ME – PhD Thesis Colloquium

Coupled vibro-acoustics of an unbaffled plate

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ABSTRACT

Thin plate-like structures are commonly found in many engineering applications such as aircraft, submarine pressure hulls, industrial machine casings, automotive body panels, building partitions, spacecraft solar arrays and barges. Due to their small thickness, they are easily excited in the transverse direction by incident sound waves or mechanical excitations and subsequently act as sources of sound radiation. Understanding the vibro-acoustic behaviour (sound radiation and transmission) of such plates is essential for predicting and controlling the noise and vibration in the applications mentioned above. In this context, most studies have focused on cases where the thin vibrating plate is mounted in an infinite rigid baffle (or wall). However, in practical scenarios plates are not surrounded by such infinite rigid baffles. Thus, in this thesis, we consider a fluid-loaded finite simply supported rectangular unbaffled plate (without an infinite rigid baffle) with the following objectives: a) to derive a closed form expression for its coupled natural frequencies, b) to numerically study sound transmission through the abovementioned plate, c) to numerically study the sound transmission through the same plate when it has perforations.

In the first problem, for deriving a closed form expression for the natural frequencies of the abovementioned plate, the plate is subjected to a harmonic point force excitation and submerged in water. The sound pressure at an arbitrary point in the surrounding water medium is expressed as an integral of the product of the pressure jump and the derivative of the Green's function over the plate surface. An improper double integral known as the modal coupling coefficient arises along the way. This improper double integral is approximated analytically using the contour integration technique. For underwater applications, keeping 10~kHz as the upper limit of the excitation frequency, approximate analytical expressions for the modal coupling coefficient are derived specifically for the corner–corner and the edge–edge type interactions. Next, a small fluid loading parameter is introduced into the coupled equation of motion for the free vibration problem through the residual contribution of the coupling coefficient. Then, the perturbation method is used to obtain the closed form expression for the coupled resonance frequencies. Using this closed form expression, the coupled natural frequencies are computed for a standard size panel and compared with those obtained from the numerical calculations. A good match is observed between the two results.

In the second problem, a plane wave is incident on this unbaffled simply-supported plate at an arbitrary angle. The pressure jump across the unbaffled plate results from the combined effects of pure diffraction and pure radiation. In pure diffraction, the plane wave interacts with the unbaffled plate considered as rigid, while in pure radiation, the pressure jump arises from the flexural vibrations of the plate. The Green's function in the 2D wavenumber domain, along with the Euler equation, leads to linear systems of equations for the pressure jump functions. The improper double integral in the expression for the transmitted pressure is evaluated using the stationary phase method and the transmitted power is then calculated numerically using this pressure field. Subsequently, the sound transmission loss is computed and compared with those of baffled and infinite-sized plates.

Finally, in the third problem, perforations are introduced into the unbaffled simply-supported plate and sound transmission through the same is studied. The pressure difference across the perforated plate is expressed as a linear combination of the admissible functions that vanish along the boundaries of the plate. The receptance method is used to determine the natural frequencies and mode shapes of the plate. The transmitted power is calculated numerically using the mean fluid particle velocity and the pressure difference due to pure radiation. The sound transmission loss is then computed by varying perforation parameters such as hole size, perforation ratio and number of holes. To quantify the reduction in transmission loss due to perforations, a term called the Effect of Perforation is calculated.

ABOUT THE SPEAKER

Hemanta Dikshit is a PhD student in the Department of Mechanical Engineering at the Indian Institute of Science, Bengaluru. He is working under the guidance of Prof. Venkata R. Sonti in the Vibro-Acoustics Laboratory. He completed his Master's degree in Machine Design from the Indian Institute of Technology (Indian School of Mines), Dhanbad, in 2018. His research interests include acoustics, vibration analysis and noise control.