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Vibration Transmission within Beam-stiffened Plate Structures Using Dynamic Stiffness Method

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Abstract

The dynamic stiffness method (DSM), which considers both in-plane and out-of-plane vibrations, is employed to investigate the vibration transmission of built-up plate structures. Two numerical examples are designated to demonstrate the capabilities of this method. First, representative transmission modes for a flat plate stiffened a single stiffener are presented, which would help us in composing physical images on wave propagation phenomenon. In addition, power input and power transmission within a two-plate structure are analyzed by following the context of in-plane and out-of-plane vibrations. This work is recommended to address in-depth the understanding of vibration transmission using the dynamic stiffness method, such as wave reflection, refraction, wave type conversion, and etc.

Keywords: Vibration tranmission; plate structures; dynamic stiffness method;

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1. Introduction

Plate structures are extensively found in many engineering applications such as ship hulls, airplane fuselages, and etc. In general, plates are joined together along their junctions with specific angles, within which the longitudinal, shear, and bending waves are travelling. Furthermore, these three types of waves can be converted into each other due to wave reflection and refraction at plate junctions [1,2]. Hence, the analysis of vibration transmission of plate structures is always of great interests to engineers during structure design.

Power flow analysis (PFA) [3-6] was well recognized as a very appealing method in characterization of

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vibration transmission within plate structures. During investigation of the dynamics of ship hulls, Bercin and Langley[1] evaluated the differences between two models, namely, "bending only" and "in-plane inclusive", in which they found that as frequency is increasing, in-plane waves play such a more important role that it provide extra transmission paths, especially over long distances. Nearly at the same time, Cuschieri and McCollum [5] addressed the power flow of an L-shaped thick plate. In their results for the vibrations in low frequencies (up to 1000Hz), power flow associated with in-plane waves is more than three orders of magnitude lower than the total power flow, therefore, most power flow is attributed to out-of-plane waves. They further concluded that for lower kh values (less than approximately 0.16. k is bending wavenumber, and h is plate thickness.), the in-plane waves are negligible.

In this paper, our recently developed dynamic stiffness method [2] is employed to address the characteristics of vibration transmission within built-up plate structures, which accounts for both in-plane and bending vibrations. The present paper is organized as follows. In Section 2, this dynamic stiffness method, together with power flow approach, is briefly summarized. In Section 3, two numerical models are designed to demonstrate vibration transmission within built-up plate structures based our proposed method

2. Brief review of dynamic stiffness method for built-up plate structures

For sake of completeness, our previous work on dynamic stiffness method [2] is briefly summarized below. Shown in Fig.1 (a) is a conventional plate structure which consists of multiple plates. Adjacent plates are simply supported at their two opposite edges and rigidly joined along common edges. β_1 and β_2 are the relative angles between adjacent plates.

An individual plate shown in Fig. 1(b) is taken from the plate structure, which has the dimension of $L_x \times L_y$ and thickness h. The global coordinates OXYZ are independent of any specific local coordinates. Once the local dynamic stiffness matrix is derived, the overall dynamic stiffness matrix of the structure can be obtained by assembling all the local stiffness matrices after coordinate transformation.

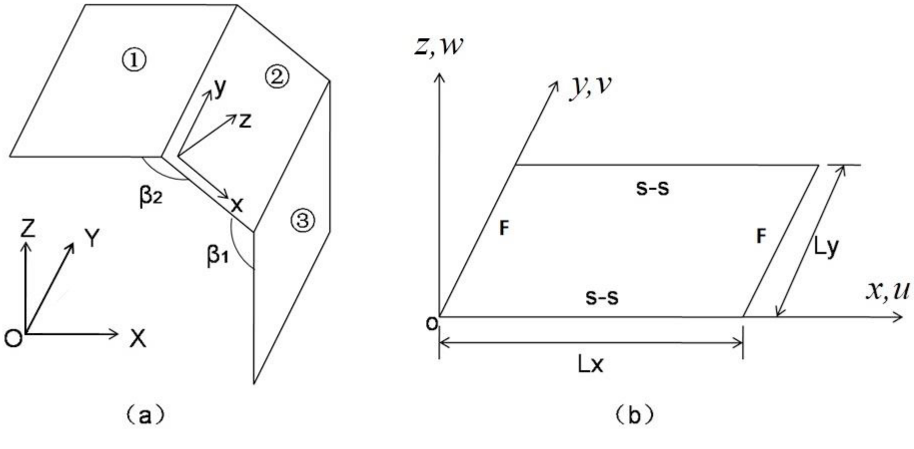

Fig. 1 (a) A built-up plate structure with arbitrarily oriented plates; (b) A rectangular plate with two opposite edges simply supported.

2.1. Development of dynamic stiffness matrix in local coordinates

Based on the classical thin plate theory, the governing equations of the in-plane and bending motions of a plate