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A Generalized Component Modal Analysis for Mega Structures

***Yaoqing Gong[1] and Earl H. Dowell [2]**

[1]School of Civil Engineering,
Henan Polytechnic University,
Jiaozuo, Henan 454000, P.R. China
gongyq@hpu.edu.cn

[2]Department of Mechanical Engineering and
Materials Science, Pratt School of Engineering
Duke University, Durham, NC 27708, USA
dowell@mail.ee.duke.edu

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ABSTRACT

It is often possible to develop analytical formulae for the eigenvalues and eigenmodes for structures with simple geometrical shapes, such as strings, membranes, beams and plates of constant mass and stiffness properties [1]. And when the mass and stiffness properties are variable, an efficient solution can be obtained by expanding the deflection of the structure in terms of the eigenmodes of the corresponding uniform property structure. Using Galerkin's method, Lagrange's equations or Hamilton's Principle one can construct a discrete model from this eigenmode expansion and determine a good approximation to the eigenmodes of the continuous, variable property structure. For structures with complex geometries, however, this approach is not as readily applicable. Thus the finite element, the finite difference or the finite volume methods are often employed as they are more readily account for the complex shapes, e.g. automobiles, aerospacecraft, ships, skyscrapers or long span bridges. In practice, such models may be of very high dimension and determining the eigenvalues may be a challenging task. Therefore, another useful modal approach, which is often called "component modal analysis", is developed, e.g. see Dowell [2]. Also see the excellent text by Craig [3].

The concept of the component modal analysis is briefly outlined as follow. Consider, for example, an airplane that may be represented as a collection of interconnected components, e.g. the fuselage, the wings, the engines, the horizontal and vertical tail. Indeed each of these components may in turn be modeled as a further collection of smaller scaled components, e.g. the thin skin and various reinforcing string structural elements such as stringers and spars. Thus it may be conceptually and computationally attractive to determine first the eigenmodes of the components and then develop a methodology to determine the eigenmodes of the overall interconnected structure. A key aspect of any component modal methodology is

Fig.1 a test model of a super tall building structure built in China to represent each component in terms of its eigenmodes which will be much fewer in number than the number of finite elements used to represent each component. Thus a reduction in order via a component modal representation is at the heart of the methodology. The beauty of the method is its conceptual application in the analysis of the eigenmodes and eigenvalue for the structures of super tall buildings or of very long span bridges.

However, the method is not yet readily applicable to the mega structures of super tall (over 100 meters tall) buildings or very long span bridges. The main task of the current study is to generalize the component modal analysis. This is a continuation of the study in [2]. The generalized modal analysis includes the coupling modes of the collection composed by several components. First, the generalized dominant conceptual component modes are selected, which are unknown single variable functions (eigenfunctions) on the nodal lines. The nodal lines are used to discretize the computational model of the structure, a three dimensional model with distributed mass and stiffness. Then, by using a Hamiltonian principle, the governing equations of the modal analysis are derived, which are ordinary differential equations (ODE) with boundary conditions. Finally, the desired eigenvalues and corresponding eigenfunctions (eigenmode) are obtained by numerically solving the system of governing equations. One of the appealing features is that the developed method can be applied directly to mega structures. This paper is structured as follows. After the methodology is described in sections 2 and 3, the method is applied to an example of tube-in-tube reinforced concrete structure in section 4. The simulation results demonstrate that the method is rational and powerful for the modal analysis of mega structures. Finally, the modeling of a tubular structure is provided in section 5 for readers who are interested in the simplification of a super tall building with tubular structure to a close-thin-walled tube supported on a semi-infinite elastic body.

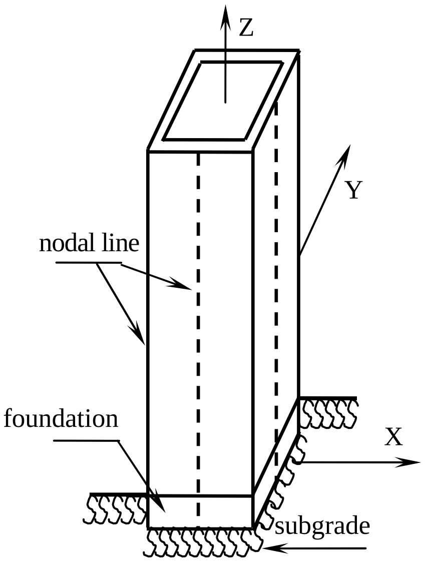

Fig. 2 model of a super tall building with tubular structure

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