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High-Impact Dynamic-Response Analysis of Nonlinear Structures

The problem:

To predict the expected deformations and stresses in nonlinear structures like electronic equipment and systems of a hard-landing spacecraft as the result of the large hard-landing impact.

The solution:

A program which determines the dynamic response of nonlinear structures of simple geometry subjected to high-impact loading.

How it's done:

In the formal analysis of equivalent linear problems, eigenvalues and associated modes are determined, using the numerous efficient numerical procedures available. For nonlinear structures, however, it is necessary to adopt an alternative recurrence formulation which involves step-by-step incremental procedures and allows for structural and damping nonlinearities.

Previously, an incremental procedure was adopted for nonlinear structural problem solutions in which the accelerations were assumed to vary linearly during each limited time increment. The dynamic equations were thus transformed into a convenient pseudostatic form, the solution of which yielded the incremental results. However, this procedure involved the repeated solution of a set of equations whose order was equal to the number of degrees of freedom of the structure, and it required large computer storage and problem solution time.

The new analysis technique is based on a node-wise predictor-corrector approach and requires only moderate computer storage and run time for most problems.

Structural nonlinearities may, in general, be classified into two distinct groups: physical, and geomet-

rical. Physical nonlinearities include those related to the material properties, such as nonlinear elastic stress-strain relations and elastoplastic behavior. Geometrical nonlinearities include large deformations which cause gross changes in the geometrical configuration of the structure, and are subdivided into three classes: (1) large rotation, small strain (pre-stress effect), (2) small rotation, large strain, and (3) combinations of (1) and (2).

The computer program developed deals only with the geometrical nonlinearities, but may be conveniently extended to include physical nonlinearities. Structural idealizations are based on the finite element method employing curved quadrilateral shell elements. The stiffness matrix of the entire structure is assembled by means of the matrix displacement method employing the direct stiffness approach.

The masses are assumed to be lumped at the nodes, each having six degrees of freedom; i.e., three translations and three rotations defined in a right-hand orthogonal coordinate system. A general step-by-step incremental time procedure was adopted for the analysis, and the structure was assumed to behave linearly within each small time increment. The Runge-Kutta method was employed for numerical extrapolation of nodal accelerations and deformations at the end of each small time increment.

Related dynamic equations are formed nodewise for each incremental time step, and the relevant solutions are added to their respective existing values at the beginning of each step to yield the corresponding updated values.

The program computes the propagation of nodal deformations and velocities as well as element stresses and support reactions throughout the impact contact time period.

(continued overleaf)

Notes:

1. Using these techniques, considerably less computer solution time and storage is required in comparison to other known methods of solution.
2. This program is written in FORTRAN V for use on the UNIVAC-1108 computer.
3. Inquiries concerning this innovation may be directed to:

COSMIC

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Patent status:

No patent action is contemplated by NASA.

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