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AUTOMOMOTIVE NOISE AND VIBRATION CONTROL

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ABSTRACT

The study of sound, noise and vibration is an emerging and interesting topic in the present era. The study on NVH has resolved lot many problems in society with respect to noise. From last few decades literature reviews that many works are done on exterior design of automotive than interior design. The reduction of noise because of vibration of parts of the body of a vehicle is a challenging task. In this paper the properties of sound, noise and vibrations are reviewed. The controlling techniques of noise and vibrations are elaborated. The properties of sound absorbing materials are explained. Finally the applications of materials for noise reduction and measuring instruments are listed.

KEYWORDS: Design, CAD, FEM, Frequency, Noise, Vibration, Harshness, vibro-acoustic materials, truck cabin, damping etc..

INTRODUCTION

The noise associated with road traffic is an important social problem. It is a problem which has grown considerably over the years, partly due to increased traffic on our roads and partly due to increased noise emissions from engines manufactured to meet the demand for more power and higher power-to-weight ratios. The social nuisance is such that many countries have enacted legislation prohibiting the use of vehicles emitting noise in excess of prescribed limits. The task of reducing the noise inside and emitted by commercial vehicles is complicated; not only are the mechano acoustic aspects complex, but there are serious commercial limitations arising from the cost of noise reduction measures in a very competitive industry.

Comparatively simple acoustic treatments such as the enclosure of the power unit often raise considerable mechanical difficulties associated with the cooling of the engine, its auxiliaries and access for maintenance. Additionally, the extra weight of the treatment may make it difficult to meet axle and tyre loading requirements. Reduction of exhaust noise is also fraught with similar difficulties, although it can generally be achieved by employing a silencer of increased volume, or tandem silencers; space limitations on the chassis of a tractor unit are so restricted that a moderate increase in silencer volume may require a major chassis change for it to be accommodated satisfactorily.

There is no magic wand that will reduce vehicle noise levels overnight. Quietness will only be effectively and economically achieved by a gradual process of evolution after the additional cost and the basic necessity to design quietness into the vehicle is accepted, as opposed to considering sound reduction measures as an afterthought [3].

I. SOURCES OF NOISE

There are many sources of noise on a vehicle, all resulting either from the application of power to propel the vehicle or from the motion of the vehicle itself. In the first category are engine block noise, intake and exhaust noise, and, in the second, road and wind noise.

Generally, the predominant sources of noise are diesel engine block noise, intake and exhaust noise, although occasionally gear whine and fan noise can make a significant contribution to the overall noise emitted by the vehicle, and such secondary sources as brake squeal, body noise and load noise can make significant contributions to the annoyance of pedestrians.

Road noise is usually associated with noise inside the vehicle, especially in cars, but external coasting noise mainly arising from the tyre and vehicle being excited by road surface roughness gives levels of 75-80 dBA.

II. NOISE CONTROL

The control of noise inside and emitted by motor vehicles is a matter of identifying the loudest component in terms of dBA at each stage of the noise reduction programme and attacking that component. Today this usually entails reduction of gas noises, followed by reduction of noise from the engine block. Although the reduction of gas noises in the most efficient manner enquires a better understanding of the fundamentals involved.

In the case of engine noise it is necessary to differentiate between airborne and structure borne noise that is between noise directly radiated by the power unit to the surrounding air, and noise radiated from the body structure which has been excited by the engine through its attachment points to the chassis. Initially, the important path is usually airborne, but if large reductions of internal or external engine noise are required, it is necessary to pay some attention to the isolation of the engine from the chassis. In general, low frequency structure borne noise limits the interior quietness of a vehicle in terms of dBA, since the isolation of structure-borne noise is limited by the allowable amplitude of the engine.

Internal noise sources in a vehicle:

Engine and powertrain, Suspensions, Tyres, aerodynamic sources, Squeaks and rattles from interior dashboard and trimmings, brakes, electrical and mechanical accessories, etc.

III. VEHICLE NOISE PATHS

Internal vehicle noise does not depend only on the acoustic and vibration sources; very important roles are also played by the different transmission paths between the sources and the receivers (i.e. the drivers and passengers ‘ears). In a vehicle there are two different categories of transmission paths: structure-borne and airborne paths. They are related to completely different mechanisms of energy transmission. In a common vehicle (like a car) experience shows that very often the structure-borne noise transmission path dominates at low frequency (<200 Hz) while the airborne noise transmission path dominates above 500 Hz. In the mid-frequency range, both transmission paths have commonly the same level of importance [5].

Structure-borne noise transmission paths:

The structure-borne path is a vibration transmission path, in which noise is emitted by the panels surrounding the internal cabin. A simple example is the case of the engine of a vehicle: if we consider the engine when running as a source of vibrations (Fig. 1), the energy associated with this vibration will be transferred to the vehicle structure through the engine mounts, then the vibration will propagate over the whole vehicle structure onto the panels facing the passenger compartment. The vibration of these panels will transfer the energy to the air cavity inside the cabin, generating the noise perceived by the occupants. The reduction of structure-borne noise is therefore focused mainly on the structure and the isolation of the vibrations: in this example the engine mounts play an important role in the attenuation of the level of vibration, the vehicle structure should have a low sensitivity to the forces coming from the mounts, and the panels should have a low radiation efficiency and possibly be damped to reduce their levels of vibration.

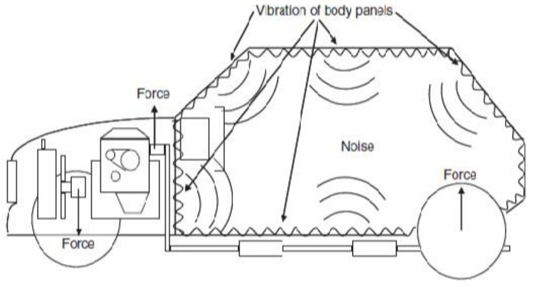


Fig. 1 Structure - borne paths

Airborne noise transmission paths:

The airborne path is a completely different transmission mechanism, as it is an acoustic transmission path. A simple example is still the engine in running conditions (Fig. 2): if we consider the engine as an acoustic source (i.e. the noise generated by the vibrating panels of the engine body), in this case the noise propagates through the air, through holes and across the surfaces of the structure. In the latter case the acoustic propagation will involve also the vibration of the panels of the structure but we are still dealing with an airborne path (the noise outside the panel makes it vibrate, and the panel will generate noise inside the passenger compartment). For these reasons the reduction of airborne noise is more focused on the acoustic path (particular attention should be paid to avoid holes and leakages), on the structure (which should work in acoustic isolation) and on acoustic absorption inside the cabin (this could be done also for structure-borne noise, but the common acoustic materials show better performance in the high-frequency range, where the noise is dominated by the airborne path).

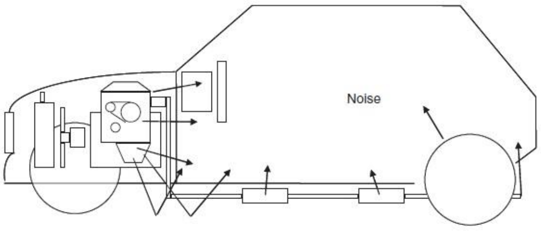


Fig. 2 Airborne paths

IV. SOUND ABSORPTION

Sound absorption is a very well-known and commonly used solution to reduce noise. It exploits the characteristics of some materials that are able to dissipate the acoustic energy. In current vehicles sound absorbing materials are applied in the passenger cabin and often in the engine bay, to reduce the interior and sometimes the exterior noise. There are three main physical phenomena related to sound absorption. The first mechanism is the frictional losses of the air molecules; a sound wave causes an oscillation in the position of the air particles: the molecules of the air interact with the pores or the fibres of the absorbing materials and are subjected to friction phenomena, causing a loss of energy (the friction slightly increases the temperature of the air and the material). A second mechanism is related to heat exchange; the sound wave generates pressure fluctuations in the air; in the free field this is an adiabatic transformation, whereas on the boundaries the presence of absorbing materials (with a large surface to volume ratio) causes a heat exchange between the air and the surrounding materials. The transformation is no longer adiabatic and shifts towards an isothermal transformation, causing a loss of energy in the sound wave. This could happen mainly at low frequencies, where there is more time during a cycle for heat exchange (at high frequency the heat exchange becomes so small that it can be neglected). The third mechanism is related to the internal losses of the acoustic materials subjected to the forced mechanical oscillations caused by the acoustic pressure: this is true mainly for closed-cell porous materials, whereas in fibrous and open-cell porous materials this effect is so low that it can generally be neglected.

The most important characteristics of the sound absorbing materials are Normal specific acoustic impedance, Energy absorption coefficient, reverberation time etc.

V. ACOUSTIC MATERIALS

The most common materials used on vehicle applications are described below.

Porous materials:

All materials with a given porosity on their surface have some sound absorbing properties. Usually the materials used are open-cell foams (i.e. polyurethane); closed-cell foams are not very useful for acoustics applications, as they work only on their surface and do not allow air to flow through them (the flow resistivity is very high). The common open cells used in acoustics have pores smaller than 1 mm, so they are much smaller than the wavelength. In many porous materials the continuous solid structure behaves also as an elastic structure, adding stiffness and damping to the panels of the structures: in this case they are called poroelastic materials.

Fibrous materials:

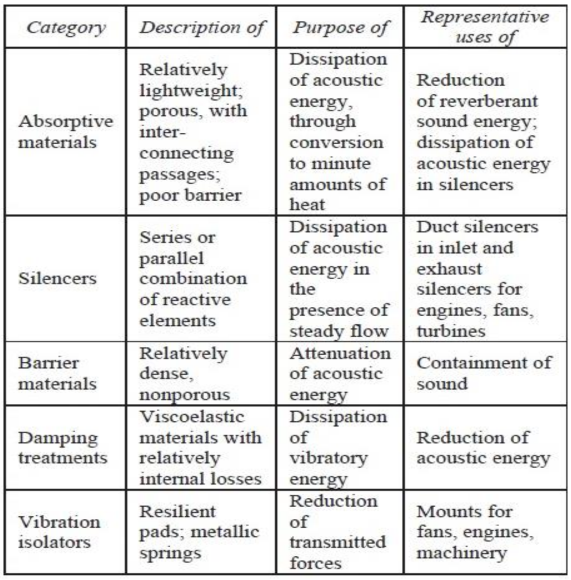
Fibrous materials are very common in sound absorbing isolation as they may be optimised to have the required specific flow resistance, porosity and tortuosity, by changing the diameter of the fibres and their geometrical orientation. Fibrous materials are in general based on mineral, glass or natural fibres.

Damping materials:

In this category falls all the materials applied to add damping on the structure. The most common are viscoelastic materials, which show both damping (high loss factor) and structural capability.

Main types of acoustic materials and their use are given in the table 1 below [9].

Table 1 Materials for noise control



Category	*Description of*	*Purpose of*	*Representative uses of*
Absorptive materials	Relatively lightweight; porous, with inter-connecting passages; poor barrier	Dissipation of acoustic energy, through conversion to minute amounts of heat	Reduction of reverberant sound energy; dissipation of acoustic energy in silencers
Silencers	Series or parallel combination of reactive elements	Dissipation of acoustic energy in the presence of steady flow	Duct silencers in inlet and exhaust silencers for engines, fans, turbines
Barrier materials	Relatively dense, nonporous	Attenuation of acoustic energy	Containment of sound
Damping treatments	Viscoelastic materials with relatively internal losses	Dissipation of vibratory energy	Reduction of acoustic energy
Vibration isolators	Resilient pads; metallic springs	Reduction of transmitted forces	Mounts for fans, engines, machinery

VI. VIBRATION MEASUREMENT

Figure 3 illustrates the basic features of a vibration measurement scheme. In this figure, the motion (or dynamic force) of the vibrating body is converted into an electrical signal by the vibration transducer or pickup. In general, a transducer is a device that transforms changes in mechanical quantities (such as displacement, velocity, acceleration, or force) into changes in electrical quantities (such as voltage or current). Since the output signal (voltage or current) of a transducer is too small to be recorded directly, a signal conversion instrument is used to amplify the signal to the required value. The output from the signal conversion instrument can be presented on a display unit for visual inspection, or recorded by a recording unit, or stored in a computer for later use. The data can then be analyzed to determine the desired vibration characteristics of the machine or structure.

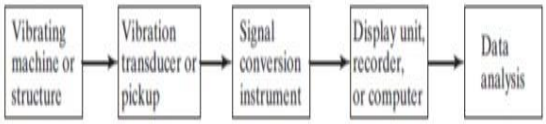


Fig. 3 Basic vibration measurement

The following considerations often dictate the type of vibration-measuring instruments to be used in a vibration test: (1) expected ranges of the frequencies and amplitudes, (2) sizes of the machine/structure involved, (3) conditions of operation of the machine/equipment/structure, and (4) type of data processing used

Some of the commonly used instruments for measuring vibrations are Transducers and Accelerometers.

VII. FREQUENCY MEASUREMENT

Most frequency-measuring instruments are of the mechanical type and are based on the principle of resonance. Two kinds are discussed in the following paragraphs: the Fullarton tachometer and the Frahm tachometer, shown in Fig. 4 below [6]

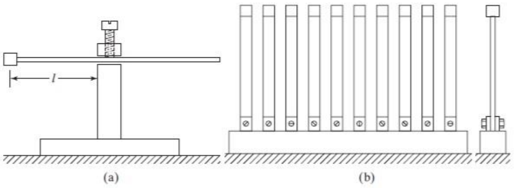


Fig. 4 (a) Fullarton tachometer (b) Frahm tachometer

VIII. SOUND MEASUREMENT

Many types of measuring systems can be used for the measurement of sound depending on the purpose of the study, the characteristics of sound and the extent of information that is desired about the sound. The various elements in a measuring system are:

a. The transducer; that is, the microphone;
b. The electronic amplifier and calibrated attenuator for gain control;
c. The frequency weighting or analyzing possibilities;
d. The data storage facilities;
e. The display.

The performance characteristics of sound measurement instruments are quantified by:

Frequency Response - Range of frequencies over which an instrument reproduces the correct amplitudes of the variable being measured (within acceptable limits). Typical Limits over a specified frequency range:

Microphones ± 2dB
Tape Recorders ± 1 or ± 3 dB
Loudspeakers ± 5 dB

Dynamic Range - Amplitude ratio between the maximum input level and the instrument's internal "noise floor" (or self noise). All measurements should be at least 10 dB greater than the noise floor. The typical dynamic range of meters is 60 dB, more is better [13].

The microphone can be connected to a sound level meter or directly to a magnetic tape recorder for data storage and future measurement or reference. The microphone is the interface between the acoustic field and the measuring system. It responds to sound pressure and transforms it into an electric signal which can be interpreted by the measuring instrument (e.g. the sound level meter). The best instrument cannot give a result better than the output from the microphone. Therefore, its selection and use must be carefully carried out to avoid errors. When selecting a microphone, its characteristics must be known so that its technical performance (e.g. frequency response, dynamic range, directivity, stability), in terms of accuracy and precision, meets the requirements of the measurement in question, taking into account the expected conditions of use (e.g. ambient temperature, humidity, wind, pollution).

The microphone can be of the following types: piezoelectric, condenser, electret or dynamic. In a piezoelectric microphone, the membrane is attached to a piezoelectric crystal which generates an electric current when submitted to mechanical tension. The vibrations in the air, resulting from the sound waves, are picked up by the microphone membrane and the resulting pressure on the piezoelectric crystal transforms the vibration into an electric signal. These microphones are stable, mechanically robust and not appreciably influenced by ambient climatic conditions. They are often used in sound survey meters.

In a condenser microphone, the microphone membrane is built parallel to a fixed plate and forms with it a condenser. A potential differential is applied between the two plates using a d.c. voltage supply (the polarisation voltage). The movements, which the sound waves provoke in the membrane, give origin to variations in the electrical capacitance and therefore in a small electric current. These microphones are more accurate than the other types and are mostly used in precision sound level meters. However, they are more prone to being affected by dirt and moisture.

A variation on the condenser microphone which is currently very popular is the electret. In this case the potential difference is provided by a permanent electrostatic charge on the condenser plates and no external polarising voltage. This type of microphone is less sensitive to dirt and moisture than the condenser microphone with a polarisation voltage.

The last type is a microphone where the membrane is connected to a coil, centred in a magnetic field, and whose movements, triggered by the mechanical fluctuations of the membrane, give origin to a potential differential in the poles of the coil. The dynamic microphone is more mechanically resistant but its poor frequency response severely limits its use in the field of acoustics [12].

IX. CONCLUSIONS

- Porous sound-absorbing materials have evolved into more advanced materials over the years. the new materials have become safer, lighter and more technologically optimized.
- Materials made from pine sawdust and polyurethane binder have a small sound absorption coefficient for low frequencies and a high sound absorption coefficient for high frequencies.
- The thickness and density of the different porous material, and the contact between the porous material and elastic panel are good baseline for future investigations.
- Frequency may have an implications for the health and comfort of vehicle travellers. The maximum vibration velocities are higher in case of the vehicle equipped with diesel engine.
- In order to maintain high standard of measurement quality, test of measurement system should be *calibrated* regularly.
- Measuring instruments should not be exposed to vibration for obvious reasons. The manual of each instrument might give special instructions concerning its handling, the storage and the maintenance. Needless to say that this must not be overlooked but must be practised during the entire life of the instrument.
- Commercial vehicles give more noise compared to family cars which have separate luggage compartment. This will help to reduce the noise in the vehicle and then increases driving comfort.
- To obtain reasonably good accuracy in the actual vibration measurements the "*apparent*" vibrations should be less than one third of the measured vibrations.

X. SCOPE FOR FUTURE WORK

- The knowledge of sound, noise and vibrations can be used for experimentation on any vibrating system.
- NVH knowledge can be applied n automotive and aerospace applications
- Knowledge of acoustic materials will help in conducting experiments on reduction of noise in any of the vibrating system.
- Knowledge of measuring instruments is very useful in conducting experiments and measuring the real values of NVH.
- With help of all the information provided in this paper the team has planned to conduct experiments on NVH studies in automobiles.

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