# NASA TECH BRIEF

## *Langley Research Center*

## Computer Program for Stress, Stability, and Vibration of Complex Branched Shells of Revolution: BOSOR 4

### The problem:

A better method was needed to help engineers design branched shells of revolution.

### The solution:

The BOSOR 4 computer program was developed in response to the need for a tool which would help engineers to design practical shell structures. An important class of such shell structures includes segmented, ring-stiffened, branched shells of revolution. These shells may have various meridional geometries, wall constructions, boundary conditions, ring reinforcements, and types of loading including thermal loading. Support points, junctures, and ring reinforcements should be accurately modeled. Seemingly insignificant parameters sometimes have a large effect on stress, buckling loads, and vibration frequencies.

### How it's done:

The BOSOR 4 program is very general with respect to the type of analysis which it will perform. Depending on the value of a control integer, the program will: (a) calculate axisymmetric stresses and displacements from a nonlinear theory for a series of stepwise-increasing thermal or mechanical loads; (b) determine critical loads corresponding to nonsymmetric buckling modes for a range of circumferential wave numbers, seeking the minimum load; (c) calculate vibration frequencies of prestressed shells corresponding to axisymmetric and nonsymmetric modes; and (d) calculate displacements and stresses in and buckling loads of nonsymmetrically loaded shells.

The assumptions upon which the BOSOR 4 code is based are:

a. The material is elastic.

b. The thin shell theory is valid; that is, normals to the undeformed surface remain normal and undeformed.

c. The structure is axisymmetric; and in vibration analysis and nonlinear stress analysis, the loads and prebuckling or prestress deformations are axisymmetric.

d. The prebuckling deflections, while considered finite, are moderate. That is, the square of the meridional rotation can be neglected compared to unity.

e. In the calculation of displacements and stresses in nonsymmetrically loaded shells, linear theory is used. This branch of the program is based on standard small-deflection analysis.

f. A typical cross-section dimension of a ring stiffener is small compared to the radius of the ring.

g. The cross sections of the rings remain undeformed during the deformations of the structure, and the rotation about the ring centroid is equal to the rotation of the shell meridian at the attachment point of the ring (except, of course, if the ring is treated as a shell branch).

h. The ring centroids coincide with the ring shear centers.

i. If meridional stiffeners are present, they are numerous enough to include in the analysis by an averaging or smearing of their properties over any parallel circle of the shell structure.

One of the more important extensions of the analysis is the capability of treating branched shells. This extension permits, for example: (a) the analysis of pressure hulls with bulkheads; (b) the treatment of ring-stiffened shells as shells with branches, thus accounting for the deformation of ring cross sections; and (c) the investigation of double-hulled vessels. Two additional important extensions of the analysis include variable mesh-point spacing within each shell segment and a reformulation of the buckling eigenvalue problem to account for the prebuckling shape change of the shell in linear buckling analyses.

**(continued overleaf)**

The BOSOR 4 code is easy to use yet is very general with respect to: (a) the type of analysis to be performed; (b) the geometry of the shell meridian; (c) the type of wall construction; (d) the type of boundary conditions, ring supports, and branching configuration; and (e) the type of loading.

**Notes:**
1. This program was written in FORTRAN IV for the CDC 6000-series computers.
2. Inquiries concerning this program should be directed to:

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