DYNAMIC ANALYSIS OF FLEXIBLE MULTIBODY STRUCTURES

by

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A system composed of several interconnected elastic components that may experience large angular motion relative to each other during operation is referred to as a flexible multibody structure. Examples of such systems are space lattice structures which are composed of truss-like members connected by hinge joints which allow for the large relative rotation of components of the structure as the structure goes from it's packaged to it's deployed state; the controlled slewing of large flexible antenna-structure systems; and robotic manipulations.

Several formulations havbe been proposed for the determination of the dynamic response of controlled flexible multibody structures. In general, these formulations consist of superposing elastic deformations of the component body (generally specified in terms of assumed deformed shapes, i.e. mode shapes) onto the large rigid body motion of the component. It has been shown that this particular methodology for combining linear structural deformations with nonlinear kinematics can lead to erroneous response predictions when either the beam member is very flexible or the rotational speed is high[1]. In addition, previous formulations introduce constraint equations to define the interrelations among system components. This approach increases the number of equations that must be solved, and may result in constraint violation when numerical error accumulates during the integration process.

In order to overcome the above difficulties, a new approach has been suggested[2]. The approach is essentially a finite element formulation which takes advantage of the fact that many multibody structures are joint dominated. A three dimensional code which implements the new methodology (Large Angle Transient Dynamic Analysis - LATDYN) is currently being developed at NASA Langley.

The purpose of the research this summer is to critically evaluate the LATDYN program for: 1) clarity of documentation, 2) ease of use, 3) "user friendliness", 4) modelling generality, and 5) accuracy of results. This required gaining a working familiarity with the code and performing several case studies, detailed below.

Case Study I modeled a rigid two dimensional slider-crank with a linear spring driving mechanism. Favorable comparison with a rigid body 2-D mechanism code (DADS[3]) was obtained. The system was also intentionally overconstrained to verify that redundant constraints are properly treated by the code.

Case Study II entailed the inverse and forward dynamic analysis of a rigid and flexible space crane currently under investigation at several NASA centers.

Case Study III investigated the in-plane dynamic response of a flexible structure attached to the interior of a rigid ring that is rotating with constant angular velocity. Modelling difficulties were encountered when attempts were made to compare the LATDYN response to the stability results of a simplified SDOF rotating structure[4]. These difficulties were attributed to the simplified nature of the SDOF model. Reasonable LATDYN results were obtained for the continuous structure that was well removed from a stability boundary predicted by linear eigen-theory. An area of future research is the development of stability results, through Lyapunov and other analytical methods, for the general nonlinear dynamics of the continuous rotating structure and subsequent comparison to LATDYN predictions.

[1] P. E. McGowan and J. M. Housner, "Nonlinear Dynamic Analysis of Deploying Flexible Space Booms," *NASA TM 87617*, Sept., 1985.

[2] J. M. Housner, S. C. Wu, and C. W. Chang, "A Finite Element Method for Time Varying Geometry in Multibody Structures," *AIAA Paper No. 88-2234CP*, presented at the 29th Structures, Structural Dynamics, and Materials Conference, Williamsburg, VA, April 18-20, 1988.

[3] DADS Users Manual, Computer Aided Design Software, Inc., P. O. Box 203, Oakdale, IA 52319, 1987.

[4] A. G. Hernried and G. B. Gustafson, "On the Dynamic Response of a Single-Degree-of-Freedom Structure Attached to the Interior of a Rotating Rigid Ring," *J. Applied Mechanics*, 1988.