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Modal structural acoustic sensing with minimum number of optimally placed piezoelectric sensors

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ABSTRACT

Structural acoustic sensing is a method of obtaining radiated sound pressure from a vibrating structure using vibration information. Structural acoustic sensing is used in active structural acoustic control for attenuating the sound radiated from a structure. In this paper, a new approach called Modal Structural Acoustic Sensing (MSAS) is proposed for estimating the pressure radiated from a vibrating cylindrical shell using piezoelectric sensors. The motion equations of a cylindrical shell in conjunction with piezoelectric patches are derived based on the Donnel-Mushtari shell theory. The locations of the piezoelectric sensors are optimized by the Genetic Algorithm based on maximizing the observability gramian matrix. The Kirchhoff-Helmholtz integral is used for estimating the sound pressure radiated from the cylindrical shell. Numerical simulations are performed to demonstrate the advantages of the proposed approach in comparison with previous methods such as discrete structural acoustic sensing and distributed modal sensors. Results show that the MSAS can increase the estimation accuracy and decrease the controller dimensionality and the number of required sensors.

1. Introduction

Active noise reduction methods are divided into three categories. The first one is active noise control (ANC) in which the acoustic noise is measured by microphones and the control action is applied through loud speakers located in appropriate locations in the field. Usually, a local noise reduction is achieved by the ANC.

In many cases, the acoustic noise is produced due to the fluid/structure interaction of a vibrating structure. Thus, the noise can be reduced in the acoustic field by suppressing the structural vibration. This is the base of the second method called active vibration control (AVC). Contrary to the ANC, the AVC focuses on reducing the structural vibration rather than the target noise. Therefore, a global noise reduction can be achieved by the AVC.

The third method is active structural acoustic control (ASAC). In the ASAC, similar to the ANC, the acoustic pressure is fed back to the controller; however, not by using microphones. The acoustic pressure is estimated via structural sensors bonded to the structure, and the control forces are applied by structural actuators. In the active structural acoustic control, the main purpose of using the controller is not to omit all the structural vibration. However, the controller suppresses those portions of the structural vibration which have high radiation efficiencies. Thus, the ASAC can attenuate the radiated sound more than that by the AVC and with less control effort [1].

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