dure was used to calculate the adhesive strength of bonded double-lap joints. The results of these calculations show the effects of loading condition, bond size, and adhesive material behavior on bonded joint strength.

Acknowledgments

This work was conducted as part of Northrop Corporation's independent research and development activity on strength and life assurance of composite structures. The author is grateful to Ravi B. Deo and Dinesh S. Joshi for helpful suggestions.

References

[1]Hart-Smith, L. J., "Adhesive-Bonded Double-Lap Joints," NASA CR-112235, Jan. 1973.

[2]Hart-Smith, L. J., "Adhesive-Bonded Single-Lap Joints," NASA CR-112236, Jan. 1973.

[3]Hart-Smith, L. J., "Designing to Minimize Peel Stresses in Adhesive-Bonded Joints," Douglas Aircraft Company, Long Beach, CA, Paper 7389, Nov. 1983.

[4]Rice, J. R., "Mechanics of Crack Tip Deformation and Extension by Fatigue," *Fatigue Crack Propagation*, American Society for Testing and Materials, ASTM STP 415, 1967, pp. 247-311.

Readers' Forum

Brief discussion of previous investigations in the aerospace sciences and technical comments on papers published in the AIAA Journal *are presented in this special department. Entries must be restricted to a maximum of 1000 words, or the equivalent of one* Journal *page including formulas and figures. A discussion will be published as quickly as possible after receipt of the manuscript. Neither the AIAA nor its editors are responsible for the opinions expressed by the correspondents. Authors will be invited to reply promptly.*

Comment on "Direct Component Modal Synthesis Technique for System Dynamic Analysis"

Earl H. Dowell*
Duke University, Durham, North Carolina 27706

THE authors of Ref. 1 have presented an excellent method which has a number of advantages over conventional component modal synthesis techniques. By eliminating the usual displacement coordinates in favor of the joint or generalized, forces between substructures, the size of the governing matrix equations is substantially reduced. Indeed, the order of the matrix is equal to the number of compatibility, or constraint, connection, and joint, conditions between substructures. The authors' examples and conclusions further support the advantages of the method.

The present writer is particularly pleased to see the publication of this paper as he developed essentially the same method some years ago, and described it in a series of publications. In the present writer's approach, the Lagrange Multiplier method is used to incorporate the constraint or compatibility conditions between substructures and the forces of constraint or compability are simply the Lagrange Multipliers themselves.[2-9] This method has also been used to incorporate the effects of nonconservative forces including damping,[5] as well as nonlinearities.[6-8]

It has also been shown how the method may be used to add or subtract a substructure without a total reanalysis of the system.[9]

Now that the method has been rediscovered, it will hopefully be more widely used.

References

[1]Lee, E. K. L., and Tsuei, Y. G., "Direct Component Modal Synthesis Technique for System Dynamic Analysis," *AIAA Journal*, Vol. 27, No. 8, 1989, pp. 1083-1088.

[2]Dowell, E. H., "Free Vibrations of a Linear Structure with Arbitrary Support Conditions," *Journal of Applied Mechanics,* Vol. 38, No. 3, 1971, pp. 595-600.

[3]Dowell, E. H. "Free Vibrations of an Arbitrary Structure in Terms of Component Modes," *Journal of Applied Mechanics,* Vol. 39, No.3, 1972, pp. 727-732.

[4]Dowell, E. H., "On Some General Properties of Combined Dynamics Systems," *Journal of Applied Mechanics,* Vol. 46, No. 1, 1979, pp. 206-209.

[5]Dowell, E. H., "Bounds on Modal Damping by a Component Modes Method Using Lagrange Multipliers," *Journal of Applied Mechanics,* Vol. 47, No. 1, 1980, pp. 211-213.

[6]Dowell, E. H., "Component Mode Analysis of Nonlinear and Nonconservative Systems," *Journal of Applied Mechanics*, Vol. 47, No. 1, 1980, pp. 172-176.

[7]Dowell, E. H., "Component Mode Analysis of a Simple Nonlinear, Nonconservative System," *Journal of Sound Vibration*, Vol. 80, No. 2, 1982, pp. 233-346.

[8]Dowell, E. H., and Tongue, B., "Component Mode Analysis of Nonlinear Nonconservative Systems," *Journal of Applied Mechanics*, Vol. 50, No. 1, 1983, pp. 204-209.

[9]Dowell, E. H., "Theory and Application of Dynamic Decoupling in Structural Analysis: Another View," *Finite Elements in Analysis and Design*, Vol. 3, No. 2, 1987, pp. 119-125.

Reply by the Author to Earl H. Dowell

Eric K. L. Yee* and Y. G. Tsuei†
University of Cincinnati, Cincinnati, Ohio 45221

We appreciate the comments from Prof. E. H. Dowell. Dowell presented a method, as discussed in his references, which is a variation of a Rayleigh Ritz approach to determine the system eigen frequency. The Lagrange multiplier lambda vector in his method corresponds to the modal force vector in the modal force method. Contrary to Dowell's variational approach, we formulate the solution equation by physical coordinates. Futhermore, after the modal force vector has been obtained, the modal force method provides the mode shape of the entire system in physical coordinates directly without any inversion of matrix.

Received Aug. 16, 1989; revision received Jan. 8, 1990.

*Dean, School of Engineering. Fellow AIAA.

Received Aug. 16, 1989; revision received Jan. 8, 1990.

*Doctor, Former Graduate Student, Department of Mechanical and Industrial Engineering.

†Professor, Department of Mechanical and Industrial Engineering, Member AIAA.