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APPLICATION OF GENERALIZED POLYNOMIAL EXPANSION METHOD TO NONLINEAR ROTOR BEARING SYSTEMS

Jon Li Hwang and Ting Nung Shiau
Institute of Aeronautics and Astronautics
National Cheng Kung University
Tainan, Taiwan, Republic of China

EXTENDED ABSTRACT

The Generalized Polynomial Expansion Method (GPEM) is utilized to model a large-order flexible-rotor system with nonlinear supports. With the application of GPEM, a set of nonlinear ordinary differential equations are obtained. A hybrid method which combines the merits of the Harmonic Balance Method (HBM) and the Trigonometric Collocation Method (TCM) is used to solve for the nonlinear response of the system. This hybrid method together with reduction techniques can efficiently solve for the motion of the system. The overall algorithm presented provides a very efficient technique for investigating the periodic response of large-order nonlinear rotor systems. Two examples are used to illustrate the merits of the method. One is the simple Jeffcott rotor which is used to check the accuracy of the present numerical algorithms. The other is a flexible shaft with multiple disks, supported by multiple bearings. It is used to show the advantages of the linkage between GPEM and the presented hybrid numerical algorithm. Some of the support bearings are modeled as a squeeze-film damper associated with a center spring. The center spring is considered to be linear and the squeeze-film damper is nonlinear. The nonlinear hydrodynamic forces are obtained using short-bearing theory.

Based on the example results, the conclusions can be summarized as follows:

(1) For a nonlinear flexible-rotor system, the number of equations needed for the system described by the Generalized Polynomial Expansion Method are always smaller than the number required by the finite element method before applying the condensation technique. This is also true for the linear case which has been discussed by Shiau and Hwang (1989, 1990).

(2) A technique of component mode synthesis has been developed based on the modeling approach of the Generalized Polynomial Expansion Method. It is applied to decouple the nonlinear independent and dependent modal coordinates. With this technique, the number of non-zero elements in the generalized modal-forces vector is equal to the number of nonlinear, dependent modal coordinates. The results indicate that the use of GPEM together with component mode synthesis not only retains its merits in solving a linear rotor-dynamic problem, but also provides attainable solutions for the nonlinear rotor-dynamic problem.

(3) The hybrid numerical algorithm developed in the present study combines both the advantages of the harmonic-balance method and the collocation method. The use of this hybrid method with condensation technique can significantly save computing time. Furthermore, it can be used to predict the periodic response, including the subharmonic response and the super-harmonic response, of a nonlinear system.

(4) The time required for the initial formulation processing with this method may be a little more than that required by the finite-element approach. However, it is very small compared to the overall time savings that are accrued.

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