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共振周波数の離調を意図した分系の慣性および剛性の最適化による振動低減

Vibration Reduction by Optimization of Mass and Stiffness Properties of a Subsystem for Detuning Resonance Frequencies

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●Introduction

In the automobile industry, a mechanical structure (whole system) consists of multiple parts (separate systems), causing problems may occur due to insufficient information transmission between the car maker and parts manufacturer during the design of noise and vibration performance. Most parts manufacturers face difficulty in considering the vibration characteristics of the entire product while designing the parts. In this paper, for a strongly-coupling subsystems, a method of designing only a single subsystem is proposed. The *kernel* Compliance Analysis (*kCA*) is applied as the foundation of this research to help determining which eigenfrequencies to be shifted. Furthermore, the structural modification suggested by the *kCA* is generally easy to be realized by modifying only the modal stiffness without modifying the mode shape at coupling region. Therefore, this paper introduces a newly developed model updating method which is suitable for *kCA*.

●Relationship between changes in modal properties and changes in self compliance matrix

The modal properties of the subsystem changes due to the structural modification, and the change of the modal properties changes the self-compliance FRF of the subsystem, and as a result, the *kernel* compliance matrix changes. The compliance matrix in the coupling degrees of freedom of the subsystem A to be designed is represented by the modal properties as follows,

$$\mathbf{G}_{cc}^A(\omega) = \sum_r \frac{\boldsymbol{\phi}_r^{Ac}(\boldsymbol{\phi}_r^{Ac})^T}{\bar{k}_r^A - \omega^2 \bar{m}_r^A}, \quad (1)$$

where $\bar{k}_r^A$ and $\bar{m}_r^A$ are the modal stiffness and modal mass of the r^{th} mode of the subsystem A respectively, and $\boldsymbol{\phi}_r^{Ac}$ is the r^{th} modal vector of the subsystem A related to the coupling region c. Desired detuning of a resonance frequency by the structural modification suggested by the *kCA* can be accomplished by only changing $\bar{k}_r^A$, whereas the modal vector $\boldsymbol{\phi}_r^{Ac}$ remains unchanged throughout the modification.

●Structural modification based on Wedderburn's Theorem

The amount of the change of modal stiffness is derived as below. Equation (2) was derived from initial inverse problem (Tao and Jimin, 1999) and was then further improved by using Wedderburn's Theorem, which aims to determine the necessary structural changes that would result in desired dynamic property changes (Wedderburn, 1964). However, physical modification allowed on a structure are usually limited only to a few locations or physical parameters to prevent drastic structural change for preserving the modal vector, $\boldsymbol{\phi}_r^{Ac}$ throughout the modification which is one of the criteria required by *kCA*. Therefore, realistic structural modification is accomplished by local structural modification. In Eq. (2), as there is no clear method to determine the assignment of the weights of change, it is assumed that all the weight is assigned to stiffness modification only. As a result, the modification can be considered a success if the modal vector remained unchanged throughout the modification as indicated in Eq. (1) and the initial eigenfrequency is shifted to desired value. Numerical examples are used to verify the proposed method.

$$\Delta \mathbf{D}^A(\omega_r^*) = \Delta \mathbf{K}^A - (\omega_r^*)^2 \Delta \mathbf{M}^A, \quad \Delta \mathbf{D}^{Am}(\omega_r^*) = - \frac{\mathbf{D}^{Am}(\omega_r^*) \boldsymbol{\phi}_r^{Am*} (\boldsymbol{\phi}_r^{Am*})^T \mathbf{D}^{Am}(\omega_r^*)}{(\boldsymbol{\phi}_r^{Am*})^T \mathbf{D}^{Am}(\omega_r^*) \boldsymbol{\phi}_r^{Am*}}. \quad (2)$$

文 献

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