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# Acoustic Materials in Automobiles

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***Abstract:-*** **Automobile comfort and design has had an important impact on the world wide economy during the past century and millions of additional vehicles have been sold because of it. Much research work is being done on automobile interior design in comparison to other industrial designs. However, sound level inside the cabins affects the journey of millions of passengers to a great degree and comfort than many other subjects. Low noise level in the cabins is a comfort parameter of high importance. Therefore an attempt has been made in this paper to review the different acoustic materials being used in various automobiles and also their properties which have impact on noise reduction.**

***Keywords: Noise, Vibration, Frequency, Harshness, vibro-acoustic materials, density, hardness, sound pressure, truck cabin, damping etc..***

## I. INTRODUCTION

Millions of people are affected by noise in homes, auditoriums, seminar halls and in transport vehicles. In fact, noise impacts more people than any other environmental source. Noise can affect the ability to work, learn, rest, relax, sleep, etc. Excessive noise can lead to mental and physical health problems. There are basically four options for controlling noise: constructing (or increasing the height of) a barrier wall, increasing the isolation quality of the cabins, masking the noise, or controlling the noise directly at the source [1]. Low noise level in the cabins is a comfort parameter of high importance. Since all most all places of work are subjected to regulations in the noise area, defining the maximum noise level a worker is allowed to be exposed to, the topic has become interesting.

## II. RECENT TRENDS IN ACOUSTIC MATERIALS

Sound-absorbing materials absorb most of the sound energy striking them, making them very useful for the control of noise. They are used in a variety of locations – close to sources of noise, in various paths, and sometimes close to receivers. Once noise and vibration sources have been identified, the noise and vibration of machinery can be reduced by the use of vibration isolation, barriers, sound-absorbing materials, machine enclosures or by cabin enclosures used to protect passengers. Sound-absorbing materials should always be used in conjunction with barriers and inside enclosures to improve their effectiveness. Sound-absorbing materials have been used increasingly in the construction of aircraft, spacecraft and ships because of their low weight and effectiveness when used correctly. This trend is driven by demands for higher load capacity and reduced fuel consumption for cars, trucks and aerospace structures. The optimum design of vibro-acoustical systems can be achieved through a variety of methods including statistical energy analysis (SEA).

Acoustical engineers now have a wide choice of sound-absorbing materials that not only provide the desired acoustical properties, but also offer an extremely wide variety of colors, shapes, sizes, light reflectivity,
fire ratings, and methods of attachment – to say nothing of the costs of purchase, installation, upkeep, etc. sound-absorbing materials change the main constituents of their products from asbestos-based materials to new synthetic fibers. The production of synthetic materials contributes to the emission of carbon dioxide (mostly from power plants and transportation), methane, and nitrous oxide. It is important to increase research on acoustical materials based on renewable resources that can lead to viable alternatives to conventional materials for current and future applications.

A wide range of sound-absorbing materials exist; they provide absorption properties dependent upon frequency, composition, thickness, surface finish, and method of mounting. However, materials that have a high value of sound absorption coefficient are usually porous. Figure 1 shows a schematic cross-section of a porous solid material.

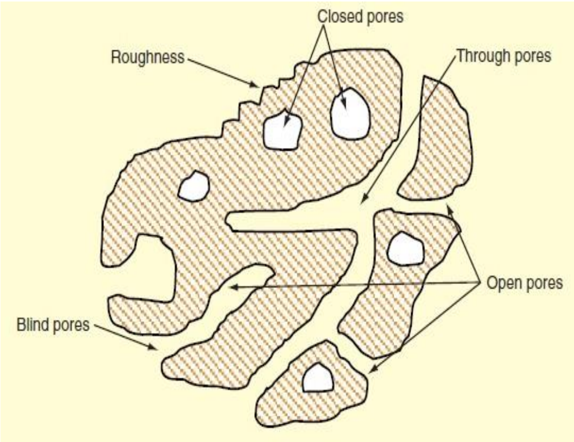


Fig.1 Schematic cross section of a porous solid material

Porous absorbing materials can be classified as cellular, fibrous, or granular; this is based on their microscopic configurations. Figure 2 shows the three main types of porous sound absorbing materials, their typical microscopic arrangements and some of the physical models used to describe their absorbing mechanisms [2].

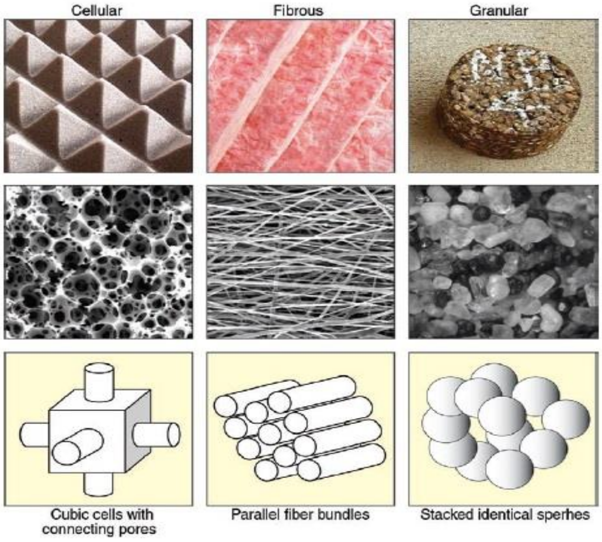


Figure 2. The three main types of porous absorbing materials

A working knowledge of acoustical materials is essential for the practicing noise control engineer. Without this knowledge, cost-effective control of noise becomes more a matter of chance than of intelligent design. In the third reference paper it is described and compared different type of acoustical materials, like and absorptive barrier materials, silencers, damping treatments and vibration isolators. The major characteristics for each of these categories are summarized in table 1. The first three categories function is to absorb or attenuate airborne sound waves. In other words, some vibrating object in contact with a medium has created sound waves whose propagation through the medium is to be minimized. The last category function– vibration isolation- is to minimize the transmission of shaking forces into a floor or other solid structure. This force, if not attenuated, can cause vibration of the structure and consequent widespread generation of sound waves. The fourth category function– damping treatments - is to reduce the amplitudes of resonant vibrations that generate airborne sound and or to minimize the transfer of vibratory energy at panel edges or attachment points to adjoining structural elements [3].

Table 1. Materials and structures 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 |

The function of absorptive materials is to transform impinging acoustic energy into heat. Because the energy contained in sound waves is normally very small, the quantity of heat generated is also small. The two mechanisms by which energy is dissipated are:

- Viscous-flow losses. An effective absorber structure consists of a series of interconnected pores or voids, by means of which sound waves propagate into and through the structure.
- Internal friction. Some absorptive materials have resilient fibrous or porous structures that are compressed or flexed by sound wave propagation. In these structures, dissipation occurs not only from viscous-flow losses but also from the internal friction of the material itself.

The absorptive characteristics of acoustical materials are determined to a large extent by the pore or void size, interconnections between pores or voids, and material thickness. The acoustical impedance at the materials surface and at various frequencies and angles of incidence is probably the best descriptor of the relationship between material properties and dissipation of acoustic energy.
The absorption coefficient can be calculated with the following equation [3]:

$$\alpha = 1 - |R^2|$$

In which;

$$R = \frac{Wref}{Winc}$$

R- The reflection factor,
$W_{ref}$ - the reflected acoustic energy,
$W_{inc}$ - the incident acoustic power.

There are essentially four different treatments for solving noise and vibration problems. Absorbers and barriers are used for airborne noise problems, and dampers and isolators are used for structure-borne noise problems. An **absorber** is a product that reduces sound wave reflections from hard surfaces and thereby minimizes sound build-up or reverberation within an enclosed space. Typically, an absorber is either a fibrous or cellular material that is both porous and elastic. Sound waves enter the material and dissipate to thermal energy via viscous dissipation and/or internal friction. The sound wave interaction between the solid constituent of the material and the air within the material influences the performance of the absorber. A critical physical characteristic that affects the performance of an absorber is flow resistance. The performance of a poro-elastic material can be enhanced using flow-resistive facings. Factors impacting performance are: bulk density; solid density; flow resistivity; Young’s modulus; shear modulus; thermal length; viscous length; tortuosity; and porosity. A **barrier** is a material that blocks sound propagating from one area to another; for example, from the engine compartment to inside the vehicle. A barrier is a nonporous, massive, and limp material. A **damper** is used to dissipate structure-borne excitation of body panels. When a structure vibrates at resonance, a damper reduces the amplitude of vibration and reduces sound radiation. A damper generally works by transferring the vibration energy into heat. In that sense, a vibration damper works like a sound absorber [4].

By varying the sound absorbing material in the cab headliner (roof) the SPL at DRE can be changed. Thus by such a CAE analysis, an effective selection of the sound absorbing material can be made [5]

Three major methods of noise control are used to reduce noise in the interior of the vehicle: (1) reducing noise and vibration sources; (2) applying barriers and other treatments to block sound from entering the passenger compartment, and (3) applying sound absorbers in both the exterior and the interior of the vehicle to dissipate sound and thus reduce the overall sound level.

Inside the vehicle, absorber pads can be effective in a variety of locations. Absorptive materials placed above the headliner, behind the door panel and pillar trim, and under the carpet have proven to be effective [5].

Porous materials such as foams and fibres are used as absorbers. Viscous losses convert acoustic energy into heat as sound waves travel through the interconnected pores (or fibres) of the material. Because motion of the air through the porous material is necessary to dissipate acoustical energy, a material tends to be ineffective when placed close to a rigid boundary (where the particle velocity is zero). Effectiveness of absorption is directly related to the thickness of the material; absorbers are most effective when their thickness is between one-fourth and one-half the wavelength of the sound, with the maximum performance where the thickness is one-fourth the wavelength. This means that sound absorbers do a very good job at high frequencies, which have short wavelengths. However, at lower frequencies, very thick materials would be required to yield high sound absorption, which would be impractical on the interior of a vehicle. A porous material with an open face or with a porous scrim carries most of the sound energy in the form of the airborne wave. The exception is a porous material that has a structural stiffness less than that of air. Some of the porous materials are punched blends of cotton or plastic fibers (“shoddies”), Polyester and polypropylene are common plastic materials used in absorbers, Fiberglass materials etc. [6].

Porous materials are extensively used in vehicle interior trim designs, e.g. dashboard, floor carpet, roof lining, seats and door panels. They are used to reduce the vehicle interior noise to enhance the cabin acoustic quality. The macroscopic sound absorbing properties of the porous material are expressed by the sound absorption coefficient as a function of frequency. The acoustic properties of the porous material effect the noise propagation inside a car cabin but have not been well investigated or validated by experiment. To understand the influence of the porous material in a car cabin by using appropriate experiment and acoustic modelling is desirable for designing, analysing and refining the acoustic quality of the vehicle interior trims [7]. In this reference paper attention has been paid to the optimization of the acoustic properties of the porous material in a coupled vibro-acoustic system, employed the concept of the mass density approach in topology optimisation to find the optimum thickness distribution of a multi-layered sound treatment inside a rectangular cavity. They have also presented a novel topology optimization method to minimize the Sound Pressure Level (SPL) in a panel backed cavity system when the porous material was added. The optimization was aiming to enhance the acoustic quality for a vehicle passenger compartment, and to reduce the weight and cost of the vehicle interior trims [7].

Modern standards of noise and vibration make the manufacturers of vehicles, machines and construction materials take into account the high demands in the design process. Often there is a need both in vibrations absorbing and in effective sound absorbers. Therefore there was a research on the concentrations of matrix components, fillers and modifiers impact on the absorbing and elastic properties of the polyurethane composites. Urethane composition was used as matrix components, consisting of component A (mass fraction of hydroxyl groups, 4.4%); Component B (mass fraction of isocyanate groups, 21.4%). A polyurethane matrix selection is due to the high popularity of polyurethanes in modern industry due to a number of valuable properties, such as resistance to mechanical and chemical influences, a wide range of physical and mechanical properties and others. Fillers and modifiers are aerosol, expanded clay, and aluminium hydroxide. With this the authors studied the change in the properties of composite materials based on polyurethane matrix to identify compounds with the highest sound absorption and vibration absorbing properties simultaneously [8].

It is known that interior parts of cabins in automobiles have significant influences on the interior noise. The interior parts are constituted of elastic materials, viscoelastic materials and porous materials. Therefore, vibration and acoustic analysis in consideration of the mixed materials are required. A seat structure has the largest surface area among interior parts in the cabin. The seat structure for automobiles is mainly composed of metal frames, porous materials (e.g. urethane foams) and surface materials. The porous material for the seat has two media for wave propagation. One is a viscoelastic resin block of the seat foam. The other is an internal air of the foam [9].

The acoustic comfort of a vehicle represents one of the most important aspects of overall quality, since it considerably affects customer’s impression and judgment about. In the field of vehicle acoustic, although exterior noise plays a significant role, the major focus is on interior noise which is influenced by many sources. Of course, the engine and powertrain act as one of the primary excitation sources, together with road noise and wind noise. Dashboard component usually is made of materials acting in controlling noise in a vehicle, but unfortunately it results to be insufficient in controlling noise propagation from the engine inside the passengers cabin, as it usually presents holes and cutouts for allowing different accessories to pass through. In order to achieve proper acoustic targets, part of the effort is also oriented directly at the engine. Generally, a conventional engine cover is composed by two parts: one is made of polyurethane foam material properly printed to follow the engine block shape, and another is a plastic component with an attractive surface appearance. The

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resulting trim panel thanks to its sound-absorbing and vibration-dampening qualities reduces engine noise level, improving passengers acoustic comfort. Some typical materials, commonly employed in automotive field, were selected. In particular, Table 2 reports a list of the considered materials, where information about composition, density and thickness can be found [10].

Table 2. Properties of the materials

| TREATMENT | | ID | SURFACE DENSITY [g/m²] | THICKNESS [mm] |
|---|---|---|---|---|
| Basalt Wool |  | 1 | 1500 | 5 |
| Basalt Wool |  | 2 | 1500 | 15 |
| Thetacell |  | 3 | 450 | 10 |
| Thetafiber |  | 4 | 1100 | 10 |
| Polyester |  | 5 | 600 | 40 |
| Polyester |  | 6 | 1200 | 5 |

Hence, improvement of a cabin body structure under the constraint of noise, vibration and harshness (NVH) behaviour is a challenging task and reduction of noise inside the cabin structure by using suitable acoustic materials is also important from the point of comfort and health issues.

## III. CONCLUSIONS

- Porous sound-absorbing materials have evolved into more advanced materials over the years. Compared with the older absorbing materials produced in the 1960s, 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.
- Perhaps the most challenging task of all is ensuring that the best sound package has been developed in terms of its value. The value (not just monetary) in today's global automotive market consists of: cost; weight; durability; functionality, recyclability; packaging space; environmental impact; performance; and ergonomics.
- Thinner materials require significantly more flow resistivity than thicker materials; therefore, materials that are nearly optimal in one application may not work well in another application. However, a specific air flow resistance of around 1000 mks rayless can yield good overall absorption regardless of the thickness of the material.
- 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.
- It should be noted that with an increase in the filler volume content, the sound-absorbing and vibration-absorbing properties of the samples are increases at the same time.

## IV. SCOPE OF WORK

Current research is focussing on development of user-friendly truck cabin which has almost zero noise in the cabin. The structural-acoustic model is established and the response of the sound pressure in frequency domain is obtained by using finite element method. The minimization of sound pressure near the driver's right ear depends on the geometry of the vehicle body structure and the layout of damping treatments. The measurement of frequency at idle and low speed conditions are to be investigated. Then suitable path where maximum frequency is to be reduced will be chosen. Physical tests are performed with different acoustic materials having different densities and thicknesses and the data are collected. The data are used to correlate the performance of FE model in numerical simulation. The vibro-acoustical virtual FE model will be tested under different variable conditions. Finally a best acoustic material is recommended for further research.

## REFERENCES

[1] Acoustic Materials handbook.
[2] Jorge P. Arenas, Malcolm J. Crocker "Recent Trends in Porous Souns-Absorbing Materials" in SOUND & VIBRATION July 2010.
[3] Tiberiu RUSU, Silviu IONESCU, Mihaiella CRETU, Adina IONESCU "Acoustic Materials – Sound Absorbing Materials Made of Pine Sawdust" RJAV vol VIII issue 2/2011.
[4] Pranab Saha, Kolano and Saha Engineers. "Developing Vehicle Sound Packages" SOUND & VIBRATION October 2011.
[5] A R. Mohanty and S. Fatima "An overview of automobile noise and vibration control" NOISE AND VIBRATION WORLDWIDE March 2014.
[6] Andrea Zent and John T. Long "Automotive Sound Absorbing Material Survey Results" SAE International 2007.
[7] Zhengqing Liu, Mohammad Fard and John Laurence Davy "ACOUSTIC PROPERTIES OF THE POROUS MATERIALS IN A CAR CABIN MODEL" icsv23, Athens (Greece), 10-14 July 2016.
[8] S M Vakhitova, I F Shaehova and E I Zharin "Study of vibro-acoustic properties of composite based on polyurethane injection" ISTC-IETEM 2015.
[9] T.Yamaguchi, T.Yamamoto, S.Maruyama, I.Shirota, M.Fujimoto and T.Fukushima "Vibration and acoustic analysis for automotive seat structures including porous materials and metal frames" Vehicle Noise and Vibration (NVH), ISMA 2010.
[10] D.Siano, M.Viscardi and M.A. Panza "Automotive Materials: an experimental investigation of an engine bay acoustic performances" ScienceDirect, 14-16 September 2016.