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NASA TECH BRIEF

Study of Dynamic Response of Elastic Space Stations

The problem:

To develop an analytical procedure and the requisite computer programs to compute the dynamic responses of two large elastic space stations; the Y configuration and the HEXagonal configuration. The programs are primarily intended for studying the response characteristics of spinning flexible space stations following the docking of another vehicle at the hub. They may also be used to obtain the unforced response to any set of small initial displacements and velocities. The cost of experimentation with space vehicles and space stations, as well as safety requirements, make it necessary to have as complete an analysis as possible of dynamic responses.

The solution:

Develop the linearized equations of motion through application of Lagrange's equations and employ the normal modes of free vibration of the nonrotating space station to define the elastic degrees of freedom. Time histories of the 6 rigid-body coordinates and the modal coordinates (12 maximum) are computed by using a Runge–Kutta integration technique.

How it's done:

Perturbations of motion of structural elements of the space station are considered to be small enough to be amenable to linearized analysis. Motion, then, consists of (1) linear combinations of free translation and rotation of the principal axes of the station and (2) elastic deformations. The configurations represented have two planes of geometric, structural, and inertial symmetry. These are the spin plane and one normal to it.

For each of the configurations, it is intended that normalized in-plane and normal-to-plane mode shapes be computed by using the other two independent modal programs prior to running the response program. The completely automated vibration mode programs compute symmetric and antisymmetric mode data at each circular frequency within a specified frequency range, and produce punched cards containing these data. All elastic and inertial properties of the lumped parameter model may be varied at the discretion of the user—only the shape of the configuration is predetermined. The maximum number of lumped parameter station points allowable in the program is large to permit lumping of very small intervals if desired by the user. The dynamic response of either elastic space station is obtained by the response program, which is designed to accommodate the punched output from the modal programs. Up to 6 in-plane and 6 normal-to-plane mode shapes (12 maximum) may be used.

Inertial coupling due to the mean spin rate (the gyroscopic and centrifugal forces), and the coupling terms of the gyroscopic wobble damper, located at the central hub, are represented. These coupling terms include force and torque increments due to deformation, and the work done in the elastic degrees of freedom as the forces and torques are applied through displacements.

Disturbances created by the docking vehicle are simulated by initial velocity increments that conserve linear and angular momentum through a perfectly inelastic impact of the vehicle and the central hub. This simulates instantaneous latching on contact.

Accelerations, velocities, and displacements in the six perturbed rigid-body coordinates, and the generalized modal coordinates are stored on tape during

(continued overleaf)

the integration cycle. These responses are computed by means of a fourth-order Runge–Kutta integration routine that will automatically vary the interval of intergration, if desired, or will operate with a fixed interval.

Notes:

1. The programs were written for the IBM 7094.
2. The programming language used is Fortran IV, version 9.
3. The computer programs have been written with sufficient generality to permit an arbitrary choice of dimensional, structural, and inertial properties for configurations that are symmetric to the spin plane and have one other plane of symmetry.
4. The large amount of response data generated is most conveniently displayed in graphical form. An optical plotter, such as the S-C4020, can be easily utilized to produce graphs from the response data stored on tape.
5. Inquiries concerning this innovation may be directed to:

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Patent status:

No patent action is contemplated by NASA.

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