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A REVIEW ON NOISE SOURCES AND METHODS OF REDUCTION OF NOISE IN DIESEL ENGINES

Murlidhar Patel*, Prakash Kumar Sen, Gopal Sahu
* Student, Mechanical Engineering, Kirodimal Institute of Technology, Raigarh (C.G.).
Faculty, Mechanical Engineering, Kirodimal Institute of Technology, Raigarh (C.G.).
Faculty, Mechanical Engineering, Kirodimal Institute of Technology, Raigarh (C.G.).

ABSTRACT
Noise reduction is one of the highest prior target for diesel engine because of the more and more strict engine noise limits, diesel engine noise has been drawing significant attention from automotive manufacturers. To effective reduce the noise level of a diesel engine the first step is the identification of different engine noise sources. The design and development of modern diesel engines is marked by a reduction in exhaust gas emissions and increase in specific power and torque.Exhaust noise is one of the major contributors to noise from vehicles powered by internal combustion engine. For the same power rating, diesel engines are noisier than gasoline engines, since the combustion characteristics of diesel engines produce more harmonics than slower combustion of gasoline.This paper reviews different noise sources and methods are available for noise reduction of diesel engine.

KEYWORDS: noise, muffler, silencer, vibration.

INTRODUCTION
Noise is one of the major contributors to noise from vehicles powered by internal combustion engine. For the same power rating, diesel engines are noisier than gasoline engines, since the combustion characteristics of diesel engines produce more harmonics than slower combustion of gasoline. An unmuffled gasoline engine radiates exhaust noise in the range from 90 to 100 dBA while an unmuffled diesel engine under identical conditions radiates exhaust noise in the range from 100 to 125 dBA. The suppression of engine exhaust noise has been a subject of interest for many years. Fortunately, however, this noise can be reduced sufficiently by means of a well-designed muffler and silencer.[1]

What is Noise?
A popular definition of noise is ‘anundesirable sound’. To what extent asound 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 willnormally 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 thesound level. [2]

Human response to sound
- The frequency range extends from 20 Hz to 20 kHz and the SPL extends from the threshold of hearing at the lowest boundary to the threshold of feeling (pain) at the highest.
- Human ear is most sensitive between 500 Hz and 5 kHz and is insensitive to sounds below 100 Hz.

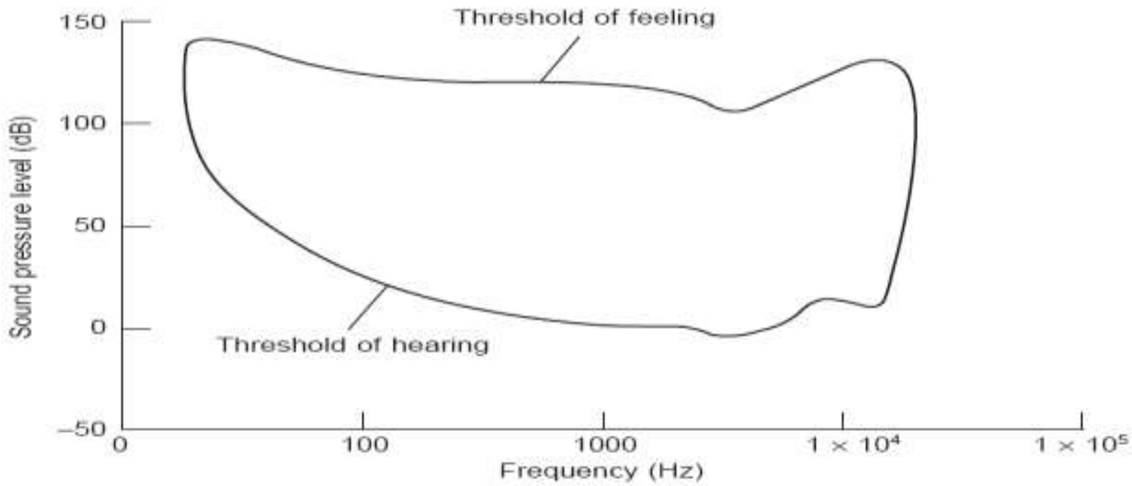

Fig.1Human threshold response to sound

SOURCES OF NOISE GENERATED FROM DIESEL ENGINE

Noise from stationary vehicles

- Vehicles in the vicinity of the exhaust silencer (ISO 5130, 1978)
- Engine running at 75% of the speed at which it develops maximum power.
- For these measurements, the exhaust outlet and microphone are in the same horizontal plane with the microphone 500 mm from the exhaust outlet and at an axis of 45° to it.
- The background noise level is also measured and the maximum difference between the vehicle noise and the background noise is then compared with vehicle's specified noise level.

Engine noise

- Engine noise originates from both the combustion process and mechanical forces associated with engine dynamics.[3]Pulses released by the exhaust are the cause of engine noise. When the expansion stroke of the engine comesnear the end, the outlet valve opens and the remaining pressure in the cylinder discharges exhaust gases as apulse into the exhaust system. These pulses are between 0.1 and 0.4 atmospheres in amplitude, with pulseduration between 2 and 5 milliseconds. The frequency spectrum is directly correlated with the pulse duration.The cut-off frequency lies between 200 and 500 Hz. Generally, engines produce noise of 100 to 130 dBdepending on the size and the type of the engine. [4]

Intake Noise

- Generated by interruption of airflow at inlet valves
- Transmitted via air cleaner
- Radiated by air duct
- Noise of 10-15 dB
- Turbo charger compressor noise also radiated from the air duct

At blade passing frequency (also higher harmonics)
Typically 2-4 kHz[3]

Exhaust Noise

The exhaust noise, which falls into low-frequency noise, is the dominant noise source of a dieselengines and tractors. It is a direct and effective way to reduce the exhaust noise by using an exhaustmuffler. However, the traditional exhaust muffler, which are normally constructed by combination ofexpansion chamber, and perforated pipe or perforated board, are with high exhaust resistance, but poornoise reduction especially for the low-frequency band noise. Normally, there is a contradiction betweenthe noise reduction and the exhaust resistance for an exhaust silencer, so it has a great significance instudying the theory or principle of the exhaust muffler with high-efficiency noise reduction and energysaving.A new theory of exhaust silencer of diesel engine based on counter-phase and split-gas rushing hasbeen proposed. The theory is, the dominant low-frequency noise components are controlled by counteractof two sound waves with counter-phases (180°phase difference); the other frequency-band noise isreduced by lowering the exhaust gas flow rate thus lowering exhaust noise. The exhaust resistance basedon the new theory is low because of the structure without perforated pipe or perforated board where smallholes are used, and the no reduction of gas-flow sections in all the way of gas flow.[5]

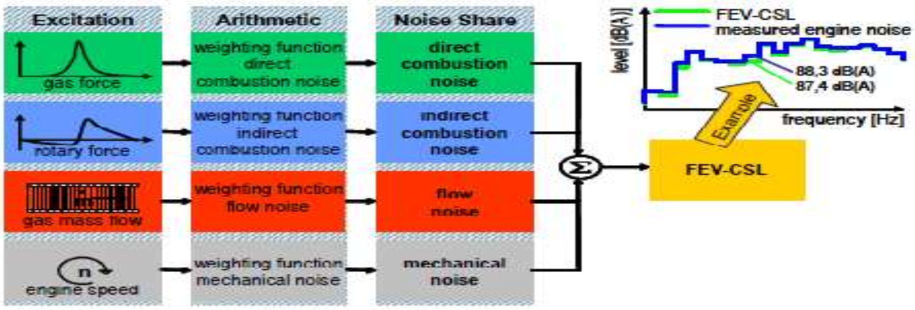

Fig.2 Combustion Sound Level Calculation

Aerodynamic Noise-For road vehicles this can be broken down into three noise generating components:

Boundary layer distributed over the vehicle body
- Boundary layer noise tends to be random in character
- Absorbent materials

Edge effects
- noise level higher than boundary layer noise
- Caused by vortices formed at edges

Vortex shedding (large vortices roll up and break into smaller ones)
at various locations on the vehicle body and also at cooling fans.
Noise from the cooling fan Blades shed helical trailing vortices Result in periodic pressure fluctuations when they strike obstacles fan rotors are made with unevenly spaced blades and with an odd numbers of blades.

Tire Noise
- Two sources of noise
  Tread pattern excited noise (affected by tire design)
  Road surface excited noise
- Tire designers reduce tire noise
- Chassis designers reduce transmission to occupant
- The mechanism of tire noise generation is due to an energy release when a small block of tread is released from the trailing edge of the tire footprint and returns to its undeformed position.

Tread patterns designed to control frequencies Models of tires with structural dynamic characteristics and the air contained within them are used at the design stage.

Brake Noise
- Mechanism of noise generation in disc and drum brakes is still not fully understood Complex system of linkages Elements of large area held in contact with hydraulic / friction loading
- Ad hoc / empirical solutions often used For low frequency drum brake noise
- Add either a single mass or a combined mass and a visco-elastic layer applied at anti-nodes of the drum back plate (Fieldhouse *et al., 1996).*
  At higher frequencies
- a redistribution of drum mass to eliminate some of the specific back plate vibration modes.

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NOISE REDUCTION METHODS IN DIESEL ENGINES

Minimizing Aerodynamic Noise

Minimizing protrusions from the body surface, making the body surface smooth and continuous and ensuring that gaps around apertures such as doors are well sealed. Vortices produced at windscreen pillars very little which can be done to improve as aerodynamics at A-pillar contradicts visibility requirements Wing mirrors and wheel trims also cause vortices

$f = \frac{S.U}{d}$

where S is the Strouhal Number (based on geometry), U is speed of air, d – obstruction diameter

f = 640 Hz, for d=10 at 70mph

inlet and outlet apertures are carefully sited and designed

•Should not generate noise and noise from engine compartment should not be transmitted to the occupant. [3]

Reduction in Piston Slap Noise:

An important mechanical noise source in reciprocating internal combustion engines isusually piston slap. This noise can be reduced by modifying the kinematics of the piston byoffsetting the piston pin. A small (about 0.5±2 mm) lateral displacement of the piston pinaway from the piston axis is provided without altering its location in the vertical direction.With this, advanced timing of the piston slap is achieved. Piston slap no longer takes placeshortly after top dead centre (TDC) under the sudden burst of combustion, but rather justbefore TDC under the compression pressure which builds up relatively slowly (Rohrle1975). Another way of reducing piston slap noise is by reducing the clearance betweenpiston and cylinder. The noise reduction achieved by reducing this clearance for an engineof a two-wheeler scooter is given in table 1 (Tandon et al 1997).In general, the danger of scuffing/seizure does not permit reduction in piston clearanceswithout using light alloy cylinders or positive oil-cooling of the piston.[6]

Table 1.The effect of piston cylinder clearances.

Piston cylinder clearance (mm)	Sound intensity level (db)
50	86.5
33	86.4
26	79.2
20	76.3

Reduction in Engine Exhausts Noise:

Engine exhaust noise is controlled through the use of silencers and mufflers. Generallyspeaking, there is no technical distinction between a silencer and muffler and the terms arefrequently used interchangeably. A silencer has been the traditional name for noise attenuationdevices, while a muffler is smaller, mass-produced device designed to reduce engine exhaustnoise.

Silencer Selection Factors

The use of an exhaust silencer is prompted by the need to reduce the engine exhaust noise. Inmost applications the final selection of an exhaust silencer is based on a compromise between thepredicted acoustical, aerodynamic, mechanical and structural performance in conjunction withthe cost of the resulting system.

Silencer Types

Despite the terms and myriad of configurations, the silencer can be broken into threefundamental types: reactive (reflective), absorptive (dissipative), and combinationreactive/absorptive. In addition to the three main silencer types, other functionality such as sparkarresting, emission control, heat recovery, etc., may also be incorporated into the silencer design.

Each type of silencer has specific performance attributes that can be used independently or incombination to produce the required IL for a specific application. A number of additionalsilencer styles and options are also reviewed in the following sections.

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Reactive Silencer

Reactive silencers generally consist of several pipe segments thatinterconnect with a number of larger chambers. The noise reduction mechanism of reactivesilencer is that the area discontinuity provides an impedance mismatch for the sound wavetraveling along the pipe. This impedance mismatch results in a reflection of part of the soundwave back toward the source or back and forth among the chambers. The reflective effect of thesilencer chambers and piping (typically referred to as resonators) essentially prevents somesound wave elements from being transmitted past the silencer. The reactive silencers are moreeffective at lower frequencies than at high frequencies, and are most widely used to attenuate theexhaust noise of internal combustion engines. A generic reactive engine silencer comprised oftwo proportionally sized chambers with a pair of interconnecting tubes is shown below.

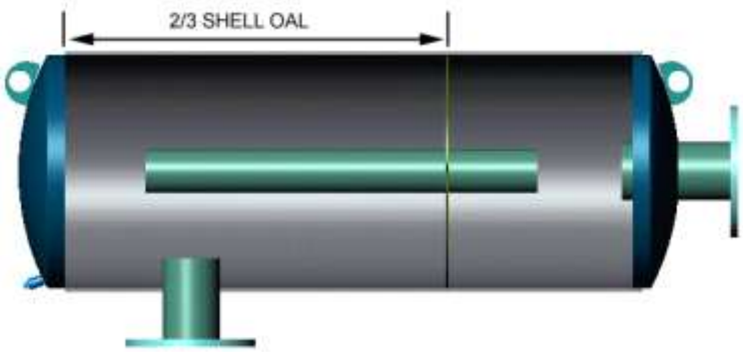

Fig:3.1 Reactive silencer

Absorptive Silencer

Absorptive silencers contain fibrous or porous sound-absorbingmaterials and attenuate noise by converting the sound energy propagating in the passages intoheat caused by friction in the voids between the oscillating gas particles and the fibrous or poroussound-absorbing material. Absorptive silencers usually have relatively wideband noise reductioncharacteristics at middle and higher frequencies. Absorptive silencers are often used to attenuatethe engine intake noise or supplement the performance of reactive silencers for the engineexhaust noise control. The sound absorbing materials are generally held in position by the use ofa perforated metal liner. Knowledge of the structural content of an exhaust system is importantwhen considering the inclusion of a catalytic element or Selective Catalytic Reduction (SCR)system in conjunction with the silencer. Particulate migration of the insulation into the exhauststream over a period of time can cause the catalytic element to become fouled and substantiallyimpact or impede its performance.

Combination Silencer

Some silencers combine both reactive and absorptive elements toextend the noise attenuation performance over a broader noise spectrum. Combination silencersare also widely used to reduce engine exhaust noise.[7]

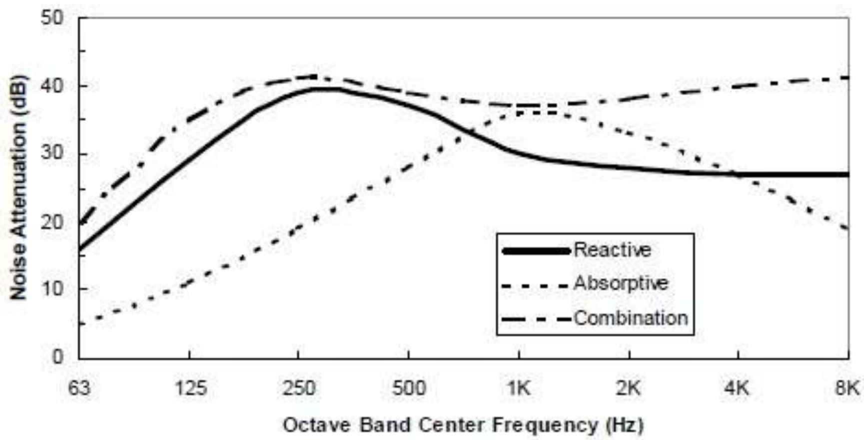

Fig-3.1 Graph between noise and its frequency

Muffler

The exhaust gases are introduced in inlet anddirected by a cone, flowing into the space between inner and outer pipes, and then distributedautomatically, coming into the chambers through the radial rectangular slits using a U-shaped bypass pipe.In each chamber, the coming exhaust gases are divided into two parts which has the same magnitude and180º phase difference, when these two parts gases are made to gather at centre-line of the chamber, they arecancelled each other, leading that gas flow rate is lowered. Also the expansion chamber in the middle of themuffler helps to reduce the noise further. Since the two openings chambers positioned at each chamber arebig rectangular slits and also the gas flow speed is lowered by the cancelling, the pressure loss is much lowerwhen gas goes through the muffler meaning at the backpressure of the muffler is lower. Mufflers are installed along the exhaust pipe as a element of the exhaust system of an IC engine toreduce its exhaust noise. Mufflers use neat technology to cancel out the noise. The muffler reduces exhaustnoise by dampening the pulsations in the exhaust gases and allowing them to expand slowly. It wasusually made of sheet steel, coated with aluminium to reduce corrosion. Some are made of stainlesssteel. [4]

Fig:3.3Reactive muffler

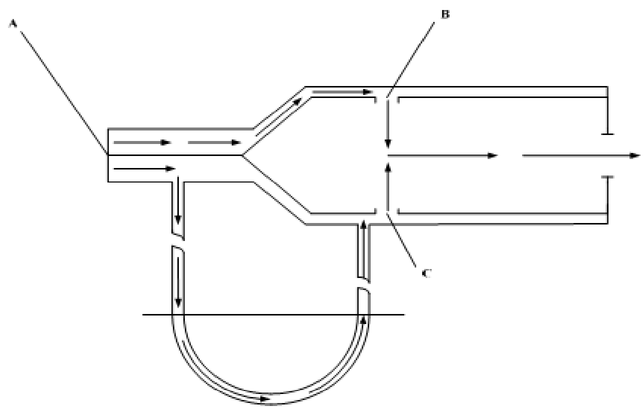

Fig:3.4Principle of the muffler using reversed-phase cancelling

Vibration control*:*

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 programme.Vibration control can be achieved by isolation, damping and by avoiding resonance instructures and machine parts.

Vibration isolation

High noise can result because of vibration transmission from a source to some structurewhich is a better noise radiator than the source itself. Hence vibration isolation is animportant consideration while designing machines and their mountings. Transmission ofvibrations from one structure to another can be reduced by the use of resilient elementsbetween them. Resilient elements which may be visualized as springs, are called vibrationisolators. Vibration isolation can be understood from the analysis of an ideal, linear, singledegreeof freedom system in which the isolator is represented by the parallel combinationof massless spring and damper. The transmissibility, T, of this system is defined as the ratioof the amplitudes of the mass displacement to that of the disturbing motion of the supportand is given as

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

Whereζ is the damping ratio and r is the ratio of the excitation frequency to the naturalfrequency of the spring mass system. The isolation range of this system is where $r > \sqrt{2}$i.e. where T is less than unity. In other words, for an isolator to be successful, its stiffnessmust be such that the mounted resonance frequency is less than 0.7 times the minimumforcing frequency. The isolation system should be carefully designed because if the valueof r is near 1.0, then instead of attenuation, the vibrations will be amplified.Such a single-degree of freedom model provides some insight into the behavior of anisolation system, but does not account for many aspects of realistic installations. Realsprings are not massless and the supported masses generally move not only vertically butalso horizontally and also tend to rock. Different types of practical isolators are availablecommercially. Most commercial isolators incorporate metallic or elastomeric resilientelements. Metallic elements are usually in the form of coil springs or flexural configurationssuch as leaf springs. Isolators with elastomeric elements normally have these elementsbonded or otherwise attached to support plates to provide convenient means offastening to other components. An elastomeric element may be used in shear, torsion,compression modes or a combination of these. The pneumatic or air spring isolators use theprinciple of compressibility of confined volumes of air. In active isolation systems, thevibration of the structure to be protected is sensed by a transducer whose output is used todrive an actuator that acts on the structure so as to reduce its vibration.[6]

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 applyingthe 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.[8]

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

Where η = Loss factor

Ψ = Damping capacity

ζ = Damping ratio

CONCLUSIONS

Noise attenuation of diesel engine is carried out using different types of mufflers. These mufflers were fitted on exhaust pipe of diesel engine. Engine as well as acoustic performance is measured for entire load range. Noise control is becoming increasinglyimportant for a wide variety of OEM designers. Examplesof products that take noise control considerations intoaccount during their design cycles include equipment suchas computer hard drives, house appliances, materialhandling and transportation equipment etc. In thetransportation market, which includes aircraft, ground andmarine segments, the demand is for low noise level goals.Achieving these goals is of primary importance for OEMto be continue to be competitive or to keep a givensupremacy in the market. The automotive industry hasbeen a leader in the adsorption of noise controltechnologies. Methods in use for several years for theprediction of interior noise levels include finite elementmethod(FEM), statistical energy analysis (SEA) boundaryelement analysis (BEA) etc. The internal combustionengine has mechanized the world. Since the early 1900s ithas been our prime source of mechanical power. The vastnumber of internal combustion engines in the world todayhas resulted in air pollution, noise pollution etc.This paper discuss about different diesel engine noisesources identification by noise grid method and the differentnoise reduction techniques. Also this study shows that vibration at base ofthe engine can be reduced by using damper which helps in noise reduction of a diesel engine.

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