International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

Noise Reduction of a Diesel Engine A Review

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Abstract - Noise rduction is one of the highest prior target for IC engine development because of the more and more strict engine noise limits.Internal combustion engine noise has been drawing significant attention from automotive manufacturers. To effectively reduce the noise level of a diesel engine the first step is the identification of different engine noise sources. This paper reviews different methods are available for noise reduction of a diesel engine.

1. INTRODUCTION

Nowadays, more and more consideration is being given to environmental issues. Noise was considered a necessary, but harmless, evil. Today, excessive noise is considered a form of pollution which, in the long run, may cause permanently reduced hearing. As a consequence, authorities now demand that noise levels are kept below certain specified limits. One of the first countries to introduce a standard for noise limits was the Federal Republic of Germany which, in 1968, issued a code regarding the noise levels permitted on its ships. Today, there are numerous national and international codes which both recommend, and demand, maximum permissible noise levels in the various parts of a ship. The greater demand for noise limitation in the maritime area has, of course, aroused wide interest. Consequently, greater demands are now made on the engine designer to provide more detailed and precise information regarding the various types of noise emission from the engine. After a brief definition of what noise actually is, this paper will attempt to clarify 'noise' as applied to MAN B&W's two-stroke engines, and will then go on
to discuss the primary noise sources and types of engine-related noise emissions, noise level limitation and the current situation in relation to noise. [1]

2. LITERATURE REVIEW

Noise reduction is one of critical phenomenon in every engine manufacturer. This paper review about different noise sources identification methods [3] described all the noise source identification. Also this paper reviews about different noise reduction methods for different components of diesel engine. [4, 5, 6].

3. WHAT IS NOISE?

A popular definition of noise is 'an undesirable sound'. To what extent a sound can be characterized as noise is, of course, a personal evaluation. However, if the sound level is so high as to be damaging to health, it will normally be considered by one and all as undesirable and, therefore, as noise. Sound is the result of mechanical vibrations occurring in an elastic medium, e.g. air. When the air starts to pulsate, the variations in air pressure will spread from the source through the transfer of energy from molecule to molecule. The more energy transferred, the higher the sound level. [2]

3.1Sound Level Measurement Units

The International Standards Organization (ISO) has determined the following reference values for acoustics.

Reference for sound intensity:
$Io = 10{-}12$ W/m2

Reference for sound pressure:
$Po = 2 \times 10{-}5$ Pa

Reference for vibration velocity:
$Uo = 2 \times 10{-}9$ m/s

The above-mentioned intensity and pressure reference values represent sound intensity and sound pressure at the lowest levels perceptible to the human ear. As the ear is not particularly sensitive and is just able to discern that a sound has doubled in intensity, a linear division of the intensity would be impractical. For this reason, decibel (dB) has been introduced as a unit for measuring sound. This unit is logarithmic and is defined as 10 times the logarithmic relationship between the actual intensity of the sound and the reference value:

Sound intensity level (dB):
$L_s = 10 \times \text{Log10}\ (I/Io)$ (1)

Reference, $Io = 10{-}12$ W/m2

As sound pressure squared corresponds to the intensity of the sound, the following corresponding values are valid when we use sound pressure as a basis
Sound pressure level (dB):
Lp = 20 x Log10 (p/po) (2)

Reference Po = 2 x 10−5 Pa [2]

4. NOISE MEASUREMENT METHODS

Engine noise source identification is essential for making noise reduction strategies. Predominant noise sources of engine are normally identified as some cover component as oil pan, valve cover and front gear cover etc. the radiated noise sources of a diesel engines are identified with two methods lead covering technique and noise grid.

1. Lead covering technique
2. Acoustic intensity techniques (Noise grid)

4.1 Lead covering technique

Lead covering technique is also called partial exposure technique and is a traditional noise source identification techniques for engines. It is still the most reliable, although it is rather costly and time cosuming. This is simply covering the whole engine or all of the components with an acoustic high transmission loss material(usually lead).[3]

It is mounted on fiberglass wool for insulation and to prevent reverberent buildup to give considerable noise reduction. A component is then uncovered and the noise increase is noted. The process is repeated for each component.

4.2 Acoustic intensity techniques (Noise grid method)

In order to identify the sources, sound intensity mapping was done on the engine and gearbox assembly in the hemi anechoic chamber. There are two methods available for intensity mapping which is Grid Method. Here Grid Method is used in order to identify the noise sources from the sound intensity mapping results.

The noise radiating components are ranked based on the above calculated sound power level and it has identified that the following components Oil Sump, Rocker Cover, Inlet Manifold, Timing Cover, Crank Case and Gearbox Casing are the critical sources for noise radiations. Critical frequencies of noise radiations can also be extracted from the intensity mapping results. In order to quantify the structural resonances parallel vibration measurement has been done and following is the list of components and its resonant frequencies.

Figure 4.2.1 Noise Grid Method [3]

5. NOISE SOURCES

An IC engine noise signal is composed of many components from different sources. These sources include combustion, mechanical, and the combination of both. The combustion noise is produced by a rapid rate of pressure rise, which besides being a source of engine structural vibrations also excites resonance in the gas inside a combustion chamber cavity. The latter is also a source of vibration and noise. The contribution of the combustion to the whole noise signal is some transient components. In a normal condition, the combustion noise is mostly in a frequency range above a few 100 hertz as the combustion energy below this range is mostly transformed into useful work by pushing pistons forward. In the case of abnormal conditions, degradation in the combustion quality may produce some low frequency content in the combustion noise [4]

A rise in the cylinder pressure pushes the piston from the top dead center advancing to the bottom dead center. In this movement, the clearance between the piston and the cylinder or damage to piston rings can cause the piston to impact with the cylinder, the phenomenon of piston slap, which is another major source of engine noises. As the piston slap is caused by both the combustion and the clearance, the noise level reflects the combustion quality and changes in the clearance. An important feature of IC engines is that they have both reciprocating and rotating parts. Different type of parts will produce different signal components contributions of different rotating parts to the noise can be identified with reference to their speeds. The timing gear chain is another source of mechanical noise.

Intake noise generated by interruption of airflow at inlet valves transmitted via air cleaner radiated by air duct. Cooling fan noise this results from the sound of air being moved at high speed across the engine and through the radiator.

6. NOISE REDUCTION TECHNIQUES

Traditional methods of noise control in most application are by using absorption and barrier techniques. These involve brackets & clamps for assembly, carrier material to hold absorbing materials. Usage of absorbing materials which could be high, as this is based on noise control technique by allowing source to produce noise and hence the cost is also higher. Based on the survey, several demerits have been studied in using absorption and barrier noise control techniques in the field of an automobile application. This paper deals with the noise control by using the application of free layer damping technique thereby overcoming the
demerits happening in using former techniques, helping better control of noise in the environment and solutions which are more durable. [5]

6.1 Damping Treatment

Based on the sound intensity mapping results, the intensity spots on radiated noise components are identified and hence the damping treatment locations are finalized. The following procedures have to be followed for applying the FLD damping material on component.

1. Clean the surface where the damper to be applied using any of the solvents benzene, acetone, etc. Appropriate methods to be used for making the surface fine before cleaning.

2. Locate the damper with adhesive on hot spot areas through proper fixtures.

3. Apply pressure over the damper for few seconds. It depends on the type of adhesive that are used for bonding.

6.1.1FRF Measurement of Oil Sump

The Frequency Response Function (FRF) measurement was conducted for various critical components based on noise source ranking. The components were tested with and without damping treatment in free-free condition in order to find FRF using simple hammer test and the results are explained as below

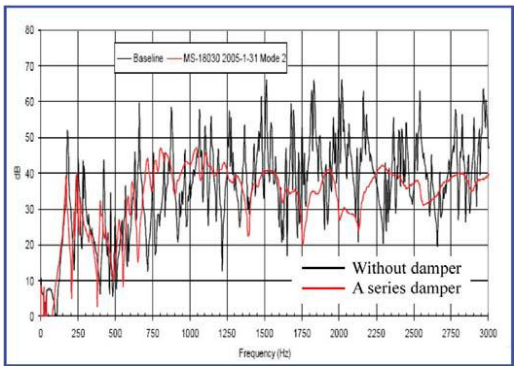

Figure 6.1.1 FRF of Oil Sump [6]

6.2 Laminated steel sheets

There are two types of laminated steel sheets unconstrained layer damping where a layer of bitumastic (or similar) high damping material is stick to the surface and constrained layer damping where a laminate is constructed.

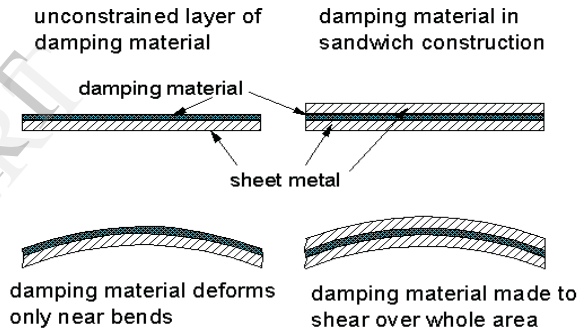

Figure 6.2.1 Laminated steel sheets [7]

6.3 Aluminum foams

Metal foam is a cellular structure consisting of a solid metal, for ex. aluminium, containing a large volume fraction of gas-filled pores. The pores can be sealed (closed-cell foam), or they can form an interconnected network (open-cell foam). Metallic foams typically retain some physical properties of their base material. Foam made from non-flammable metal will remain non-flammable and the foam is generally recyclable back to its base material.

Al foams are very effective in terms of acoustical absorption, effective in terms of electromagnetic shielding and structural damping, absorb impact energy regardless of impact direction, much more stable than organic materials like wood or plastics and are decorative are completely recyclables and hence do not cause any harm to our environment. [8]

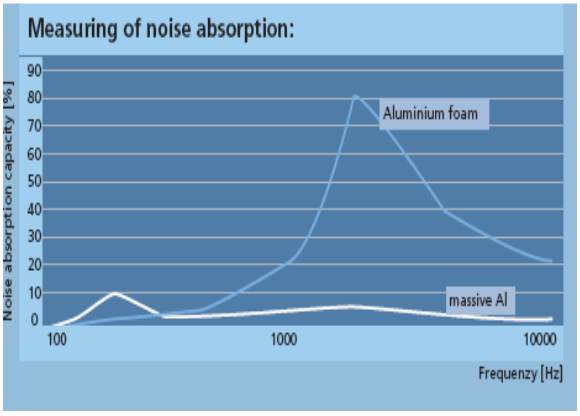

Figure 6.3.1 Noise comparison for aluminum foam and aluminum [8]

Provides sound absorption at low frequencies at a smaller material thickness in comparison with other absorption materials such as glass or mineral wool fibers or polymer foams.

6.4 Isolation mounts

Vibrating equipment creates sound pressure waves (noise) in the surrounding air. Anything that is physically connected to a generator set can cause vibrations to be transmitted to the building structure. These connection points include skid anchors, radiator discharge air ducts, exhaust piping, coolant piping, fuel lines and wiring conduit. Fitting these connections with flexible joints effectively reduces noise transmission. Mounting a generator set on spring type vibration isolators effectively reduces the vibration and noise that are transmitted through the floor.

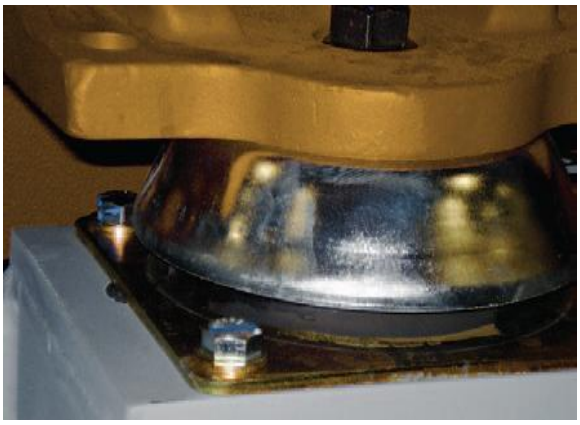

Figure 6.4.1 Isolation mounts at the base of Engine [9]

7. CONCLUSION

This paper discuss about different engine noise sources identification by noise grid method and the different noise reduction techniques like for mainly noise making components in engine are oil sump and rocker which can be manufactured with laminated steel sheets and aluminum foam sheets. Also this study shows that vibration at base of the engine can be reduced by using modified isolation mounts which helps in noise reduction of a diesel engine.

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