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Technical note: Coherence analysis of the transfer function for dynamic force identification

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ABSTRACT

Identifying dynamic forces with structural response signals is important when direct measurement is difficult or impossible. The minimized condition number method was introduced to reconstruct the forces with selected spatial distribution of response locations. This paper presents another way to optimize the selection of the response locations. The coherence of transfer function matrix is analyzed and the coherence factor of the transfer function matrix is introduced to optimize the response locations. Numerical simulations of the coherence analysis show that it is effective and requires less computational effort than the condition number method. The validity of the analysis is verified by applying it to the identification of the suspension forces on a vehicle cab.

1. Introduction

Dynamic forces are important boundary conditions in engineering applications, such as mechanical system dynamics analysis, structural optimization and control, and vibration and noise reduction. However, in many cases, the dynamic forces, such as the forces at suspension points of a truck cab, are difficult to measure directly. Therefore, many methods to identify the dynamic forces indirectly have been developed.

Force identification is a dynamic inverse problem; it uses the response (such as the acceleration) measured at a series of locations and also the characteristics of the structure. Bartlett and Flannelly [1] first used the measured data at selected response locations and the transfer function to determine the vibratory hub forces on a helicopter. Because the process requires inverting of the transfer function, it is sometimes difficult to accurately reconstruct the dynamic forces due to the ill-conditioned nature of the transfer function matrix. To eliminate the ill-conditioned aspects, many numerical methods were proposed. Liu et al. [2] used the singular value decomposition technique to process the ill-conditioned transfer function matrix, and they used this method to identify the flight loads of an aircraft. Thite and Thompson [3] developed improved singular value rejection methods based on errors in either the transfer functions or operational responses. And the weighted singular values methods were introduced to choose the optimal value of the regularization parameter [4–6]. Choi et al. [7] compared these methods and gave suggestions to select these methods.

To reconstruct the dynamic forces with the smallest possible number of sensors was studied. Several methods based on finite element models were developed to choose the measurement locations, which was mainly used in modal testing. These include the visual inspection method, the Guyan reduction approach, methods of maximum modal kinetic energy and maximum average modal kinetic energy [8–11]. These methods intend to make the mode shapes of interest as linearly independent as possible in the response data.

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