**Acoustic Emission Monitoring of Lube Oil Condition in Large IC Engines**

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**ABSTRACT:** Need for condition monitoring of machinery, especially large IC engines, have increased over the years. Acoustic Emission (AE) has emerged as an important tool in the field of condition monitoring of machinery. One of the major failures in large engines is scuffing. Scuffing in cylinder occurs due to lack of lubrication and can happen without warning. So the necessity of an indicator that can accentuate any change in lube oil level is high. The objective of this presentation is to demonstrate that the AE signals, when analyzed in frequency domain, can provide such an indication of changes in the lubrication inside the IC Engine cylinder. This work deals with the identification of a frequency band which is most sensitive to changes in the lube oil quantity level in large engines.

Keywords: Acoustic Emission, Frequency Analysis, Scuffing, Engine Condition monitoring

**INTRODUCTION**

Most failures in an IC Engine are preceded by a characteristic indication that can serve as a warning. Effective identification of these warnings can lead to timely identification of faults hence minimize the damage. The major challenge is the detection of such faults in their early stages of occurrence in a nonintrusive way.

Acoustic emission (AE) is the propagation of transient elastic waves that are generated within or on the surface of a material by fundamental processes that define friction and wear such as deformation and micro fracture. Acoustic Emission has gained popularity in the condition monitoring of machinery especially IC Engines. AET offers the advantage of earlier failure detection due its inherent higher sensitivity as compared to the low frequency vibration signals. [1-2].

Scuffing is one of the critical failures encountered in the case of Large engines especially, those in the marine field. Scuffing between rings and liners, particularly during the running-in period of an engine, has been a problem for many years and has usually been overcome by design alterations and the use of materials other than cast iron on an ad hoc basis. In recent years, the problem has become more difficult to deal with as a result of engines being designed with greater specific power, higher speeds and the desire to keep oil consumption to a minimum [3].

Studies have found that Acoustic Emission is far more effective as an early indicator for bringing out any defect in machine components when compared to traditional methods. Figure 1 below shows the time response of various techniques during testing of a defective bearing [7].
ACOUSTIC EMISSION IN ENGINES

Any dynamic machinery like an engine has plenty of moving parts all of which are good sources of friction. Since friction is a major source of AE, it can be utilized as a very efficient tool in studying the condition of any moving part non-intrusively. This is possible only if the sensor can be mounted in a suitable position on the engine to pick up the emissions. The major sources of AE in an IC Engine are:

1) Engine piston movement inside the cylinder
2) Gear meshing
3) Bearing movement
4) Engine valves opening and closing events and so on.

Research has already been carried out to study the AE generated for Bearing Condition monitoring (4), Gear Box condition monitoring (5) and to detect exhaust valve leakage (6). Also, extensive work has been carried out to study the interaction between piston ring and cylinder liner using AE.

OBJECTIVE

Scuffing is one of the major causes of failures when it comes to a marine engine. Scuffing is often attributed to lack of lubrication between the piston and cylinder liner. Studies have found that Frequency analysis of AE signals provide a very efficient tool in bringing out the change in lubrication condition in engines [8]. The AE from Marine Diesel Engines contains frequencies ranging from 20-300 kHz. Different sources within the engine generate AE of different frequencies. Thus, the need to identify the frequency band/bands that is most sensitive to any change in the level of lubrication in the cylinder is crucial. The intention of work presented here is to evaluate the AE signals from a Marine Engine in the frequency domain and find out the frequency band where any change in lubrication level is most accentuated.
EXPERIMENTAL SETUP

Experiment was done on a Two-stroke Cross-Head Diesel Engine. The engine had 10 cylinder units. An AE system developed in-house was used for the study. The system comprises of a custom designed piezoelectric sensor to detect the AE, a signal conditioning unit with Amplifier and Filter and an NI5132 Data Acquisition card to acquire the AE signals and convert them to digital data for further analysis. Figure 2 below shows the organization of the experimental setup.

![Experimental Setup Diagram](image)

**Figure 2: The Experimental Setup**

EXPERIMENTAL PROCEDURE

The AE sensor was mounted on the outer skirt of the engine cylinder, about 20cm above the scavenge port. The sensor was connected to signal conditioning unit and thereon to the DAQ card. The Acoustic Emission was converted into digital form and was fed to a PC with a custom developed LabVIEW program acting as the interface. The engine was run at 3 different lubricant oil levels – at steps of 12.5% - and AE signals were recorded.
RESULTS

A typical AE signal obtained from the engine is shown below in Figure 4(a) and Figure 4(b) shows the frequency distribution for the same.

The Spectrum was divided into 5 bands for ease of analysis. They are

1. 20-30kHz
2. 80-100kHz
3. 110-130 kHz
4. 140-155 kHz
5. 185-195 kHz

Next, the components corresponding to each of these bands were filtered out from the raw data using a band-pass filter designed in LabVIEW. Then the energy content for each band was calculated for 12 sets of data in each lubricant oil level. The energy content for each trial for the 20-30 kHz band is plotted in figure 5. As expected, the AE energy content was found to be inversely proportional to the lubricating oil level.

![Figure 5: Energy content in the 20-30 kHz band for 12 trials](image)

Figure 6 shows a bar chart comparing the energy content for each band.

![Figure 6: Energy level comparison for various frequency bands](image)
CONCLUSION

As expected, the energy content was found to be inversely proportional to the lubricant oil level. This can be attributed to the increased friction that comes into play as a result of lack of lubrication. Even though almost all the bands showed this trend, the 20-30 kHz band was found to be most sensitive to changes in lubricating oil. Thus continuous monitoring of the energy content of the 20-30 kHz band will give good indication when there is a reduction in lubricant level. This can help in taking timely prevention and help minimize the damages for operators.

REFERENCES