

AD-A123 182 NONLINEAR TRANSIENT ANALYSIS OF LAYERED COMPOSITE
PLATES(U) VIRGINIA POLYTECHNIC INST AND STATE UNIV
BLACKSBURG DEPT OF E. J N REDDY JUL 82
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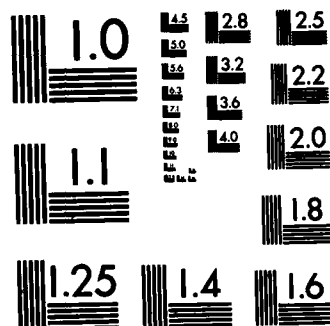
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ANNUAL REPORT
ON
NONLINEAR TRANSIENT ANALYSIS OF LAYERED COMPOSITE PLATES
(Grant AFOSR-81-0142)

Submitted to
STRUCTURAL MECHANICS SECTION
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Bolling Air Force Base, Washington, D.C. 20332

by
J. N. Reddy
Department of Engineering Science and Mechanics
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

July 1982

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1. (a) Title of Research

Nonlinear Transient Analysis of Layered Composite Plates

(b) Principal Investigator

Professor J. N. Reddy

2. (a) Key Words

Analysis, classical

Materials, composite

Analysis, finite-element

Materials, fiber-reinforced

Analysis, nonlinear (geometric)

Structures, laminated

Analysis, transient

Structures, plate

Analysis, vibration (free oscillations)

(b) Technical Objective (Phase I: First-Year)

1. To develop a finite-element analysis for nonlinear transient response of laminated, anisotropic composite plate structures constructed of fiber-reinforced, filamentary composite materials.
2. To assess the accuracy of the analysis by comparison of numerical results for problems that are amenable to exact-form of solutions, and provide bench mark results for future investigators.

3. Approach Utilized in Research Completed (Phase I)

The approach used in Phase I (plates) research is two-fold:

- 1) the development of nonlinear (in the von Karman sense) transient analysis capability by the finite element method for layered composite plates
- 2) Classical (spatial) solutions for special cases of plate geometry, loading, boundary conditions, and lamination scheme.

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MATTHEW J. KEMER
Chief, Technical Information Division

4. Summary of Progress Made in Phase I Research

Forced motions of laminated composite plates are investigated using a finite element that accounts for the transverse shear strains, rotary inertia, and large rotations (in the von Karman sense). The present results when specialized for isotropic plates are found to be in good agreement with those available in the literature. For two different lamination schemes, under appropriate boundary conditions and sinusoidal distribution of the transverse load, the exact form of the spatial variation of the solution is obtained, and the problem is reduced to the solution of a system of ordinary differential equations in time, which are integrated numerically using Newmark's direct integration method. Numerical results for deflections and stresses are presented showing the effect of plate side-to-thickness ratio, aspect ratio, material orthotropy, and lamination scheme. Although the results obtained are for certain geometries, loadings, lamination scheme, and material properties, it should be pointed out that the element developed herein can be employed to laminated plates of arbitrary geometry, lamination scheme, material properties, boundary conditions, and loading (only limitations are those assumed in the laminated plate theory). The present analysis does not account for material damping effects.

5. Technological Significance and Relevance to the Air Force.

The results obtained in this research should be of interest to composite-structure (and aircraft) designers, and to experimentalists and numerical analysts in verifying their results. Research in the following categories, among others, of systems of

— engineering interest is expected to benefit from the results of this research. ←

- (1) Cord-reinforced rubber skirts for air-cushion vehicles
- (2) Cord-reinforced rubber tires and belts
- (3) Filament-wound shell structures, such as rocket-motor casings, deep-diving submersibles, piping, and other pressure vessels
- (4) Wire-reinforced solid-propellant rocket grains
- (5) Ablative materials, such as quartz-phenolic and carbon-carbon
- (6) Aircraft structural components such as wing panels
- (7) Concrete and masonry structures undergoing bending

6. Bibliography

This bibliography is limited to technical reports, journal articles and conference papers published, and journal articles and conference papers accepted since the initiation of the Grant in April 1981.

(a) Technical Reports Issued

1. Reddy, J. N., "Analysis of Layered Composite Plates Accounting for Large Deflection and Transverse Shear Strains," Technical Report No. 1 (VPI-E-81.12), May 1981.
2. Reddy, J. N., "On the Solutions to Forced Motions of Layered Composite Plates," Technical Report No. 2 (VPI-E-81.24), September, 1981.
3. Reddy, J. N., "Geometrically Nonlinear Transient Analysis of Laminated Composite Plates," Technical Report No. 3 (VPI-E-82.8), March 1982.



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(b) Journal Articles and Conference Papers Published

1. Reddy, J. N. and Chao, W. C., "Nonlinear Oscillations of Laminated, Anisotropic, Rectangular Plates," Journal of Applied Mechanics, Vol. 49, pp. 396-402, 1982 (based on Technical Report No. 1).
2. Reddy, J. N., "Analysis of Layered Composite Plates Accounting for Large Deflections and Transverse Shear Strains," in Recent Advances in Nonlinear Computational Mechanics, edited by E. Hinton, D. R. J. Owen, and C. Taylor, Pineridge Press, Swansea, pp. 155-202, 1982 (based on Technical Report No. 1).
3. Reddy, J. N., "On the Solutions to Forced Motions of Rectangular Composite Plates," Journal of Applied Mechanics, Vol. 49, pp. 403-408, 1982 (based on Technical Report No. 2).
4. Reddy, J. N., "Nonlinear Vibration of Layered Composite Plates Including Transverse Shear and Rotatory Inertia," ASME 18th Vibration Conference, ASME Paper No. 81-DET-144, Hartford, Connecticut, 1981 (based on Technical Report No. 1).
5. Reddy, J. N. and Chao, W. C., "Nonlinear Oscillations of Laminated, Anisotropic, Thick Rectangular Plates," Symposium on Structures and Materials III: Impact and Vibration of Composites and Structures, 1981 ASME Winter Annual Meeting, November 15-20, 1981, Washington, D.C. (based on Technical Report No. 1).
6. Reddy, J. N. and Mook, D. J., "Dynamic (Transient) Analysis of Layered Anisotropic Composite Plates," in Computational Methods and Experimental Measurements, edited by G. A. Keramidas and C. A. Brebbia, Springer-Verlag, New York, pp. 737-748, 1982 (based on Technical Report No. 2).

(c) Journal Articles and Conference Papers Accepted:

1. Reddy, J. N., "Nonlinear Transient Response of Layered Composite Plates," International Conference on Finite Element Methods, August 2-6, 1982, Shanghai, China (based on Technical Report No. 2).
2. Reddy, J. N., "Dynamic (Transient) Analysis of Layered Anisotropic Composite-Material Plates," Int. J. Numer. Meth. Engng., to appear (based on Technical Report No. 2).
3. Reddy, J. N., "Geometrically Nonlinear Transient Analysis of Laminated Composite Plates," AIAA Journal, to appear (based on Technical Report No. 3).

7. Project Personnel

J. N. Reddy, Principal Investigator
 J. D. Mook, Graduate Research Assistant (M.S.)
 N. S. Putcha, Graduate Research Assistant (Ph.D.)
 Richard Tam, Graduate Research Assistant (Ph.D.)

8. Honors and Awards

Professor J. N. Reddy:

- * Organized two sessions on recent developments in finite elements at Eleventh Southeastern Conference on Theoretical and Applied Mechanics (SECTAM XI), University of Alabama in Huntsville, Apr. 8-9, 1982.
- * Invited to present a paper at a session on nonlinear structural dynamics at the Eleventh Southeastern Conference on Theoretical and Applied Mechanics (SECTAM XI), Huntsville, Alabama, Apr. 8-9, 1982.
- * Invited to present a paper at a session on finite elements in fluid flow at the Eleventh Southeastern Conference on Theoretical and Applied Mechanics (SECTAM XI), Huntsville, Alabama, Apr. 8-9, 1982.
- * Invited to present a paper at a session on computational strategies for inelastic and nonlinear problems at the ASCE National Convention, New Orleans, LA, Oct. 25-29, 1982.
- * Co-authored a book, Advanced Engineering Analysis (with M. L. Rasmussen), published by John Wiley & Sons, New York, 1982.
- * Organized a session at the 19th Annual Meeting of the Society of Engineering Science, University of Missouri-Rolla, Oct. 27-29, 1982.
- * Invited as a General Lecturer to a Seminar on Mechanics of Materials and Structures, University of Rome, May 4-7, 1982.
- * Invited to present a paper on three-dimensional flows at 10th IMACS World Congress on Systems Simulation and Scientific Computation, August 8-18, 1982, Montreal, Canada.
- * Invited to present lectures on the Numerical Simulation of Three-Dimensional Flows at the Joint Institute for Acoustics, Stanford University, February, 1982.

- * Invited to present two papers at the 19th Annual Meeting of the Society of Engineering Science, University of Missouri-Rolla, Oct. 27-29, 1982.
- * Invited to present a lecture at ARO Workshop on Computational Aspects of Penetration Mechanics, Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, April 27-29, 1982.
- * Invited to present a 90-minute lecture as part of a University/Industry program at Carnegie-Mellon University, Pittsburg, November 23, 1982.

J. D. Mook:

- * Awarded M. S. Degree in Summer 1982.

