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STUDY OF THE SOUND PRESSURE LEVEL (SPL) PER OCTAVE MEASURED DURING NO-LOAD MECHANICAL RUN TEST AND DEVELOPMENT OF AN ACOUSTIC HOOD

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Abstract: This study aims to investigate the sound characteristics exhibited during the no load mechanical run test of a gearbox and develop an effective acoustic hood to mitigate the resulting noise. The experimental setup involves subjecting the gearbox to a no load mechanical run test, which simulates its normal operating conditions without any external load. During the test, sound pressure levels are recorded using Bruel and Kjaer meter at three different locations surrounding the gear. The recorded data is then analyzed by dividing it into octave bands to determine the distribution of sound energy across different frequency ranges. The analysis indicates peak sound energy levels at specific frequencies and provides valuable information of designing an effective noise reduction solution Based on the findings, an acoustic hood is developed to attenuate the sound produced by the device and effect of the acoustic hood will be evaluated. The developed acoustic hood successfully reduces the sound pressure levels in the identified frequency ranges. The results demonstrate the importance of frequency-specific noise reduction measures in improving the acoustic performance of the device.

***Index Terms*–Sound pressure level, octave bands, acoustic hood, glass wool.**

I. INTRODUCTION

About Gears

Gears are toothed members which transmit power / motion between two shafts by meshing without any slip. Hence, gear drives are also called positive drives.

Gear noise can be a sign of a problem with the mechanical system and can lead to reduced efficiency, increased wear and tear, and even failure of the system if left unchecked. To reduce gear noise, it is important to properly maintain and lubricate the gears, ensure proper alignment, and use high quality gears that are designed for the specific application. As with any occupational hazard, control technology should aim at reducing noise to acceptable levels by the action on the work environment. Such action involves the implementation of any measure that will reduce noise being generated, and/or will reduce the noise transmission through the air or through the structure of the workplace. Such measures include modifications of the machinery, the workplace operations, and the layout of the workroom.

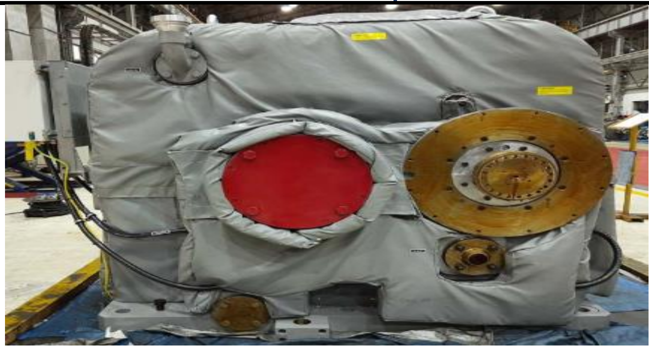


Figure: 1 View of a gearbox

In fact, the best approach for noise hazard control in the work environment is to eliminate or reduce the hazard at its source of generation, either by direct action on the source or by its confinement. Gear noise is a serious impediment to an optimum gear performance. Actually gear noise is the result of some process errors. The source of gear noise has come to a definitive conclusion that one of the causes of gear noise is transmission error. In this study a gearbox figure 1 having 36 and 121 teethes of pinion and gear respectively, having center distance 35 inches and speed of the pinion and gear being 5042 rpm and 1500 rpm respectively, have been tested.

1.1 Sound Measuring Instrument

A sound level meter(Bruel and Kjaer meter) is a measuring instrument, designed to measure sound levels in a standardized way. Commonly referred to as a sound meter, noise meter, decibel meter, or sound pressure level meter, a sound level meter is designed to respond to sound in approximately the same way as the human ear. The purpose of a sound level meter is to give objective, reproducible measurements of sound pressure levels (SPL). At its very core, a sound level meter basically consists of a microphone, a preamplifier, a signal processing unit, and a display. The most suitable type of microphone for a sound level meter is a condenser microphone, which combines precision with measurement reliability. The microphone converts the sound signal to an equivalent electrical signal. The electrical signal produced by the microphone is at a very low level and must be enhanced by a preamplifier, before reaching the main processor.

Figure: 2 Sound level meter and Microphone

In a sound level meter, octave bands refer to the frequency bands into which the audible range of human being is divided. These bands are based on the concept of octave, which represents a doubling or halving frequency. By measuring the sound levels in each octave band, a sound level meter can provide a more detailed analysis of the sound spectrum, allowing for better understanding of the distribution of found energy across different frequencies.

1.2 Octave bands in Sound level meter

An octave refers to the interval between one frequency and its double or its half. There is one octave band between frequencies 1000 Hz and 2000 Hz. There is another one octave band between 1000 Hz and 500 Hz. In Engineering applications, sound spectrums are usually represented in octave or one-third octave frequency bands rather than in narrow frequency bands.

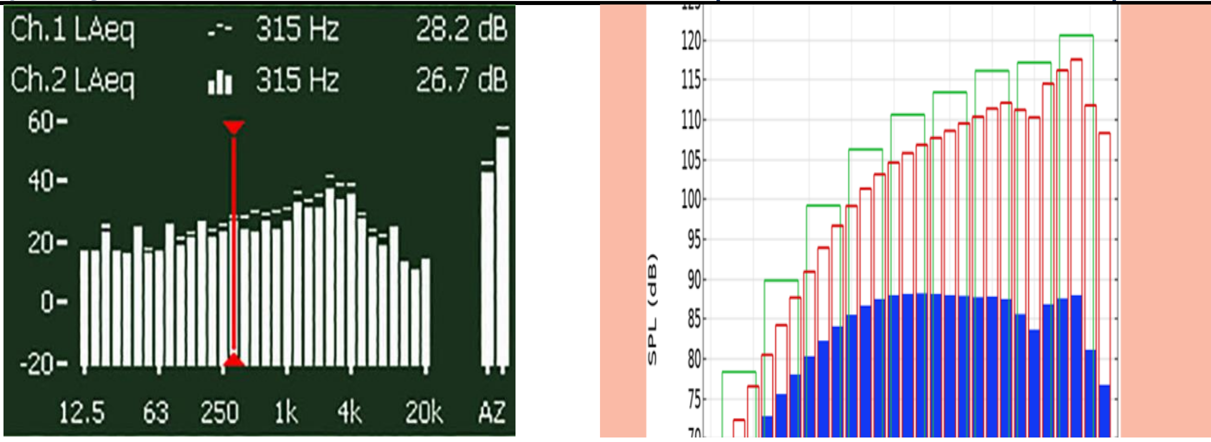


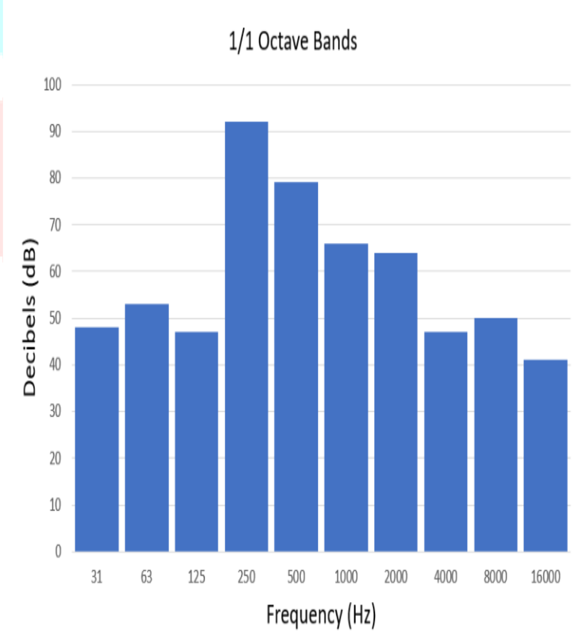
Figure: 3 View of an octave Bands

This frequency representation is linked to the perception of sound by a human ear and it allows a compression of the amount of information. An important part of the information is however lost when converting results from narrow frequency bands to octave or one-third octave frequency bands

1.2.1 1/1 octave band

1/1 Octave Band measurements are used when the frequency composition of a sound field is needed to be determined. Octave analysis is often used in noise control, hearing protection and sometimes in environmental noise issues.

The common octave frequency bands are: — 31Hz, 63Hz, 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz and 16kHz – and their composition is made up of the Lower Band Limit, Centre Frequency and Upper Band Limit.

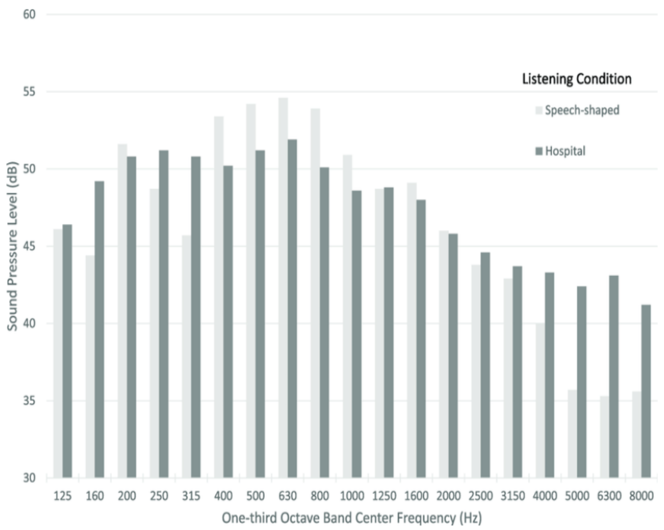


Octave middle frequency	Octave band
15.6 (preferred: 16)	11.0 - 22.1
31.3 (preferred: 31.5)	22.1 - 44.2
62.5 (preferred: 63)	44.2 - 88.4
125	88.4 - 176.8
250	176.8 - 353.6
500	353.6 - 707.1
1000	707.1 - 1 414.2
2000	1 412.2 - 2 828.4
4000	2 828.4 - 5 656.9
8000	656.9 - 11 313.7
16000	313.7 - 22 627.4

Figure: 4 graph of 1/1 octave bands and table of octave band and octave band middle frequency

1.2.2 1/3 Octave band

Mainly used in environmental and noise control applications, 1/3 Octave Bands provide a further in-depth outlook on noise levels across the frequency composition. Each 1/1 (single) Octave is further split into three, providing a more detailed view of noise content.1/3 Octave Bands provide a further in-depth outlook on noise levels across the frequency composition. Each 1/1 (single) Octave is further split into three, providing a more detailed view of noise content.



15.6 (preferred: 16)	13.9 - 17.5
19.7 (preferred: 20)	17.5 - 22.1
24.8 (preferred: 25)	22.1 - 27.8
31.3 (preferred: 31.5)	27.8 - 35.1
39.4 (preferred: 40)	35.1 - 44.2
49.6 (preferred: 50)	44.2 - 55.7
62.5 (preferred: 63)	55.7 - 70.2
78.7 (preferred: 80)	70.2 - 88.4
99.2 (preferred: 100)	88.4 - 111.4
125	111.4 - 140.3
157.5 (preferred: 160)	140.3 - 176.8
198.4 (preferred: 200)	176.8 - 222.7

Figure: 5 Graph of 1/3 ocatve band and table of octave band and octave band middle frequency

The use of 1/3-octave bands is more convenient mathematically than the use of critical bands, so for analysis and equalization. We can pin point the particular frequency in 1/3, but not using 1/1 band and It closely related to the human perception of sound.

1.3 Objective and Scope of the Study

1.3.1 Objective

The main idea of the project work is to study and understand the sound pressure level measured at eight octaves at their center frequencies during no load, full speed mechanical run test and also development of an acoustic hood.

1.3.2 Scope of the Study

- To study the sound pressure level of a gear during no load mechanical run test.
- To set up an experimental apparatus to conduct the no load mechanical run test.
- To perform measurements of the sound pressure level generated by the gear across different octave bands.
- To analyse the collected sound pressure level data to identify any excessive noise levels produced by the gear.
- To develop a noise control strategy to control noise in gear based on collected sound pressure level data.
- To build an acoustic hood to reduce the noise generated by the gear.
- To test an acoustic hood to assess its effectiveness in reducing the sound pressure level of a gear.

II. METHODOLOGY

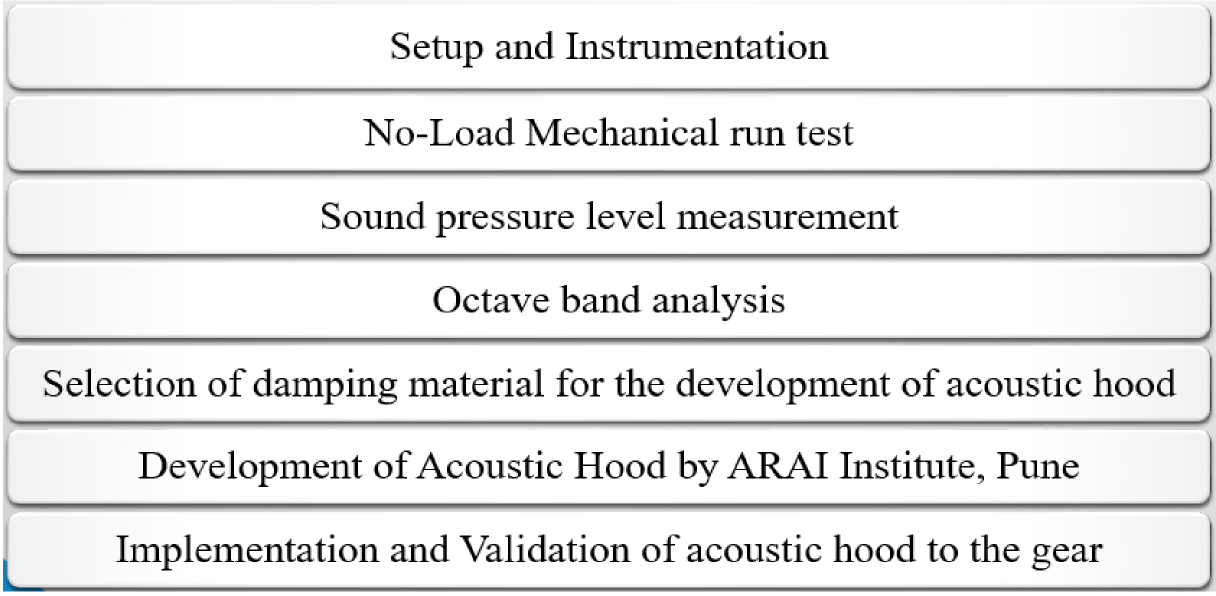


Figure: 6 Methodology process

Setup and Instrumentation: Set up the test environment with the gearbox in a controlled space. Install microphones or sound level meters at various locations around the gearbox to measure sound pressure levels. Ensure the instruments are calibrated properly.

No-Load Mechanical Run Test: Conduct a no-load mechanical run test on the gearbox, where the gears are run without any load applied. This allows for the measurement of noise generated by the gearbox itself, independent of external factors.

Sound Pressure Level Measurement: During the no-load run test, measure the sound pressure levels using the microphones or sound level meters placed at different locations around the gearbox. Ensure measurements are taken in octave bands, covering the frequency range of interest.

Octave Band Analysis: Analyse the measured sound pressure levels per octave band. This involves dividing the frequency spectrum into octave bands (centered around frequencies such as 31.5 Hz, 63 Hz, 125 Hz, etc.) and determining the sound pressure level in each band. This analysis helps identify the frequency components contributing to the overall noises.

Based on the noise analysis results, design an acoustic hood or enclosure to reduce the noise generated by the gearbox. Consider factors such as material selection, geometry, internal linings, and access points for maintenance. The acoustic hood should aim to attenuate the noise within the target frequency range and meet any applicable noise reduction.

Selection of material: Glass wool's ability to absorb sound waves and reduce noise is a crucial consideration. Look for glass wool with a high noise absorption coefficient, which indicates its effectiveness in attenuating sound.

Acoustic hood design: Utilize acoustic simulation software or build a prototype of the acoustic hood to assess its effectiveness. Simulations or physical testing can help refine the design and ensure it provides the desired noise reduction performance.

Testing and Implementation: Once the acoustic hood design is finalized, implement it on the gearbox and conduct further tests to validate its effectiveness in reducing the sound pressure levels. Measure the sound pressure levels with the acoustic hood installed and compare them to the baseline measurements taken during the initial no-load run test.

III. EXPERIMENTAL PROCEDURE

3.1 Sound test microphone position diagram

The microphone in a sound level meter is designed to convert sound waves into electrical signals When sound waves reach the microphone, they cause changes in air pressure, which in turn cause the diaphragm of the microphone to vibrate. These vibrations are then converted into electrical signals proportional to the sound pressure. Before using a sound level meter, it is essential to calibrate the microphone to ensure accurate measurements.

The microphone is to be located perpendicular to the center of a vertical surface at a distance of one meter and not less than one foot above the test floor or plate. The distance between the microphone and gear unit depends on the unit size. Both the overall sound level (gear unit plus ambient) and the ambient level alone are to be recorded.

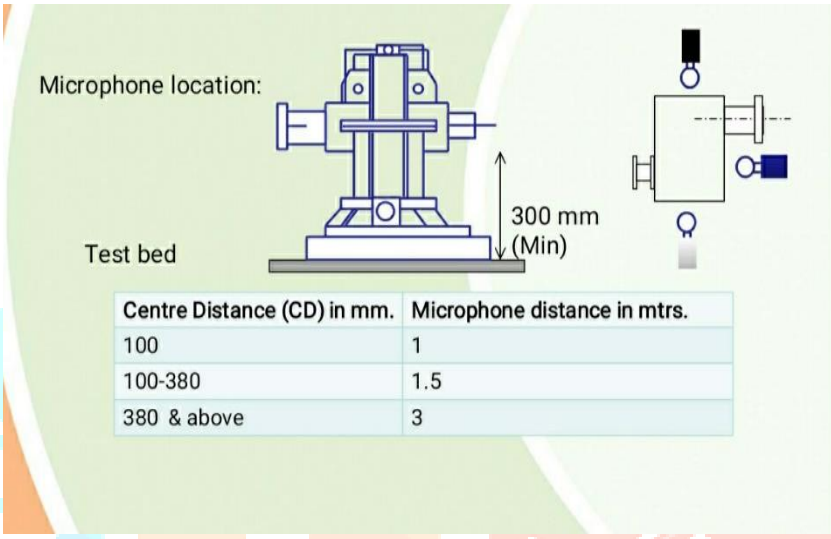


Figure: 7 Sound test microphone position diagram

Corrections for the influence of the ambient on the gear unit's sound level are made to provide a truer indication of the gear unit's sound level. The average meter reading is to be recorded when the sound pressure level fluctuates.

3.2 Observations

The sound pressure level is observed when the gearbox is running with a pitch line velocity 107m/s. The sound pressure level observed for gearbox without acoustic hood is shown in figure 6.

	Octave band centre frequency.										
Octave Bands Hz	31.5	63	125	250	500	1K	2K	4K	8K	16K	Over all SPL
	Octave band centre frequency.										
Location A dBA	26.7	42	49.1	61.2	67.9	80.9	72.1	66.6	64.5	47.6	83.8
Location B dBA	27.2	45.1	49.4	62.7	69.4	82.1	70.2	64.3	60.4	47.7	83.8
Location C dBA	28.5	44.4	49	63.3	70.7	90.3	72.5	64.2	63.2	44	90.8

Figure: 8 Sample of sound pressure level without acoustic hood

Standard sound pressure level of a gear should be 85decibel. From this observation sound pressure level exceeds 90decibel hence development of acoustic hood is necessaryto reduce the noise in gear.

IV. MATERIAL USED FOR ACOUSTIC HOOD

Glass wool is highly effective in providing thermal insulation. The trapped air pockets within the material help reduce heat transfer through conduction, convection, and radiation. It helps maintain comfortable indoor temperatures by minimizing heat loss during cold weather and heat gain during hot weather. Glass wool also exhibits excellent sound absorption characteristics, making it useful for controlling noise levels in buildings and industrial settings.

The fibrous structure of glass wool allows it to trap and dissipate sound energy, reducing reverberation and improving acoustic comfort. Glass wool is non-combustible and has a high resistance to fire. It does not contribute significantly to the spread of flames, making it a safe insulation choice. It can help delay the spread of fire by providing a barrier and reducing the heat transfer to the adjacent areas.

Figure: 9 Glass wool material

Glass wool is lightweight and easy to handle, making it convenient for installation in various applications. It can be cut, shaped, and fitted into irregular spaces, making it suitable for insulating walls, roofs, floors, and HVAC systems. Glass wool is inherently resistant to moisture, which helps prevent the growth of mold, mildew, and bacteria. It does not absorb water or moisture from the surrounding environment, maintaining its thermal and acoustic insulation properties over time. Glass wool can produce airborne fibers during installation or if it is damaged. Inhalation of these fibers can irritate the respiratory system and skin.

It is important to use appropriate personal protective equipment (PPE) such as gloves, goggles, and masks when handling glass wool. Proper installation techniques and adherence to safety guidelines help minimize the risk of fiber release and exposure. Glass wool is made from recycled glass, which helps reduce waste and conserve resources. It is also recyclable at the end of its life cycle. However, the manufacturing process does require a significant amount of energy.

4.1 Development of acoustic hood

Glass wool is lightweight and easy to handle, making it convenient for installation in various applications. To use glass wool as an acoustic hood for gears, it can be cut to size and wrapped around the gears.It can be held in place with fasteners..The thickness of glass wool is 1.5inch.Below 1.5 range thickness it can easily breakdown

This acoustic hood is developed by ARAI Institute located in Pune, India. Test report by Automotive Research Association of India (ARAI) provide the glass wool Measurement of Sound Absorption Coefficient is 0.8, density of 48kg/m3 and 1.5inch thickness as perISO 354/ ASTM C423 Standard.

V. RESULTS AND DISCUSSIONS

5.1 Implementation of acoustic hood

Figure 8 shows the gearbox after implementation of acoustic hood made up of glass wool 48kg/m 3 density and 1.5inch thickness. The gearbox is having sound pressure level greater than 85dB before implementation of acoustic hood

Figure: 10 Glass wool gearbox insulation

The acoustic hood is provided to one of the gearbox shown in figure 8 was tested without and with the blanket and found 5dBA reduction and the overall sound pressure levels are found within 85dBA. Thus the case studies and the development of noise attenuation blanket was found effective in reducing the sound pressure level (noise level) greater than 85dBA of gearboxes.

5.2 Observation

After implementation testing is re-conducted and the differences in sound pressure level reduction is observed as shown in the figures 9. This observation is obtained for the glass wool of thickness 1.5inch. SPL exceeds 90dBA. Hence implementation conducted, after implementation the sound pressure level is reduced to 5dbA.

	Octave band centre frequency.										
Octave Bands Hz	31.5	63	125	250	500	1K	2K	4K	8K	16K	Over all SPL
	Octave band centre frequency.										
Location A dBA	27.3	59.2	51.3	61..8	71.7	67.9	65.3	61.6	57.3	43.6	82.9
Location B dBA	26.6	59.8	50	59.6	70.4	68.8	64.1	59.8	52.9	41.8	79.7
Location C dBA	30.4	66.9	53.6	62.9	74.3	69.1	65.3	64.2	60.4	48.9	81.9

Figure: 11 Sample of sound pressure level with acoustic hood

Sound pressure levels corresponding to front, rear and side end. Reduction is observed in SPL. Due to this reduction the SPL of gearbox will be within acceptable limit. Hence this implementation will be more effective.

VI. Conclusion

The study of sound pressure levels per octave during a no-load mechanical run test provides valuable insights into the noise characteristics and dominant frequency components of a gearbox. By measuring and analyzing the sound pressure levels in octave bands, specific noise sources and frequencies contributing to the overall noise can be identified.

Based on the findings from the study, the development of an acoustic hood is a viable solution to reduce the noise generated by the gearbox. The acoustic hood, designed based on the identified noise sources and dominant frequencies, aims to attenuate the noise within the target frequency range.

The acoustic hood design involves careful consideration of factors such as material selection, geometry, internal linings, and access points for maintenance. Acoustic simulation or prototyping helps assess the effectiveness of the hood design before implementation.

Once implemented, further validation tests are conducted to measure the sound pressure levels with the acoustic hood installed. The results are compared to the baseline measurements taken during the initial no-load run test, and any necessary adjustments or refinements are made to achieve the desired noise reduction targets.

Overall, the study and development of an acoustic hood provide a systematic approach to address gearbox noise issues. It helps identify specific noise sources, determine dominant frequencies, and develop an effective solution to reduce noise levels, improving the acoustic performance of the gearbox system.

VII. Acknowledgment

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