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Energy transmission through a double-wall structure with an acoustic enclosure: Rotational effect of mechanical links

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Abstract

This paper investigates the rotational effect of mechanical links on energy transmission of a double-wall structure with an enclosure. A criterion is proposed to identify energy transmission mechanisms and predict the dominant transmitting path. Studies in different frequency ranges show a more significant energy transmission due to the rotational effect of the link at higher frequencies compared with lower ones. Comparison between the translational effect and the rotational effect on energy transmission shows that although both effects are important for the transmission mechanism analysis, the rotational effect on energy transmission is more remarkable at high frequencies for a soft translational link; whereas is insensitive for a stiff one.

Keywords: Energy transmission; Rotational effect; Double-wall structure; Links

1. Introduction

Energy transmission through double-wall structures has been widely studied during the past decades [1,2]. A clear understanding of the energy transmission

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mechanism between the two panels is essential for vibroacoustic analysis or active noise control of such structures [3–10]. Most previous work focused on structures without any mechanical joints between the two walls, in which energy is entirely transmitted through the air gap, forming the acoustic transmitting path. Recently, studies on energy transmission between the two panels connected with mechanical links or connectors have been presented [11–16]. For example, Lin et al. [11] investigated the transmission of a plane sound wave through two infinite parallel plates connected by identical periodically spaced frames, and also compared the strengths of the two transmission paths (structural path through the studs and the airborne path through the cavity). Bao et al. [12] experimentally examined the effect of the mechanical path on sound transmission through double walls for active acoustic control applications. It was observed that, in some circumstances, a significant portion of energy could be transmitted from these links, referred to as structural transmitting path. In general, a realistic mechanical link conveys energy between the two panels through transverse forces and the moments, which are caused by the translational and rotational effects of the link, respectively. Effects of the translational link on energy transmission have been extensively investigated in [13–16]. In our previous work [13], the respective effects of the air gap and the links on energy transmission and noise insulation properties have been assessed. It was observed that the translational stiffness of the mechanical link and the aerostatic stiffness of the air gap are the two parameters governing the energy transmission process. A criterion was also proposed to analyze different transmission mechanisms and then to predict the dominant transmitting path.

As far as the rotational effect on sound/vibration transmission is concerned, there is a considerable amount of literature dealing with other configurations such as beams or plate-like structures [17–21]. For example, Petersson et al. and Sanderson et al. [17–19] investigated the important role played by the moment excitation in vibration transmission in built-up structure. Koh et al. [20] claimed that both force and moment excitations are critical in the energy transmission through beams or plate-like structures, in which moment excitations were considered through moment mobilities using Rayleigh–Ritz method. Gardonio et al. [21] studied translational and rotational excitations in the energy transmission of a vibrating mass isolated from a finite plate, and showed that at high frequencies, the energy was transmitted through axial and angular vibration simultaneously. Investigations by Goyder and White [22] revealed that, in the high frequency region, the vibrational power input to a beam or a plate due to a moment excitation exceeds that due to a force excitation. All these evidences suggest that the rotational effect is important to be considered in sound/vibration transmission analysis.

Compared with aforementioned configurations, double-plate structures with rotational links, however, received much less attention. One of a very few existing examples is the work of Takahashi [23], in which the sound radiation from periodically connected infinite double-panel structures were investigated. That work concluded that the stiffness of the connectors has important effects upon the radiated power. However, no systematic analysis has been reported so far to investigate the rotational effect of links on energy transmission for a double-wall structure coupled with