11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Vibroacoustic modeling of structures with attached noise control materials using wave-based methods

Noureddine Atalla[1], Luca Alimonti[2]

[1] Université de Sherbrooke, noureddine.atalla@usherbrooke.ca, www.gaus.ca
[2] Université de Sherbrooke, luca.alimonti@usherbrooke.ca, www.gaus.ca

Key Words: *Computational Vibroacoustics, hybrid methods, porous materials, transmission, absorption*

This paper discusses the modeling of the vibration and acoustic responses of structures with attached sound packages, using wave-based methods. It consists of two parts. In the First, the ability of the classical Transfer Matrix (TM) Method[1] to model various types of structures in various mounting conditions (single wall and double wall) together with the calculation of various vibroacoustics indicators (vibration response, radiated power, transmission loss, added damping, air-borne insertion loss, Structure-borne insertion loss...) under various excitations (acoustical, mechanical and Turbulent Boundary Layer) is investigated. Three problems are investigated[2]: (i) the Transmission Loss (TL) of sandwich-composite panels; (ii) TL of a flat panel with added noise control materials under various types of excitations and (iii) TL of light Double Wall (DWL) constructions with mechanical connections. Examples are presented to compare the performance of the presented TN based models to both FE and tests. In particular, their range of applicability and usefulness will be demonstrated.

In the second, the accuracy and rage of validity of a hybrid FE-TM method is discussed. In this class of methods, the subsystems characterized by geometrical complexity and longer wavelengths (i.e. master structures and cavities) are modeled by standard FE schemes and modal synthesis, whereas the subsystems with much shorter wavelengths, such as the acoustic treatment, are modeled by means of the TM. However several assumptions must be introduced. Namely, the soft structure is assumed flat and laterally unbounded. Under these conditions, the Fourier Transform (FT) can be employed and the substructure problem can be solved analytically in terms of Green's functions. In this context, TM method can be employed as a generic and efficient analytical tool. For instance, in the hybrid methodology proposed by Tournour et al.[3], the acoustic treatment is taken into account in a locally reacting sense by the frequency dependent coefficients of its transfer matrix. The approach developed by Shorter and Mueller[4] exploits, instead, a Green's function formulations in terms of self and mutual piston impedances, allowing one to couple the FE model of a structure with an analytical model of the acoustic trim radiating in a semi-infinite fluid medium. The methodology proposed by Courtois and Bertolini[5] uses the Inverse Fourier Transform (IFT) to explicitly find the Green's functions of the acoustic treatment to be employed in the boundary terms of a standard FE approximation. These approaches are referred to as hybrid FE-TM methodologies. On the other hand, Rhazi and Atalla[6] proposed a different hybrid approach based on the use of orthogonal trigonometric functions (i.e. Ritz method). This approach may be referred to as a hybrid modal TM method. Conversely, the approach proposed by Fernandez and Soize[7] tackles the hybrid modeling from a stochastic viewpoint, as the sound package is modeled as a fuzzy system. However, the above described body of work does not provide a comprehensive discussion on the generic properties and performance of hybrid FE-TM methodologies (i.e. domain of validity of the approximation, accuracy and computational efficiency with respect to well-established FE based substructuring procedures). In this talk, a hybrid FE-TM approach based on the Green's functions formalism is presented[8]. The methodology is introduced as a comprehensive framework for this class of hybrid approaches. Namely, simplified models (i.e. modal[6] and locally reacting[3] approaches) can be retrieved from the proposed model. Numerical examples are then provided in order to understand the behavior of the hybrid model and its domain of validity. The results prove that, under certain conditions, the analytical model of the acoustic treatment can give a good approximation of the dynamic response of the substructure as long as a strong resonant behavior is not experienced in the observed frequency range. However, when discontinuous signals are considered (e.g. pressure inside an acoustic cavity), the accuracy in the low frequency range worsens, as spurious short wave components are allowed to propagate in the analytical model (i.e. Gibb's phenomenon). These errors are intrinsic within the TM model the acoustic treatment. Overall, the hybrid approach can predict typical vibroacoustic indicators (e.g. radiated power, quadratic velocity and pressure) reducing the computational burden with respect to well-established FE methodologies. Moreover, it overcomes limitations and difficulties inherent within the use of the locally reacting approximation.

REFERENCES

[1] J.F., Allard and N., Atalla, *Propagation of Sound in Porous Media: Modeling Sound Absorbing Materials*, 2009, 2e, John Wiley & Sons Ltd.

[2] N. Atalla, "Modeling the sound transmission through complex structures with attached noise control materials," Wave Motion, DOI: 10.1016/j.wavemoti.2013.11.001 (2013).

[3] M. Tournour, F. Kosaka and H. Shiazaki, Fast acoustic Trim Modeling using Transfer Matrix Admittance and Finite Element Method. SAE 2007 Noise and Vibration Conference and Exhibitions, St. Charles, IL, USA.

[4] P., Shorter and S., Mueller, Modeling the mid-frequency response of poroelastic materials in vibro-acoustic applications. SAPEM 2008, 2nd international Symposium on Acoustic Poroelastic Materials, Bradford, UK.

[5] Courtois, T. and Bertolini, C. A procedure for efficient trimmed body FE simulations, based on transfer admittance model of the sound package. SAE Int. J. Passeng. Cars – Mech. Syst., 3, 1-13, 2010.

[6] D., Rhazi, and N., Atalla, Acoustic and Vibration Response of a Structure with Added Noise Control Treatment under Various Excitations. J. Acoust. Soc. Am., 135(2), 693-704, 2014.

[7] C. Fernandez, C. Soize and L. Gagliardini, Fuzzy structure theory modeling of sound-insulation layers in complex vibroacoustic uncertain systems: Theory and experimental validation, J. Sound Vib. 125, 138-153, 2009.

[8] L. Alimonti, N. Atalla, A. Berry and F. Sgard, "A hybrid modelling approach for vibroacoustic systems with attached sound packages" POMA-ICA, 19, pp. 065002, 2013.