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Editorial

State-of-the-Art on Vibro-Acoustics of Structures

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1. Introduction

Structures when subjected to time varying loads will vibrate and generate acoustic waves. The characteristics of the acoustic waves generated by the structure may depend on the vibration behavior of the structure, which in turn depends on different factors such as the properties of structural materials, types of loads, location of load application, structural configuration, boundary conditions, etc. The development of methods for vibro-acoustic characterization and control has become an important topic of research. In this Special Issue, theoretical methods have been proposed to identify the vibro-acoustic characteristics of different types of structure, appropriate experimental techniques have been developed to measure realistic vibro-acoustic behavior of structures, and techniques utilizing the information of structural vibro-acoustic characteristics have been established to control structures to achieve different objectives.

2. Vibro-Acoustics Characterization

The determination of the true vibro-acoustic characteristics of a structure is essential for the correct prediction of the actual vibration and sound radiation behaviors of the structure. Therefore, because of its importance, the vibro-acoustic characterization of structures has drawn close attention. Fortini et al. [1] determined the vibro-acoustic characteristics of a sandwich plate consisting of phenolic open-cell foam core using both theoretical and experimental methods. The vibro-acoustic characteristics were then used in Nilssion's sandwich beam bending model to calculate the sound transmission loss of the plate. For verification, they made a comparison between sound transmission loss predictions and measurements in sound transmission suites according to ISO 10140-2. The suitability of Nilssion's mathematical model was also investigated via the use of the nominal dimensions of the constituent layers to calculate the sound transmission loss of the sandwich beams. The calculated results have shown that the dimension variations of the constituent layers induced in the manufacturing process may affect the accuracy of the model. Guo et al. [2] studied the effects of vibro-acoustic characteristics on the average sound radiation efficiency of a sandwich plate with periodically local resonant (LR) units. In the vibro-acoustic characterization, they first derived closed form solutions to study the band-gap properties of an infinite periodic structure and the vibrational response of a finite periodic structure. They then used the concept of modal radiation to calculate the acoustic radiation efficiency of the LR sandwich plate. The theoretical results show that the acoustic radiation power can be reduced significantly not only in the band-gap but also at the frequencies in the neighborhood just below the band-gap. For frequencies in the neighborhood just above the band-gap, the acoustic radiation efficiency did not decrease but rather increased. They also studied the effects of damping and effective masses at the LR units on the sound radiation efficiency of the sandwich plate. It has been shown that the addition of small damping to the resonator can reduce the sound radiation at the frequencies above the band-gap and thus further broaden the attenuation frequency band. It has also been shown that an increase in effective mass corresponds to a decrease in radiation efficiency and vice versa. Therefore, it has been demonstrated that the periodic resonators may have the capability of providing a broader attenuation band for the purpose of noise reduction. Lin et al. [3] studied the vibration characteristics of a dual-bimorph piezoelectric pumping element under fluid–structure coupling via both theoretical and experimental approaches. They used amplitude-fluctuation electronic speckle pattern interferometry and a laser Doppler vibrometer to measure, respectively, the visible displacement fringes and point-wise displacements. It has been shown that the experimental resonant frequencies and the corresponding mode shapes are in good agreement with the theoretical results obtained using the finite element method. The experimental results were also used to elucidate the anti-phase as well as the in-phase motions associated with vibration. It has been shown that the gain in flow rate obtained via the anti-phase motion of the dual-bimorph pumping element is larger than those obtained via the in-phase motion and using the single bimorph pumping element. It has been pointed out that the vibration characteristics of the piezoelectric pumping elements with two bimorphs may provide valuable information for the future development of bionic pumps. Du et al. [4] studied the vibro-acoustic characteristics of circular plates embedded with two-dimensional acoustic black holes (ABHs) via both theoretical and experimental approaches. In the theoretical study, series of vibro-acoustic coupling finite element (FE) models for transmission loss (TL) analysis of ABH circular plates were established by the automatically matched layer (AML) method. In the experimental study, an experimental platform for measuring TLs of ABH circular plates and uniform plates was constructed. The accuracy of the FE analysis was verified by experimental measurements. The effects of the parameters such as damping layer thickness and dimensions of ABHs on TLs of ABH circular plates were studied to analyze the influence mechanism of these parameters. It has been shown that the damping layer thickness may have beneficial or adverse effects on the TLs of embedded circular plates, depending on the design of the ABH circular plates. Park [5] studied the vibro-acoustic characteristics of a 17-story structure in South Korea. With the consideration of the presence of walls and floors, a numerical model for the 17-story structure was developed to analyze the vibro-acoustic characteristics of the structure. Field sound pressure measurements were carried out to validate the theoretical predictions. The preliminary results show that proper numerical analyses may have the potential to resolve floor noise problems arising in multi-unit residential structures.

3. Vibro-Acoustic Control

Vibro-acoustic control plays an important role in enhancing the performance of a structure. Once the information about the vibro-acoustic characteristics of a structure is available, an appropriate technique can be established to control the behavior of the structure for achieving a specific objective. Therefore, the development of proper and effective techniques for the vibro-acoustic control of structures has become an important topic of research. Chen et al. [6] proposed a new parallel viscous damping scheme to study the load-bearing design and vibration reduction of a satellite payload adaptor fitting (PAF). The finite element method was used to determine the vibration characteristics of the PAF. Observing the vibration characteristics information, the appropriate number and coefficient of dampers used to design the parallel damping system for the PAF were determined. The topology and sizing optimization techniques were applied to design, respectively, the configuration of the parallel damping system and the lightweight supports for the PAF. The PAF consisting of the parallel damping system was tested for model verification. The test results show that the proposed damping system was effective at suppressing vibration and maintaining stiffness simultaneously. Luong et al. [7] studied the vibration behavior of landing gears consisting of magnetorheological (MR) dampers. A mathematical model of a landing gear equipped with an MR damper was presented to study the vibration characteristics of the landing gear. A new robust controller based on model reference sliding mode control and adaptive hybrid control was established to improve the efficiency of landing impact energy absorbing with the consideration of aircraft weight, sink speed, ambient temperature, and passive damping coefficient. The performances of the present and skyhook controllers were studied in a series of comparative numerical simulations. Compared to the skyhook controller, the present controller can improve the total energy absorbing efficiency by up to 10% and it also has better adaptability and robustness for different landing scenarios and parametric uncertainties. Chen et al. [8] presented a review of the recent advances in using vibration-induced acoustic wave and vibration-induced streaming flow devices for micromanipulation. In the review, they summarized the fundamental theories of manipulation driven by vibration-induced acoustic waves and streaming flow. The recently proposed representative vibro-acoustic-driven micromanipulation methods were also introduced and their advantages and disadvantages summarized. The prospect and development trend of micromanipulation were presented and discussed. Liu et al. [9] presented a comprehensive review of current acoustic methods and recent advances in the localization of buried pipelines. In the review, investigations were conducted from multiple perspectives including the wave propagation mechanism in buried pipe systems, the principles behind each method along with advantages and limitations, representative acoustic locators in commercial markets, the condition of buried pipes, as well as the selection of preferred methods for locating pipelines based on the applicability of existing localization techniques. In addition, the key features of each method were summarized and suggestions for future work were proposed. They pointed out that acoustic methods for locating underground pipelines were proven to be useful and effective supplements to existing localization techniques. Furthermore, the ability of acoustic methods to locate non-metallic objects might be of particular practical value.

4. Needs for Engineering Applications

It has been shown that vibro-acoustics can be a useful tool for the development of different applications. When used properly, vibro-acoustics information can help not only solve engineering problems but also develop practical applications in different industries. It is thus worthy to perform an extensive and in-depth study about the current status of vibro-acoustics being used to solve the practical engineering problems in the industries. For instance, vibro-acoustics has been used to identify material properties of structures, detect damages in structures, and conduct health monitoring and assessment of existing structures. These applications have not been included in this Special Issue but should be considered in other issues in the future.

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