DEVELOPMENTS OF SOLUTION ALGORITHMS FOR DYNAMIC ANALYSIS OF HETEROGENEOUS JOINTED STRUCTURES

X. Yue and K. C. Park

Department of Aerospace Engineering Sciences and
Center for Aerospace Structures
University of Colorado, Campus Box 429
kcpark@titan.Colorado.EDU

The dynamic behaviors such as system fundamental frequencies, vibration modes and energy dissipation mechanism of jointed structures are determined by joint and interface mechanics. A validated joint modeling capability and a proper model-based simulation procedure are key ingredients of dynamic analysis of these joint-dominated structures. Since joint modeling poses several difficulties such as: exclusivity in model selection; non-scalability of experimental results; difficult isolation of joint properties; ambiguous and uncertain sources of joint nonlinearities; non-repeatable interface behavior and interface stiffness incompatibility. The conventional linear joint model based simulation procedures often fail to capture the dominant physics and result in significant deviations from the response data obtained from experiments.

This paper presents an approach for constructing predictive models of structures with joints which can not be modeled by conventional finite elements. The proposed approach partitions the whole jointed structure into linear substructures and nonlinear joint components. It is assumed that the linear substructures can accurately modeled by finite elements. It is also assumed that joints are the only sources of system nonlinearities. We have previously proposed a class of nonlinear discrete joint elements designed to model representative types of joints. The joint model is further validated by correlating with the classical quasi-static solution of the Mindlin problem. The paper develops a nonlinear partitioned simulation algorithm tailored to simulate structures with nonlinear joints or interfaces. The algorithm utilizes a scaled localized version of the method of Lagrange multipliers that improves the conditioning of the ill-conditioned system stiffness matrices emanating from heterogeneous interface flexibilities. The numerical accuracy of the algorithm when used with different scaling methods is studied. The partitioned system equations of motion are solved for the dynamics of each substructure coupled with the proposed interface joint model using the mid-point integration rule and modified Newton's iteration method. Numerical experiments illustrate that the solution algorithm yields accurate and stable solutions.

The paper also presents an inverse procedure to identify the nonlinear joint model. The procedure is based on the relation between the isolated analytical joint FRFs and the global experimental ones. The partitioning of the global structures by the method of localized Lagrange multipliers and localized system identification techniques are used to identify the equivalent linear joint model. Then, the nonlinear joint parameters are indirectly determined by correlating with the equivalent linearized joint matrices and the experimental data. The application of the procedure to a bolted beam structure shows that the identified joint model traces the predominant joint FRFs and the error of the reconstructed system response is within the specified tolerance.

References

[1] X.Yue, K.C.Park, "Modeling of Joints and Interfaces", *Modeling and simulation-Based Life Cycle Engineering*, pp60-pp75, published 2002 by Spon Press, New York. ISBN-0-415-26644-0

[2] L.A.Bergman, C.J.Hartwigsen, "Damping in Bolted Joints", Internal Experiment Research Report, Aeronautical and Astronautical Engineering Department, University of Illinois at Urbana-Champaign.