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

APPLICATION OF THE PEDE$_M$ TO THE EVALUATION OF RADIATED ACOUSTIC POWER

Sergio De Rosa[1], **Francesco Franco**[1] **and Elena Ciappi**[2]

[1] pasta-Lab, Dept. of Industrial Engr., Aerospace Section, University of Naples "Federico II", Via Claudio 21, Napoli, Italy - sergio.derosa@unina.it, francesco.franco@unina.it, www.pastalab.unina.it

[2] CNR-INSEAN, Istituto Nazionale per Studi ed Esperienze di Architettura Navale, Via di Vallerano, Roma, Italy - elena.ciappi@cnr.it, www.insean.cnr.it

Key words: *Vibroacoustics, Pseudo excitation method, Acoustic radiated power.*

The evaluation of the stochastic response of a linear system is a problem which involves several engineering fields. In fact, many dynamic load cases have stochastic behaviour as wall pressure fluctuations due to the turbulent boundary layer (TBL). Nevertheless, the frequency formulation, even when using a discrete coordinate set, can become computationally challenging and this can be only partially mitigated by using a modal representation. A new method named as frequency Modulated Pseudo Equivalent Deterministic Excitation, (PEDE$_M$), is here applied to calculate the response of a linear elastic system excited by TBL. It is based on the Pseudo Excitation Method, (PEM) which can be considered as an exact and efficient representation of the full stochastic response (FSR) of a linear system. The FSR in term of output displacements is the following

$$\mathbf{S_{WW}}(\omega) = \mathbf{\Psi}\ \mathbf{H}(\omega)\ \ \mathbf{\Psi}^T\ \mathbf{S_{FF}}(\omega)\ \ \mathbf{\Psi}\ \mathbf{H}(\omega)^*\ \ \mathbf{\Psi}^T \tag{1}$$

being ω, the circular excitation frequency; $\mathbf{S_{WW}}$, the output cross-spectral density matrix; $\mathbf{H}$, the diagonal matrix of the modal mobilities; $\mathbf{\Psi}$, the eigenvectors matrix of the dynamical system; $\mathbf{S_{FF}}$, the cross-spectral density matrix of the input load. The superscripts T and $*$ denote the transposition and conjugation of the matrix, respectively. The PEM solution is:

$$\mathbf{S_{WW}}(\omega) = \sum_{i=1}^{NG} \mathbf{w}^*(\omega, i)\ \ \mathbf{w}^T(\omega, i) \tag{2}$$

$$\mathbf{w}(\omega, i) = \mathbf{\Psi}\ \mathbf{H}(\omega)\ \ \mathbf{\Psi}^T \mathbf{\Theta}^{<i>} \sqrt{d_i(\omega)} \tag{3}$$

$$\mathbf{S_{FF}}(\omega) = \sum_{i=1}^{NG} d_i(\omega)\ \mathbf{\Theta}^{<i>}\ \mathbf{\Theta}^{<i>T} \tag{4}$$

where $\mathbf{\Theta}$ and d are the eigenfunctions of the load matrix; NG is the number of degrees of freedom. Finally, the PEDE$_M$ solution is:

$$\hat{\mathbf{S}}_{\mathbf{WW}}(\omega) = \sum_{i=1}^{NG} \hat{\mathbf{w}}^*(\omega, i)\ \hat{\mathbf{w}}^T(\omega, i) \tag{5}$$

$$\hat{\mathbf{w}}(\omega, i) = \mathbf{\Psi}\ \mathbf{H}(\omega)\ \mathbf{\Psi}^T \sqrt{\mathbf{S_{FF}}^{<i>}(\omega)} \tag{6}$$

Thus, PEDE$_M$ tries to overcome the analysis of the eigensolutions of the load matrix in order to reduce the computational cost. This can be done for the present application by analysing the limits of the $\mathbf{S_{FF}}$ in the *low* and *high* frequency range. In the present work, PEDEm is applied to evaluate the acoustic radiated power from an elastic surface, Π, for the effect of TBL. Its expression can be written as:

$$\Pi(\omega) = \frac{\omega^4 \rho_a}{4\pi c_a} \mathbf{A}^T \mathbf{\Psi}\ \mathbf{H}(\omega)\ \mathbf{\Psi}^T\ \mathbf{S_{FF}}(\omega)\ \mathbf{\Psi}\ \mathbf{H}(\omega)^*\ \mathbf{\Psi}^T \mathbf{A} \tag{7}$$

where $\mathbf{A}$ is the equivalent nodal area vector; ρ_a and c_a are the fluid density and speed of sound of the fluid, respectively. The results will show that PEDE$_M$ can be very useful to further simplify the solution response.

REFERENCES

[1] I. Elishakoff. *Probabilistic Methods in the Theory of Structures*. Wiley Interscience, New York, 2nd edition, Dover Publications, Mineola, New York, 1999.

[2] S. De Rosa, F. Franco, E. Ciappi. Deterministic equivalent loads for reproducing the stochastic excitation and response. Proceedings of Flinovia Symposium, www.dias.unina.it/flinovia, Springer, to appear in 2014.

[3] J. Lin, Y Zhao and Y. Zhang. Accurate and highly efficient algorithms for structural stationary/non-stationary random response. Comput. Methods Appl. Engr. 2001, 191, 103-111.

[4] J. H. Lin, Y. H. Zhang and Y. Zhao. Pseudo excitation method and some recent developments. Procedia Engineering, 2011, 14, 2453-2458.

[5] G. Zhao, G. Chen and Z. Kang. An iterative algorithm for analysis of coupled structural-acoustic systema subject to random excitations. Acta Mech. Sin, 2012, 28(2), 458-467.