822. Non-iterative mode shape expansion for three-dimensional structures based on coordinate decomposition

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Abstract. The direct mode shape expansion method is an iterative technique, one can conclude that the convergence performance maybe challenged when applied to three-dimensional structures. In addition, mode shape values at different DOFs (degrees-of-freedom) sometimes are not in a same order of magnitude, which will produce much error for the estimation of small values of unmeasured mode components. Therefore this paper proposed a non-iterative mode shape expansion method based on coordinate decomposition technique. The advantage of coordinate decomposition is that the unmeasured components of mode shape values could be estimated with different weighting coefficients, even in a physical meaningful interval. Numerical studies in this paper are conducted for a 30-DOF cantilever beam with multiple damaged elements, as the measured modes are synthesized from finite element models. The numerical results show that the approach can estimate unmeasured mode shape values at translational and rotational DOFs in x, y and z directions with different weighting coefficients, respectively; and better mode shape expansion results can be obtained when proper constraints are employed. A numerical three dimensional structure is also investigated, and results indicate that the estimation of unmeasured components can be improved by imposing reasonable constraints based on the coordinate decomposition technique, even only translational DOFs of two diagonal nodes of the first floor are measured.

Keywords: non-iterative, direct mode shape expansion, three-dimensional structure, coordinate decomposition.

Introduction

For model updating and damage detection of structures [1-2], modal parameters such as frequencies and mode shapes are often required based on a limited number of sensors assembled at the joints of the structure. However, compared with the number of DOFs (degrees-of-freedom) of the corresponding finite element model, the number of sensors is less than the DOFs of the finite element model, which will cause spatial incompleteness of measured mode shapes.

To deal with incompleteness of measured mode shapes, Guyan [3] and Irons [4] firstly reported reduction method, in which the mass and stiffness matrices are partitioned into a set of master and slave DOFs. This method neglects the inertial term thus the higher mode shapes are mainly influenced, it only approximates the eigen analysis of the full system, and the results depend upon the type and number of master DOFs. Many attempts have been made to improve the accuracy of the static condensation by employing model-reduction transformation matrix to expand the measured spatially incomplete modes, such as the work by Kidder [5] and Miller [6], Michael and Ephrahim [7], which require proper selection of master DOFs. The System-Equivalent-Reduction Expansion Process (SEREP) method [8] utilizes the analytical mode shapes to generate a transformation matrix between the measured DOFs and the unmeasured DOFs. The SEREP method may produce poor expansion estimates if the experimental mode shapes are not well correlated with the corresponding analytical mode shapes, which often happens in cases with large modelling errors in the analytical model. In addition, the penalty