Noise reducing Methods for an I. C. Engine: A Review

S. R. Patil[1] , S. S. Shinde[2]

[1] Assistant Professor A.I.S.S.M.S.C.O.E., Mechanical Engg. Department, Pune.

[2] Assistant Professor, A.I.S.S.M.S.C.O.E., Mechanical Engg. Department, Pune.

***Abstract:* —** Any sound which irritates can be called as noise. As with any occupational hazard, control technology should aim at reducing noise to acceptable levels by 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. Major noise sources in a noisy portable I. C. engine driven generator set have been identified. The separation of engine combustion and mechanical noise indicated that their contribution was almost equal. The main noise sources were considered to be mechanical in nature. In general, the larger the vibrating panel, the more sound is radiated from the surface. Sound pressure level measurements performed to identify major noise sources in the engine when exhaust will duct away. For noise reduction muffler, silencer, vibration control, barriers and enclosures can be used and should be considered at the design stage. A of method of noise reduction is depends upon the application of an I. C. Engine. Such as for generator enclosure, barrier along with absorptive material with total enclosure will provide better noise reduction than a partial enclosure. In vehicles muffler, silencer is used along with absorptive material. It is advisable and better to consider noise control measures at the design stage itself rather than after the product is manufactured and installed. This paper presents the different methods of noise reduction of an I. C. Engine.

Keywords — Noise reduction, muffler, Silencer, Barrier, Acoustic enclosure, Acoustic material, Vibration control.

I. NTRODUCTION

Noise is defined as a sound, generally of a random nature, the spectrum of which does not exhibit distinct frequency component. Noise also defined as an unwanted sound. Since noise can affect human in number of ways like their hearing, ability to communicate and their behavior. Noise is a hazardous that we expose ourselves to everyday without consideration. It can cause physical problems such as permanent hearing loss, as well as psychological traumas like stress (6). More and more requirements by regulating bodies are being applied to facet of daily life in order to reduce noise pollutions. The first task of any noise control program is to identify the major sources of noise radiation. The greatest reduction in noise can only be achieved by reducing the noise radiated from the noisy sources. The noise of vehicles and machines is mainly defined by the noise generated by their power plant which is usually an engine. One of the predominating contributors to the total engine noise is the noise emitted by the engine surfaces. Although strides of progress have been made in source noise reduction, some type of industrial and manufacturing equipment such as hammer mills, power presses, plastic grinders, diesel engines etc. are still quite noisy. In addition there are many equipment installation where the cost to develop noise reduction measures for old equipment is prohibitive. In these situations the acoustical engineers must be considered enclosing the equipment in the either partial or total enclosure. It must be emphasized that noise reduction at source always enjoys top priority but with systematic approach and carefully attention to design detail, enclosures can be one of the most powerful noise reduction measures available to the acoustical engineer.

Engine noise is caused by various types of force generation within the engine and is transmitted to the radiating outer surfaces. The transmission path properties are determined by the vibration modes of the structure. The properties of the outer surface will also influence the sound radiation. Number of ways in which the final sound radiation may be influenced: reduction at the source of combustion forces and mechanical forces, reduction of the vibration transmission between the sources and the outer surface, reduction of the sound radiation of the outer surface, reduction of combustion pressures is intimately coupled to changes in the combustion process or combustion chamber shape. Since any changes to the design of the combustion chamber or to the combustion process will also have an effect on engine performance and exhaust gas emissions this is a difficult path for a noise control engineer. Unfortunately most design changes which would reduce noise would also increase exhaust emissions (7).

II. MUFFLER OR SILENCER

The mufflers are typically installed along the exhaust pipe as part of the exhaust system of an internal combustion engine to reduce its exhaust noise. Mufflers or silencers are used which are placed in a flow duct to prevent sound from reaching the openings of the duct and radiating as far-field sound. Reactive silencers do this by reflecting sound back towards the source while absorptive silencers attenuate sound using absorbing material (6). The muffler accomplishes with a resonating chamber, which is specifically tuned to cause destructive interference, where opposite sound waves cancel each other. Exhaust gases leave the engine under extremely high pressure. There are numerous types of muffler present to reduce the sound produced in the engine exhaust. The transmission loss (TL) is defined as the ratio between the sound power incident to the muffler (Wi) and the transmitted sound power (Wt) for the case that there is a reflection-free termination on the downstream side (3), TL = 10 log (Wi/Wt)

In order to select a suitable muffler type, some basic information are necessary regarding how industrial general), attenuate noise by two fundamentally different methods. The first method, called reactive attenuation - reflects the sound energy back towards the noise source. The second method, absorptive attenuation – absorbs sound by converting sound energy into small amounts of heat. There are three basic industrial muffler types that use these methods to attenuate facility noise – reactive silencers, absorptive silencers and anyone or both of them combined with resonator. The proper selection of a muffler is performed by matching the attenuation characteristics of the muffler to the noise characteristics of the source, while still achieving the allowable muffler power consumption caused by muffler pressure drop. Insertion loss is defined as the difference in sound pressure level at some measurement point in the pipe or outside the opening when comparing the muffler element under test to a reference system.

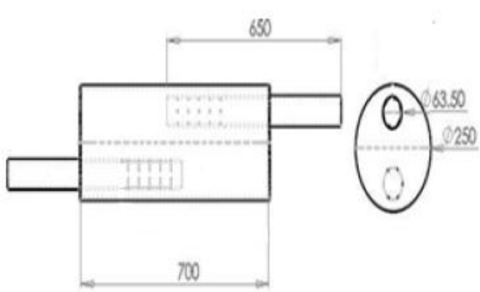

Figure 1: 2D view of three pass perforated muffler

The maximum noise reduction recorded with the developed and existing muffler was in average range of 15 dB and 12 dB respectively while comparing the reading taken without muffler. Also the possible sound reduction of new muffler is 4 dBA comparing with exist muffler. The engine break thermal efficiency is improved up to 2.4 percentages by using the developed muffler instead of existing muffler and the maximum efficiency is found out to be 35% on an average (3). Mufflers or silencers are devices used in a flow duct to prevent sound from reaching the openings of the duct and radiating as far-field sound. Sound reduction in mufflers: use of sound absorbing materials in which sound energy is converted into heat mainly by viscous processes. Typical sound absorbing materials used are rock wool, glass wool and plastic foams (6). The muffler is capable of attenuating noise by about 25 to 35 dBA. The muffler is designed to attenuate both high and low frequency noises. The reactive portion of the muffler has been covered with a layer of absorptive material which considerably decreases the self generated noise of the muffler. The material used in the muffler is capable to withstand temperature of higher order (4). The reduction of external noise is now days one of the important issues in car development. The legislators are lowering the noise emission standards continuously in the different countries. For example, the pass by noise level for passenger cars is reduced from maximum 77 dBA to 74 dBA in 1995. To control the flow in the exhaust duct, a valve is placed in the flow. The resistance of the valve is continuously variable by applying an external signal. It is assumed that the valve is purely resistive; it isn't capable to store energy from the gas flow. The active silencer is capable to reduce the exhaust noise from 91 dBA to 78 dBA after the tail pipe outlet, with a back pressure of 3 kPa to the engine (2).

III. ACOUSTIC BARRIER

Barriers are placed between a noise source and a receiver as a means of reducing the direct sound observed by the receiver. In rooms, barriers suitably treated with sound-absorbing material may also slightly attenuate reverberant sound field levels by increasing the overall room absorption. Barriers are a form of partial enclosure usually intended to reduce the direct sound field radiated in one direction only. For non-porous barriers having sufficient surface density, the sound reaching the receiver will be entirely due to diffraction around the barrier boundaries.

In estimating the Insertion Loss of a barrier installed in a large room the following assumptions are implicit:

- ✓ The transmission loss of the barrier material is sufficiently large that transmission through the barrier can be ignored. A transmission loss of 20 dB is recommended.
- ✓ The sound power radiated by the source is not affected by insertion of the barrier.
- ✓ The receiver is in the shadow zone of the barrier; that is, there is no direct line of sight between source and receiver.
- ✓ Interference effects between waves diffracted around the side of the barrier, waves diffracted over the top of the barrier and reflected waves are negligible (10).

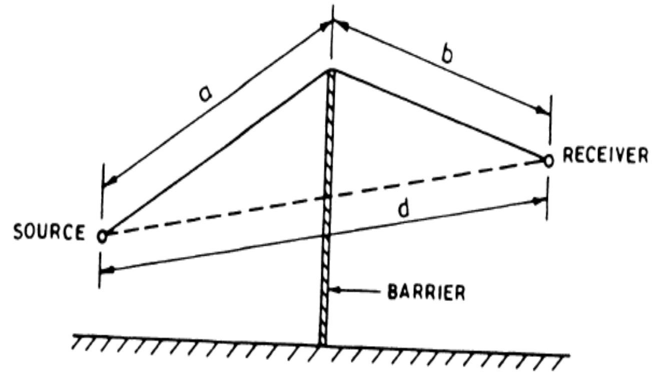

Figure 2: A Barrier

Fresnel number, N of the barrier is defined as,

$N = \pm (2/\lambda)(a + b - d)$;

+ When receiver is in shadow zone,

- When receiver is in bright zone.

The barrier attenuation for a point source can be calculated as:

Attenuation = $20 \log \frac{(2\pi N)^{1/2}}{\tanh (2\pi N)^{1/2}} + 5$ for N ≥-0.2

= 0; otherwise (6).

IV. ACOUSTIC ENCLOSURE

Enclosure is a commonly used form of noise control at the workplace. In an enclosure, any pipes from the machine should not be rigidly attached to the enclosure, but should be supported by vibration isolating hangers. Air gaps need to be minimized. Ducts for fresh air and exhaust gases should be adequately silenced. The insides of the panels of enclosures are lined with absorbent materials to avoid build-up of noise due to reflections. (6) The wall of an enclosure may consist of several elements, each of which may be characterized by a different transmission loss. Each such element must be considered in turn in the design of an enclosure wall, and the transmission loss of the wall determined as an overall area weighted average of all of the elements.

For this calculation the following equation is used:

$$TL = 10\log10 \frac{\sum_{i=1}^{q} S_i 10^{-TL_i/10}}{\sum_{i=1}^{q} S_i}$$

Where,

S_i is the surface area (one side only), and

TL_i is the transmission loss of the *i*th element.

Design guide lines of an enclosure

- ✓ According to size and shape of the source, decide the overall dimensions of the enclosure.
- ✓ The distance between the source and the enclosure should be at least half of the wave length of the lowest frequency of interest.
- ✓ The distance between the source and the enclosure should be more than the largest dimension of the source.
- ✓ Out of these thumb rules, the greater of the two should be taken. If the available space does not allow such a big enclosure, heavy absorption have to be used.
- ✓ After fixing the dimensions of the enclosure, provide doors, ducts, silencers etc. according to the requirements of ventilation and maintenance.
- ✓ Opening should be avoided as far as possible, because this reduces enclosures efficiency drastically.
- ✓ Also, all joints should be carefully considered, since these are the main sources of leakages.

The first few panel resonance frequencies of the enclosure should not be in the frequency range in which sound attenuation is desired, acoustic resonances occur at the standing wave frequency given by (Ubhe 1996),

$$F = c / 2d,$$

Where c is the speed of sound and d is the distance between source and panel.

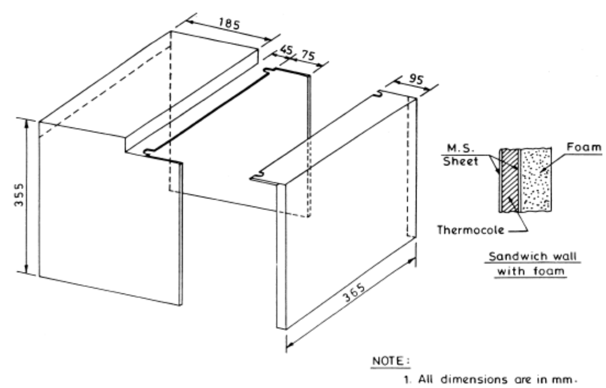

Figure 3: Partial enclosure for the generator set

The result of experiment performed on the generator set gives reduction of 3.5dBA (1).

Table 1: Sound pressure levels of generator.

	Sound Pressure level (dBA)					
	Front		Back		Top	
	No load	800W load	No load	800W load	No load	800W load
Without Enclosure	85.5	87.0	82.0	82.5	82.0	82.5
With partial Enclosure	82.0	84.0	80.0	81.0	77.0	78.0

A reduction of 3 to 5 dBA was obtained. In full enclosures with minimum openings, insertion losses of more than 20 dBA can easily be obtained.

V. ACOUSTICAL MATERIALS

Acoustical material plays a number of roles that are important in acoustic engineering such as the control of room acoustics, industrial noise control, studio acoustics and automotive acoustics. Sound absorptive materials are generally used to counteract the undesirable effects of sound reflection by hard, rigid and interior surfaces and thus help to reduce the reverberant noise levels (5). Acoustical materials for the purpose of noise reduction are materials that absorb sound, reflect sound, or dampen vibrations. Acoustical properties of the materials used in different situations should be taken into account during the design stage. Wherever possible, quieter plastics should be used in place of metal components. Cast iron has better material damping than steel. Acoustical materials usually convert some of the sound energy which strikes them into thermal energy (4). Sound absorbing materials are fibrous, lightweight and porous, possessing a cellular structure of intercommunicating spaces. It is within these interconnected open cells that acoustic energy is converted into thermal energy. Thus the sound-absorbing material is a dissipative structure which acts as a transducer to convert acoustic energy into thermal energy. The actual loss mechanisms in the energy transfer are viscous flow losses caused by wave propagation in the material and internal frictional losses caused by motion of the material's fibers. The absorption characteristics of a material are dependent upon its thickness, density, porosity, flow resistance, fiber orientation, and the like (8). Materials which reflect or insulate noise are used as barriers. While any material will reflect some of the noise reaching it, only dense and airtight materials are really effective in blocking noise. Some good insulating materials are concrete, thick steel sheets, glass, lead and thick PVC sheets. Sound-absorbing materials are used to reduce noise levels within spaces, to prevent reflections from surfaces and to control reverberation within spaces. Unfortunately, most good noise absorbents are poor noise barriers. They are usually porous and lightweight. Foam, fiberglass, cork and mineral wool are common sound-absorbing materials. Metal wools can be used in situations where high temperatures are encountered. Materials used to damp vibrations are usually viscoelastic materials such as filled bitumen, specially formulated elastomers and some types of polymer plastics (6).

VI. VIBRATION CONTROL

Noise radiation from the silencer shell and related piping or ``shell noise" is problem that has recently grown in importance as outlet noise levels have been reduced. The noise radiated by the silencer can be reduced by controlling its vibration by modification of the dynamic characteristics by changing stiffness or mass of the structure, by isolation of the source of vibration from the body of the noise radiating structure, or by use of damping materials (1).

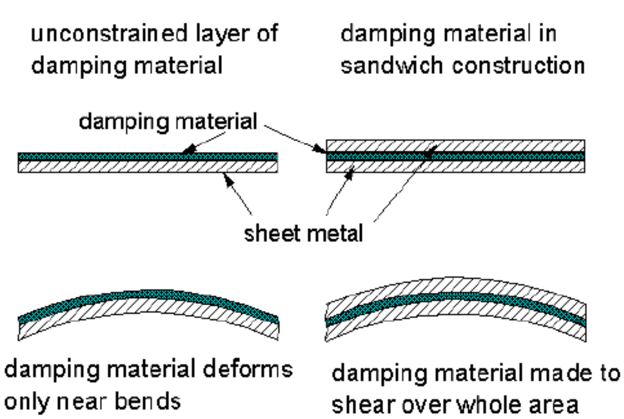

Figure 4: Vibration Damping

Most noise sources (except for aerodynamic noise) are associated with vibrating surfaces. Hence the control of vibration is an important part of any noise control program. Vibration control can be achieved by isolation, damping and by avoiding resonance in structures and machine parts.
Transmission of vibrations from one structure to another can be reduced by the use of resilient elements between them which is called as vibration isolator. The transmissibility, T, of this system is defined as the ratio of the amplitudes of the mass displacement to that of the disturbing motion of the support and is given as,

$$T = \left\{\left[1 + (2\zeta r)^2\right] / \left[(1 - r^2)^2 + (2\zeta r)^2\right]\right\}^{1/2}$$

Where ζ is the damping ratio and r is the ratio of the excitation frequency to the natural frequency of the spring mass system. The isolation range of this system is where r > 2 p i.e. where T is less than unity.
Noise characteristics of structures are determined by mass, stiffness and damping. Whereas mass and stiffness are associated with the storage of kinetic and strain energy respectively, damping relates to the dissipation of energy. The increased damping results in faster decay of unforced vibrations and reduced amplitude at resonance of structures subject to steady excitations. The ratio of the energy dissipated per cycle to the energy present in the system is called the specific damping capacity ψ. The loss factor η is often used to specify material damping and the relationship between these quantities is:

$$\eta = (\psi / 2\pi) = 2\zeta.$$

It is possible to introduce additional damping to a structure by means of damping layers of viscoelastic material. The damping layer is subjected to shear deformation, as it is sandwiched between two sheets. Sandwich sheets with the damping material in between two steel sheets are commercially available (6).

VII. SUMMARY

Control and reduction of noise is necessary and can be achieved by different methods such as muffler, silencer, acoustic barrier, acoustic enclosure, and acoustic materials. After use of these methods there will be noise generation due to vibration, so vibration damping is necessary after noise reduction. These methods can be used according to noise pressure level available and require, space available. Silencer or muffler can reduce noise up to 13dBA, Acoustic barrier and enclosure can be used up to 20dBA reduction etc. Numbers of noise absorbing materials are available and can be used according to parameter which affects their performance.

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