of lubrication needed. Repeatability of these measurements requires using the same measuring method and setup each time. The speed and load on the machine also should be duplicated.

Accurate record keeping is essential. Some recommended metrics to document for each point are:

- Date;
- Original baseline reading;
- Last ultrasonic reading;
- Type of grease used;
- Amount of grease delivered;
- Motor speed (if variable);
- Motor load (current reading from variable frequency drive (VFD) if used);
- Ambient temperature;
- Bearing temperature;
- Sound recording (if receiver has capability);
- Technician taking readings.

Refer to this information as needed to help determine bearing condition. Knowing the total amount of grease delivered will help control over greasing.

Calibrating the Grease Gun and Use of an Electronic Grease Metering Device

Knowing how much grease is delivered per stroke of the grease gun is essential. Many motor manufacturers recommend a specific amount of grease to be delivered per run time hours. This may prove useful as an initial guide. A simple way to measure grease output per stroke is to discharge the grease into a one ounce container (the equivalent of a shot glass) and count the number of strokes required to fill the container. Calculate the amount of grease per stroke from this information. Electronic grease measuring devices are commercially available. These devices make totaling the grease delivered easier.

Calibrating the Ultrasound Receiver

The manufacturer of your ultrasonic device can verify accuracy of your instrument. Refer to the manufacturer's instructions regarding calibration. Periodic calibration is recommended. Unless damaged, ultrasonic sensors generally do not go out of calibration. When, by necessity, field verification of the receiver with structure-borne sensor combination is desired, an ultrasound source, such as an ultrasound generator, can provide a precise amount of energy. Pick an amplitude level and an attachment location for the sensor



and compare to previous readings. Dedicating a small machine, such as a bench grinder, as an ultrasound source (bearings) is an alternative. If a handheld probe is to be tested, it must be held to the structure-borne ultrasound source with the same pressure for each comparative reading. Skill and care will be necessary for accuracy when comparing with a handheld probe.

Ultrasound receivers and sensors are precise, scientific devices and must be protected from rough handling. Improper handling can render them inaccurate.

Analog versus Digital

Ultrasound instruments with a digital output give more useful readings in firm numbers. Analog meters rely, to some degree, on the user's interpretation. For greatest accuracy, consider using a digital display.

Working with VFD Controlled Motors

When a motor is controlled by a variable frequency drive (VFD), the practitioner must be aware of how the carrier frequency of the VFD can skew acoustic readings. VFDs can create a signal that suggests a bearing is going into failure, or possibly mask the bearing's condition. Some VFDs have better filtering and this effect is less pronounced. The main point is to capture significant changes in dB readings from previous readings.

The preferred means of sensing the signal is to connect the sensor mechanically or magnetically to the same point each time. Using the same receiver and sensor adds to the accuracy.

Recommended Practice to Achieve Good Readings

The use of permanently mounted sensors is encouraged since this provides the best repeatability. Threaded mounts require tightness of the securing hardware to be periodically torque checked.

When using a magnetic sensor, the measurement point should be clearly identified for repeatability. Slight differences in the measurement point location can affect dB readings.

When a handheld probe is used, the practitioner must be experienced in applying the correct pressure to hold the probe tip onto the reading point. This requires the practitioner to practice repeatability on a stable subject piece of equipment.

When a grease fill point is the closest location for capturing the ultrasound signal, an adapter incorporating the sensor is a great option (see Figure 2). An adapter provides a hands off solution that improves the link between the greasing and listening task. It also allows the practitioner to reach recessed fittings, and grease the bearing while focused on watching/listening to the coordinated sound level response.

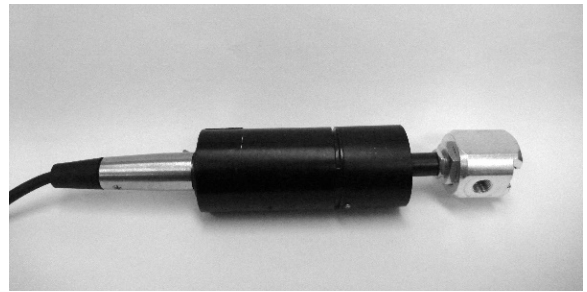
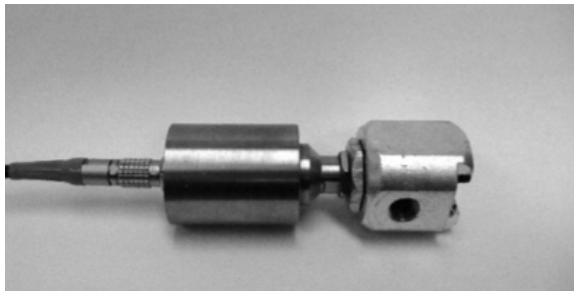


Figure 2: Button and hook with ultrasonic sensor adapter and cable

Types of Grease Fill Fittings

Two common grease fittings are the zerk and button head type. When an ultrasound greasing adapter is used, the button head type fitting is preferred because it allows a more repeatable connection. After the adapter is attached, no manual force is required.

Connecting an ultrasound adapter with a zerk fitting requires more care. The adapter must be kept in line with the axis of the zerk fitting for the most accurate readings and the coupling held firmly in place to avoid grease leakage. The manual force with which the coupler is held onto the zerk should be approximately the same for the reading.

Grease Delivery

The layout and length of the grease delivery route will determine how the practitioner delivers grease to the bearing. “Hard” piped grease delivery lines are prone to interfering with ultrasound signals and should not be used for this purpose.

Purging air from grease delivery lines is necessary to ensure the amount of grease pumped from the grease gun actually arrives at the bearing cavity.



Figure 3: Examples of an acoustic lubrication delivery system.
Note: An ultrasound instrument and a grease gun can also suffice.

If the motor is fitted with grease relief fittings, the fittings and/or tubing should be inspected to confirm condition. If a grease relief plug is installed, it must be checked for proper operation.



If no grease relief is installed, the plug should be removed prior to greasing. Greater caution is required while greasing without a relief and the requirement of recording total amount of grease delivered becomes more important. Caution must be exercised to avoid grease being pushed into the windings and compromising the motor.

Analyzing the purged grease can be helpful in determining bearing condition and providing alerts to pending issues. If purged grease is to be captured, the area from which it purges must be clean and a clean receptacle used to ensure a clean catch. A lubrication laboratory can also provide additional guidance and analysis.

Delivering Grease to the Bearing – Make certain the machine is running at operating temperature. Cold grease will not support the capillary action needed to properly move the oil into the bearing. When the desired load, speed and other conditions are met and taken into consideration the practitioner may begin delivering grease to the bearing. *Again, clean fittings, testing of the grease gun, verification of grease compatibility, purging of air from grease delivery lines and an open grease line are necessary before delivering grease.*

Using compatible headphones, the practitioner first listens to the bearing for telltale signs of bearing condition (e.g., popping, hissing, etc.), making note of the dB reading. A constant fluidic rushing sound denotes a healthy bearing.

Be familiar with the sounds of bearings:

- Good bearing — even, rushing noise
- Lack of Lubrication — slightly louder rushing noise
- Bearing in Failure — crackling or rough
- Damaged Ball — clicking sound
- Damaged Race — uniformed roughness

Follow the manufacturer's recommendations for detailed settings of the instrument used to measure the ultrasonic sound. On some equipment, a midrange is recommended as a starting point, on others an indicator tells the practitioner if the signal is being clipped high or low.

An increase of 10 dB above baseline or 10 dB from the last reading is a noteworthy change that indicates the need for lubrication.

The practitioner should reference the previous greasing history when performing routine lubrication preventive maintenance.



Note:

We are looking for a rising inflection point in the greasing process. This is the point where adding grease raises the dB level and the dB level does not return to the level that existed prior to the last stroke added.

To begin, the practitioner should start with one half stroke of the grease gun and deliver approximately 1 cc of grease.

The practitioner should then wait 10 to 20 seconds between grease additions, listening for a signal and/or dB change. If no changes are noted, a subsequent half to full stroke of grease should be applied. The practitioner should again wait 10 to 20 seconds.

The practitioner should continue applying half to full strokes of grease in the same fashion until the audible signal changes (e.g., louder or quieter) and/or the dB changes. If an excessive amount of grease is applied without a response, the practitioner should stop and investigate further. The amount of grease delivered should be recorded.

Scenario 1 — After adding grease, the dB level increases (1 to 3 dB) or the audible signal becomes louder. Stop adding grease. Wait 30 to 90 seconds to see if the dB level drops to the dB level prior to grease delivery. If the sound quality has or has not improved and/or the dB level remains higher than the original starting level, no more grease should be added at this time since the bearing was already well lubricated. If the noise level is higher than desired, further investigation should follow.

Scenario 2 — After adding grease, the dB level changes slightly up or down, or the audible signal become louder or softer. Pause adding grease. Wait 30 to 90 seconds to see if the dB level returns to the dB level prior to grease delivery. If the sound level has or has not improved and/or the dB level remains at or lower than the original starting level, continue repeating this process until the sound level and/or the dB level begins to rise (inflection point). No more grease should be added at this time since this bearing was in need of relatively normal lubrication.

Scenario 3 — After adding grease, there is no notable change in the dB level or audible signal. Wait 30 seconds to see if the dB level changes. Continue repeating this process until you obtain the sound quality and/or dB level response as in Scenarios #1 or #2. If no improvement is noticed after adding a reasonable amount of grease, investigate further as this bearing is likely in need of service.

Note: If the bearing is large, or you know the bearing notably lacks lubrication, consider using full strokes.

Note: It may be necessary to re-adjust the sensing range of the ultrasound receiver being used to ensure the best quality signal is being monitored.



Note: If a shielded bearing is being lubricated, extra care is warranted so as not to crush the shield into the rolling elements.

Note: A severely under lubricated (and likely damaged) bearing should respond to lubrication. However, its dB level may return to the starting level in a relatively short time. This bearing is a candidate for replacement.

Note: Cold grease may temporarily increase dB levels. Dry, caked up grease can hamper the delivery of new grease. Ambient temperature will affect the measurement process.

Trending

Recording the ultrasound data can reveal changes in dB levels over time. This data also can be compared to similar machines. Historical data can assist in root cause analysis (RCA) efforts and in the prediction of machine performance over time. The best scenario is to take the machine out of service prior to an in-service failure and rebuild at a lower cost than to suffer a major operating failure that requires higher cost repairs.

Some manufacturers provide advanced features, like fast Fourier transform of time domain, to assist in performing bearing defect analysis.

Ultrasound Lubrication Adapter

An adapter for delivering grease and capturing the signal is recommended with the following in mind:

- A stronger ultrasound signal will be received when the adapter is kept short and the ultrasound sensor is as close as possible to the source of the signal. If the grease gun was supplied with a steel, 1/8" NPT tube, it should not be used for the adapter. Again, cleanliness for all parts of the assembly is stressed; clean out all debris.
- Use caution when selecting parts. With some parts, the manufacturing quality varies and the bore is not or cannot be easily or adequately cleaned. Stainless steel parts are more corrosion resistant. Machined parts are generally made to higher standards.
- The adapter should not be screwed directly to the grease gun. A flexible hose between the grease gun and adapter is recommended.
- Whenever possible, locate the ultrasound sensor as close as possible to the output end of the adapter. Most ultrasound grease adapters are supplied from the manufacturer with a female pipe thread for connecting the grease gun.
- Use of a button head type grease fitting is recommended, when possible. Several versions are available to adapt to your grease tube. This may require replacing and/or adding a coupling or metric adapter to convert the grease tube.



- If, by necessity, the sensor must be away from the grease fill fitting of the machine, try to keep it no more than 10 inches away on the adapter pipe. For accuracy, always use the same adapter and sensor assembly each time a specific point is read.

How to Use a Grease Gun

Note: Some technicians and experts will claim the following steps are unnecessary precautions and a waste of time. But, failing to take these basic steps compromises the precision that went into manufacturing the rolling element bearing and shortens the bearing's useful life.

In any lubrication practice, cleanliness is paramount. Nothing wipes out the value of lubrication more effectively than contamination by abrasive grit or other foreign matter. The area where the grease gun is filled must be clean, well lit, have a work tabletop at a convenient height and clean rags at hand. The workspace must be free of dust and atmospheric contamination.

A competent lubrication practitioner must verify the work of those being trained and periodically inspect, without prior notice, the trainee's work. The use of a checklist is helpful.

A dedicated grease gun is necessary for each type of grease being used. Powered grease guns are not desirable, except in instances where very large amounts of grease are required.

Before filling the grease gun, it must be thoroughly disassembled and inspected under good light for harmful debris inside and out. If there is any doubt as to the quality or cleanliness of the grease gun, procure a better quality one. A pistol grip grease gun is recommended as it allows one-handed operation, with the other hand being used to hold the grease deliver hose or adapter.

Using a grease cartridge is the preferred means of loading a grease gun. In the most critical applications, you may test the grease for contaminants. There are also laboratories available that will test grease samples. If there is any doubt of contamination, have the grease tested.

If the grease gun is filled by either sucking the grease into the barrel of the gun or spooning it in, be aware of the need to avoid air pockets in the filled area. These could be introduced into the grease delivered to the bearing. Everything that comes in contact with the grease gun and the grease must be free of contamination.

Any compressed air used in cleaning the grease gun must be filtered close to the point of use. Control compressed air use so it does not stir up dust in the workspace.

Once the grease gun is filled, pump grease into a receptacle until all air is purged from the delivery line or hose. If an ultrasound lubrication adapter is used or permanently attached



to the grease gun, it also must be purged. Wipe the end of the female grease coupling after each use and wrap the coupling with clean plastic when not in use. Protect the grease gun from contamination by placing it in a clean and sealed plastic bag to transport it.

Grease guns can easily produce over 4000 PSI of pressure. This can damage a bearing by damaging a seal or forcing a shield into the rolling element if grease delivery is not carefully controlled.

Document Credits:

Thank you to the following individuals for the time and energy they spent helping to promote this document through their technical knowledge and willingness to go where no one else has ventured with regard to the depth of establishing a standard or practice promoting acoustic lubrication through ultrasonic inspection of electric motors.

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