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A Review on Methods of Noise Attenuation in Engineering Design Applications

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Abstract

Nose is an unwanted sound that causes annoyance. It has been proved that the noise has an adverse effect on living things including human beings. Noise pollution norms have been laid down by OSHA (Occupational Safety and Health Administration) and Euro Norms. It is apparent that there exists a scope for the research in the design and development of noise attenuation methods and materials.

In present review, the contributions of the researchers in design, testing and implementation of noise engineering in attaining the attenuation is focussed. Application of numerical, finite element analysis and experimentation analysis to study and to investigate acoustic materials in achieving noise attenuation are discussed. It also provides useful information in extending these studies and approaches with respect to macro and micro level material analysis in engineering design applications and thin film noise attenuation as well.

***KeyWords:** Noise, attenuation, macro and micro analysis.*

1. INTRODUCTION

Noise and Noise Engineering: Noise is unwanted sound produced by many sources such as a running engine, man's vocal cord, a vibrating machine and is unpleasant, loud or disruptive to hearing.

Noise Engineering is to study the characteristics of the noise produced by different sources and vibration analysis by different numerical and experimental methods.

Noise attenuation and control:

Attenuation is a general term that refers to any reduction in the strength of a signal. Attenuation occurs with any type of signal, whether digital or analog. Sometimes called loss, attenuation is a natural consequence of signal transmission over long distances. The extent of attenuation is usually expressed in units called decibels (dBs).

Requirements for the control of low frequency noise in enclosed spaces, especially for aerospace applications, have recently taken on more importance. This can attributed to the need for increased noise reduction with a minimum of additional weight. Traditional methods for low frequency noise control dictate a mass law dependence for increased transmission loss through the sidewall. Aerospace vehicles such as the advanced turboprop aircraft, helicopters and weight sensitive in their implementation and all suffer from noisy interiors, particularly at low frequencies. One innovative technique currently under study is active noise control. This technology utilizes additional interior noise sources to provide control of the acoustic cabin environment.

Method of Noise analysis:

In noise engineering the noise analysis is carried out using numerical and experimental methods. The Finite Element Method (FEM) is used in numerical analysis as this method has been extensively adopted by many researchers in the field of design and analysis. The sophisticated instrumentations are used in the design for noise and vibration experimentation. Hence it is apparent that the reduction in the cost and time of the experiments would lead to more appropriate outcomes with regards to the productivity and at the same time the quality of the work.

Coupled-field analysis:

A coupled-field analysis is a combination of analyses from different engineering disciplines that interact to solve a global engineering problem, hence, it is often referred to a coupled-field analysis as a multi physics analysis. When the input of one field analysis depends on the results from another analysis, the analyses are coupled. There are two types of coupling, they are one-way coupling and the two-way coupling. In a fluid-structure interaction problem, the fluid pressure causes the structure to deform, which in turn causes the fluid solution to change. This problem requires iterations between the two physics fields for convergence. The induction heating problem is complicated further by the fact that the material properties in both physics simulations depend highly on temperature. Some of the applications in which coupled-field analysis may be required are pressure vessels (thermal-stress analysis), fluid flow constrictions (fluid-structure analysis), induction heating (magnetic-thermal analysis), ultrasonic transducers (piezoelectric analysis), magnetic forming (magneto-structural analysis), and Micro-Electro-Mechanical systems (MEMS). [1]

2. LITERATURE REVIEW

K. D. Wang et.al used coupled-field finite element method to determine noise and vibration characteristics. Integration of the computational fluid dynamics and finite element techniques was used to determine noise and vibration characteristics of a system analytically. A gray-iron steel ring was selected for the study. The analytical results obtained were compared with the measurements. The verified FE model can be expanded to predict noise and vibration in a drive train and can also be suggested to eliminate noise and vibration. [2]

D. Lavazec et.al proposed to reduce the noise and the vibrations on a broad low-frequency band through a micro structured material by inclusions that were randomly arranged in the material matrix (which is also structural). Because the dissipative porous material (like fiberglass) structures cannot be used to reduce the large wavelength acoustic waves and mechanical vibrations at low frequencies. The simplest mechanical model developed should have the capability to nearly predict the experimental results that were measured. Authors presented the design in terms of geometry, dimension and materials for the inclusion. The results obtained were compared with prevision given by the stochastic numerical model with the measurements, which exhibit the physical attenuation over a broad low-frequency band, as intended. [3]

Umberto Berardi and Gino Iannace have discussed an inverse method to predict the acoustical properties of nine natural fibers. Since the natural materials are the good noise absorbents. Natural fibers have been selected for the study because of their good thermal insulation properties, lack of harmful effects on health, and availability in large quantities. The authors selected six vegetative fibers: kenaf, wood, hemp, coconut, straw, and cane; one animal fiber, sheep wool; recycled cardboard; and granular cork for the study. A least square fit procedure based on the Nelder-mead method is used to calculate the coefficients that best predict both acoustic impedance and propagation constant laws. The inverse approach used by the researchers allows to determine physical parameters and to obtain formulas to include the investigated natural fibers in software modelling for room acoustic applications. [4]

Yufei Zhang et.al studied the sound transmission between rooms through the flexible partition with its edges elastically restrained. The fundamental significance was to understand the acoustical behaviour of rectangular cavities connected by flexible panel structure. The structural-acoustic coupling system modeling uses the energy variational formulations in conjunction with Rayleigh-Ritz procedures with the improved Fourier series. They presented Numerical examples to demonstrate the reliability and effectiveness of the current model through the comparison with the predicted data obtained by Finite Element Analysis using NASTRAN. High accuracy, stable numerical computation had been observed in the analysis. The result computed by finite element method using NASTRAN were used as comparison results for the proposed analysis. [5]

Jian Kang in his research used different modelling techniques for sound propagation at micro-scale in urban areas. As most of the acoustic problems cannot be solved purely through practical analysis, engineers heavily rely on the developing computer simulation. A series of simulation techniques used for the study were energy-based image source method, ray-tracing method, radiosity method, transport theory, finite element method and boundary element method, equivalent sources method for parallel street canyons, finite-difference time-domain method and parabolic equation method, empirical formulae and other methods. [6]

Z. Fang, Z.L. Ji and C.Y. Liu had proposed the coupling method based on subdomain division technique for multi-chamber silencers with non-uniform cross-sections at axial direction. The silencer was divided into several subdomains and the impedance matrixes were calculated by using the suitable 3-D methods. For the double-chambered silencer, the transmission loss and computational speed results from the proposed method, the numerical mode matching (NMM) method, 3-D finite element (FE) method predictions and experimental measurements are compared, which verifies the accuracy and efficiency. [7]

Richard J et.al examined the physical mechanisms governing the use of active noise control in an extended volume of a cylindrical shell. An active noise control system was implemented in the cylinder using a fixed array of discrete monopole sources, all of which lie in the plane of the exterior noise sources. For both the analytical model and experiment, the radiation of external monopoles was coupled to the internal acoustic field through the radial displacement of the thin, elastic cylindrical shell. The measured data was compared with computed results from a previously derived analytical model based on infinite shell theory. The results obtained shows a good agreement between measurement and prediction for both the internal pressure response and overall noise reduction. [8]

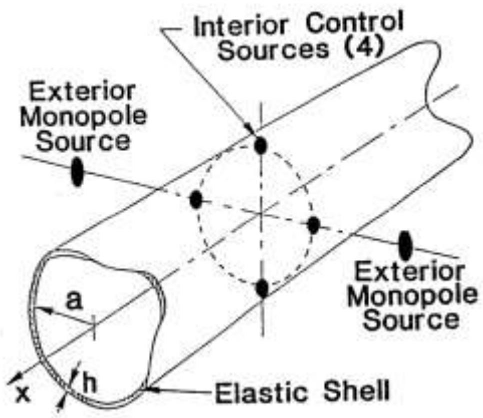

Fig. 1: Schematic of infinite elastic shell and point sources of analytical model.

Materials

Cecile Dutrion, Frank Simon examined the possibility of designing an acoustic cloak using a bi-layer elastic cylindrical shell to eliminate the acoustic field scattered from a rigid cylinder hit by waves. This field depends on the dimensional and mechanical characteristics of the elastic layers. Making of an object invisible to acoustic waves could prove useful for military applications or measurements in confined space. It was computed by a semi-analytical code modelling the vibrations of the coating under plane wave excitation. [9]

Raitis Brencis, Juris Skujans and Uldis Iljins studied the development of foam gypsum sound absorption material production technology, in order to obtain materials with the rules of sound absorption coefficient at the same time fulfilling the strength requirements. An impedance tube and a reverberation chamber was used to carry out the experiment. The study shows the foam gypsum production technology executes the strength requirements and provides a Class B sound absorption material. It had been determined that foam gypsum and mineral wool had analogical behaviour between sound absorption coefficient and the material thickness, although the materials are of different structures. Fig 2 shows the Frequency response curve of 1/3 octave bands foam gypsum with production technology w/g ratio 0.6, SAS 4 ml. [10]

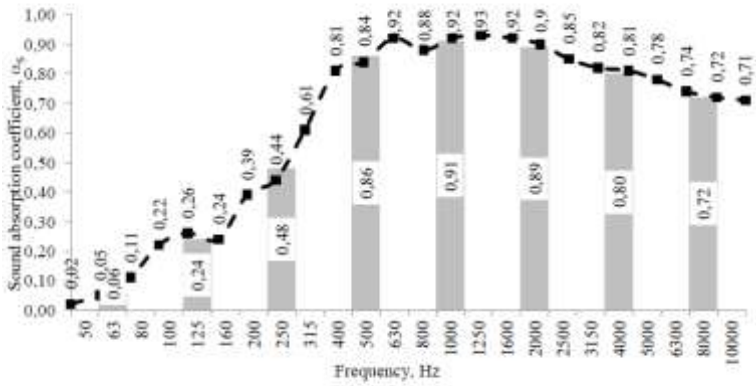

Fig. 2: Frequency response curve of 1/3 octave bands foam gypsum with production technology w/g ratio 0.6, SAS 4 (ml).

Bo Xin et.al had presented the numerical study of acoustic instability in a partly lined flow duct using the full linearized Navier-Stokes equations. The lined ducts were extensively applied to suppress noise emission from aero-engines and other turbo machines. Here, a numerical simulation of the acoustic instability had been performed in a two-dimensional partly lined duct with flow. The model developed is based on the solution of the full linearized Navier-Stokes equations with eddy viscosity considered in the frequency domain using a Galerkin FEM. [11]

Yunju Yan, Pengbo Li and Huagang Lin have developed a hybrid FE-SEA model based on the wave coupling method for the analysis and experimental validation of the middle-frequency vibro-acoustic coupling property for aircraft structural model. The FE-SEA method was used for the numerical analysis of the structural vibration and the cabin noise field responses under the vibro-acoustic coupling model and the corresponding experiment was carried out to verify the simulated results. The study throws light on the reliability of the FE-SEA method and results can be applied to overcome the strict limitations of the traditional method for a large complex structure with uncertainty factors. The fig.3 and fig.4 shows Hybrid FE-SEA model of the aircraft cabin and modal density of the acoustic cavity respectively. [12]

Fig. 3: Hybrid FE-SEA model of the aircraft cabin

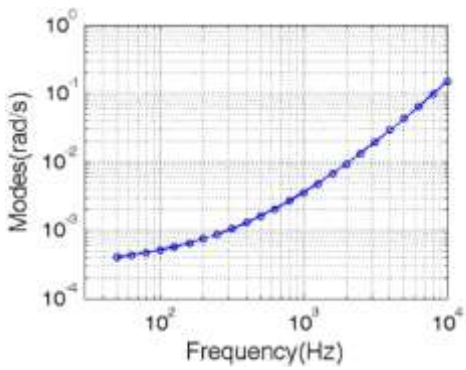

Fig. 4: Modal density of the acoustic cavity

Experiment

Joong Seok Lee et.al proposed a direct hybrid finite-wave based modelling technique for efficient analysis of poroelastic materials used for the noise reduction in acoustic problems. The proposed hybrid technique maximises the advantages and compensates the drawbacks of the FEM and the wave based (WB) numerical methods. According to the geometrical characteristics and boundary conditions the poroelastic domain described by Biot's theory is divided into two groups of poroelastic subdomains. These two groups are classified on the basis of the geometrical variations including corner singularities and the complex geometries. Two types of system equations obtained from the modelling approaches were assembled directly, ensuring the continuity of relevant physical quantities on the interface by applying mathematically exact coupling between differently modelled poroelastic domains. The results obtained shown that the proposed hybrid FE-WB technique was outstanding for the analysis of poroelastic materials containing corner singularities. [13]

Heng Li et.al carried out LES-FEM coupled analysis and experimental research on aerodynamic noise of the vehicle intake system by adopting k-ε model to simulate the steady state fluid dynamic. The large eddy simulation and the finite element method were employed to thoroughly explore the aerodynamic noise in order to achieve a more efficient engineering application for a vehicle intake system in numerical simulations. The aero acoustic characteristics were validated through the experimental data. The simulated and measured results were consistent in general, which proves the accuracy of the LES-FEM coupled approach in aero acoustic simulation. Fig.5 shows flow chart of the aero acoustic research for the intake system. [14]

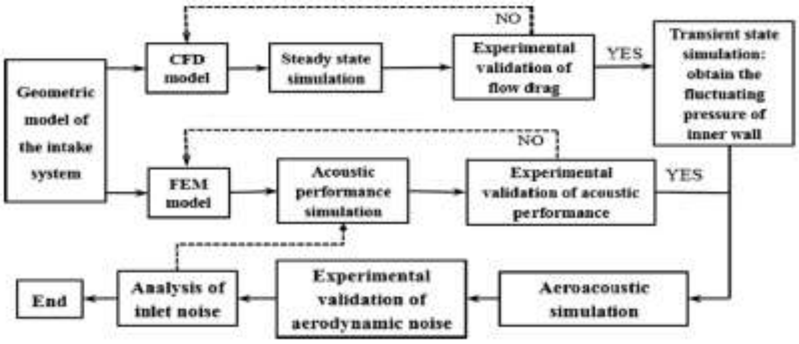

Fig. 5: Flow chart of the aero acoustic research for the intake system

The author Cha-Yi Liao and Chien-Ching Ma presented the vibration characteristics of an elastic thin elastic plate placed at the bottom of a three dimensional rectangular container filled with compressible inviscid fluid in terms of a mathematical derivation. The pressure from the fluid over the fluid-plate interface was integrated to form a virtual mass matrix. It was possible to obtain the dynamic characteristics of the fluid-plate system, such as resonant frequencies, corresponding mode shapes, and velocity of the fluid by solving the frequency equations. The proposed method could be used to predict resonant frequencies and mode shapes with accuracy compared to that of incompressible fluid theory (IFT). The fluid compressibility influences on vibration characteristics in which a decrease in sound velocity was shown, corresponds to a decrease in resonant frequency. [15]

Validation

K. Gao et.al have investigated the acoustic problems in porous materials and discussed the Biot's poroelastic theory through a novel multiscale perspective. The study involved an assumption that a macroscopic point in the porous material can be described by a microscopic Representative Volume Element (RVE) consisting of solid and fluid. A two-scale energy consistency method was used to develop the relations for the micro-to-macro scale transition. The Biot's parameters were obtained directly through the response of the RVE in the regime of Darcy's flow using the homogenization frame work. A porous material with an idealized partially open microstructure described by the Biot's equations was to conduct the numerical experiment in the form of a sound absorption test. The obtained result was evaluated by comparison with the Direct Numerical Simulations (DNS) which shows a comparison of superior performance of this approach to an alternative semi-phenomenological model for estimating Biot's parameters of the studied porous material. [16]

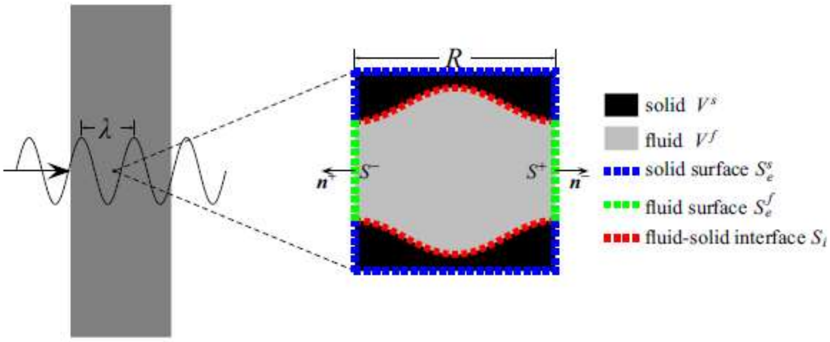

Fig. 6: Illustration of a sound propagation in a porous medium and a sketch of an RVE with size R. The wavelength of the acoustic wave is λ (alpha).

3. CONCLUSIONS

The noise attenuation is an important consideration in fulfilling the noise pollution norms laid down by WHO, OSHA and Euro Standards. It is observed from the literature review that the research work is mainly focussed on the different methods and approaches in the study of behaviour of acoustic materials. Many of the researchers observed that the noise attenuation is related to the development of different combinations of materials and their properties and the investigation of absorption coefficient in different conditions. There exists a scope for the comprehensive research in the development of noise attenuation approaches at macro and micro level materials for engineering applications.

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