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Vertical Load Analysis of Cylindrical ACS Support Structures*

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A new concept in LMFBR design ACS (above-core structures) supports which has generated some interest is to use a single large radius cylinder, as shown in Fig. 1 where it is identified as the upper internal structure. The advantages of a single cylinder are reduced cost of fabrication, increased lateral stiffness, which enhances seismic resistance, and easier access to the fuel. However, the performance of these support structures when submitted to vertical loads from the core area may be substantially different, for the buckling and postbuckling behavior of a cylinder differs substantially from that of cylindrical beams.

In this paper, a comparative analysis of an old prototypical support by 4 columns (henceforth called design A) is compared with a cylindrical support (henceforth called design B). It is assumed that the single cylinder replaces the 4 columns in the original design. The dimensions of the two designs are compared in Table 1. The thinnest cylinder considered here has a cross-sectional area equivalent to that of design A.

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The support structures are loaded vertically by a load which is piecewise linear with the following pressures: 34.47 MPa (0.02 ms); 0.0 MPa (0.15 ms); 24.13 MPa (0.22 ms); 13.79 MPa (0.25 ms); 5.52 MPa (0.90 ms); 0.0 MPa (1.80 ms); 0.0 MPa (thereafter). Design B in addition was subjected to an external pressure load as follows: 9.65 MPa (0.3 ms); 2.41 MPa (0.6 ms); 5.17 MPa (0.9 ms); 0.0 MPa (1.0 ms); 2.07 MPa (1.3 ms); 0.0 MPa (1.6 ms): 0.0 MPa (thereafter). This load was omitted from design A because the far greater thickness/radius ratio of the columns makes this load ineffective. The load was taken from SRI[1] scale model tests and simulates a 992 MW-s energy release.

The analysis was performed with the computer program SAFE/RAS[2], which is a finite element program with explicit time integration which treats both material and geometric nonlinearities. The plastic yield strength of the material is 240 MPa, and its ultimate stress is 620 MPa. The element chosen for this analysis is a 4 node quadrilateral with one quadrature point per element[3]; a hourglass procedure is used to control spurious modes. This element is very efficient: 640 elements require 1.2 CPU seconds per time step on an IBM 3033.

Results are given in Table 1 and Fig. 2. It can be seen that while design A buckles laterally with change in cross-section, design B exhibits a symmetric nodal buckling into almost a diamond shaped pattern (see Fig. 2b). It is seen that the cylinder with an equivalent cross-sectional area (1.651 cm thickness) as that of the 4 columns cannot withstand the pressure; it is shown in Fig. 2b early in the simulation and subsequently it fails dramatically. Increasing the wall thickness of the cylinder somewhat allows the cylinder to maintain its integrity as given in Table 1. The cylinder with a wall thickness of 2.4765 cm has an axial displacement similar to that of the 4 column support. The cylinders with different wall thicknesses deform similarly to that shown in Fig. 2c. It can be seen that the axial stiffness of the single cylinder design is less than design A unless extra material is used. Although the single cylinder requires extra material for axial stiffness, the advantages of fabrication, seismic resistance, fuel accessibility, etc., more than compensates for the extra material. The axial stiffness is of importance for certain new concepts of mitigating hypothetical accidents in which the accident is confined to the core. For this concept, high axial stiffness of the ACS supports is very desirable.

REFERENCES

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2. J. M. Kennedy and T. B. Belytschko, "Formulation and Application of a Three-Dimensional Structural Model for Upper Internal Structures," Nuclear Engineering and Design, 55, 1979, pp. 173-184.

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Table 1. Dimensions and Deformations of Above-Core Structures

Dimensions

Design A - Column Support		Design B - Cylindrical Support	
Wall thickness, cm	2.540	Wall thickness, cm	1.651 to 3.302
Column diameter, cm	33.02	Cylinder diameter, cm	203.2
Cross-sectional area, cm^2	263.5	Cross-sectional area, cm^2	1054.0 to 2108.0
Column length, cm	406.4	Cylinder length, cm	406.4

Deformations

Design	Wall Thickness (cm)	Maximum Axial Displacement (cm)	Time of Maximum Axial Displacement (ms)
A	2.540	58.3	3.0
B	1.6510	fails	---
B	2.4765	62.0	3.3
B	2.8892	16.5	1.8
B	3.3020	7.4	0.9

LIST OF FIGURES

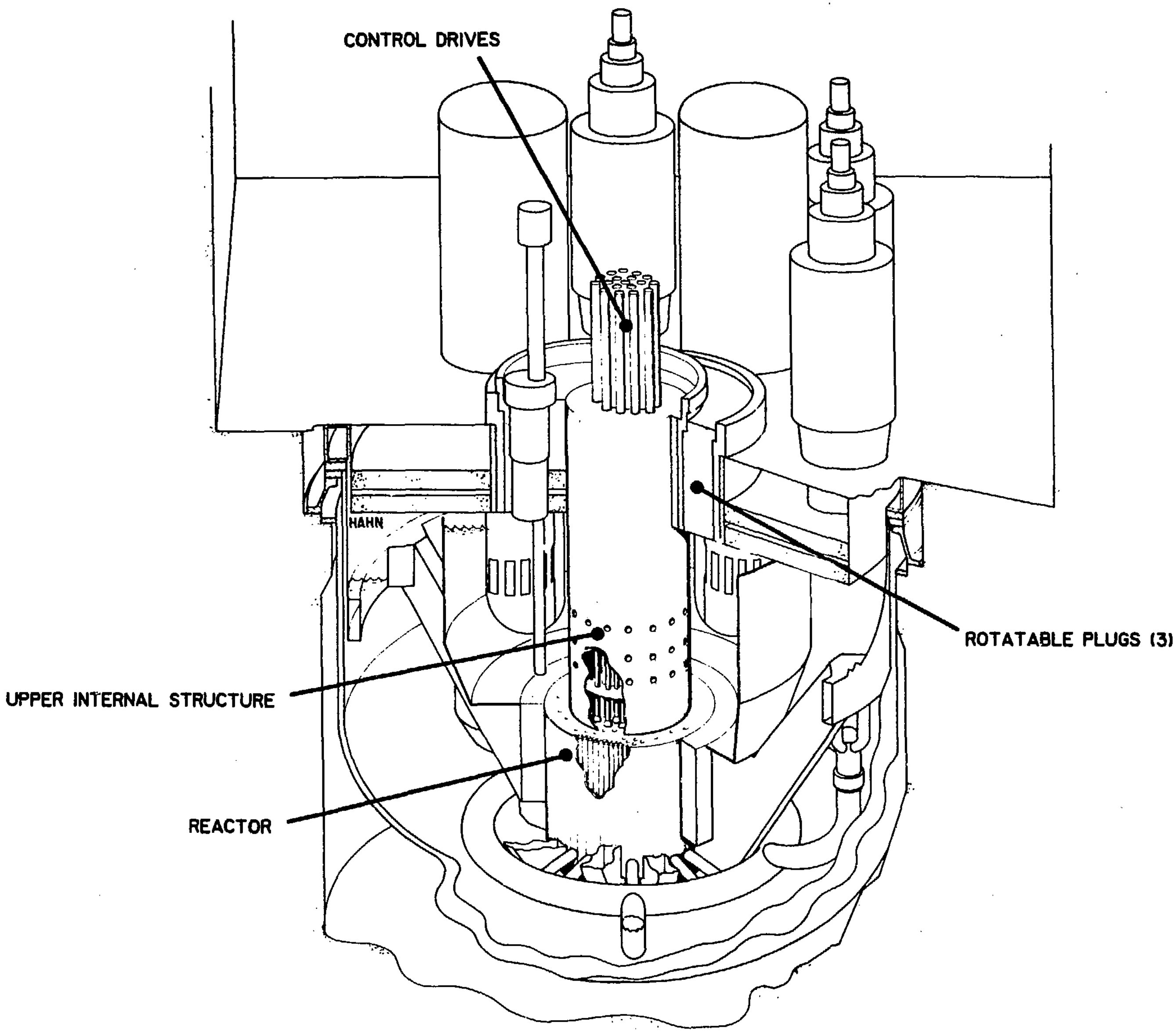

Figure 1. LMFBR Design with Cylindrical ACS

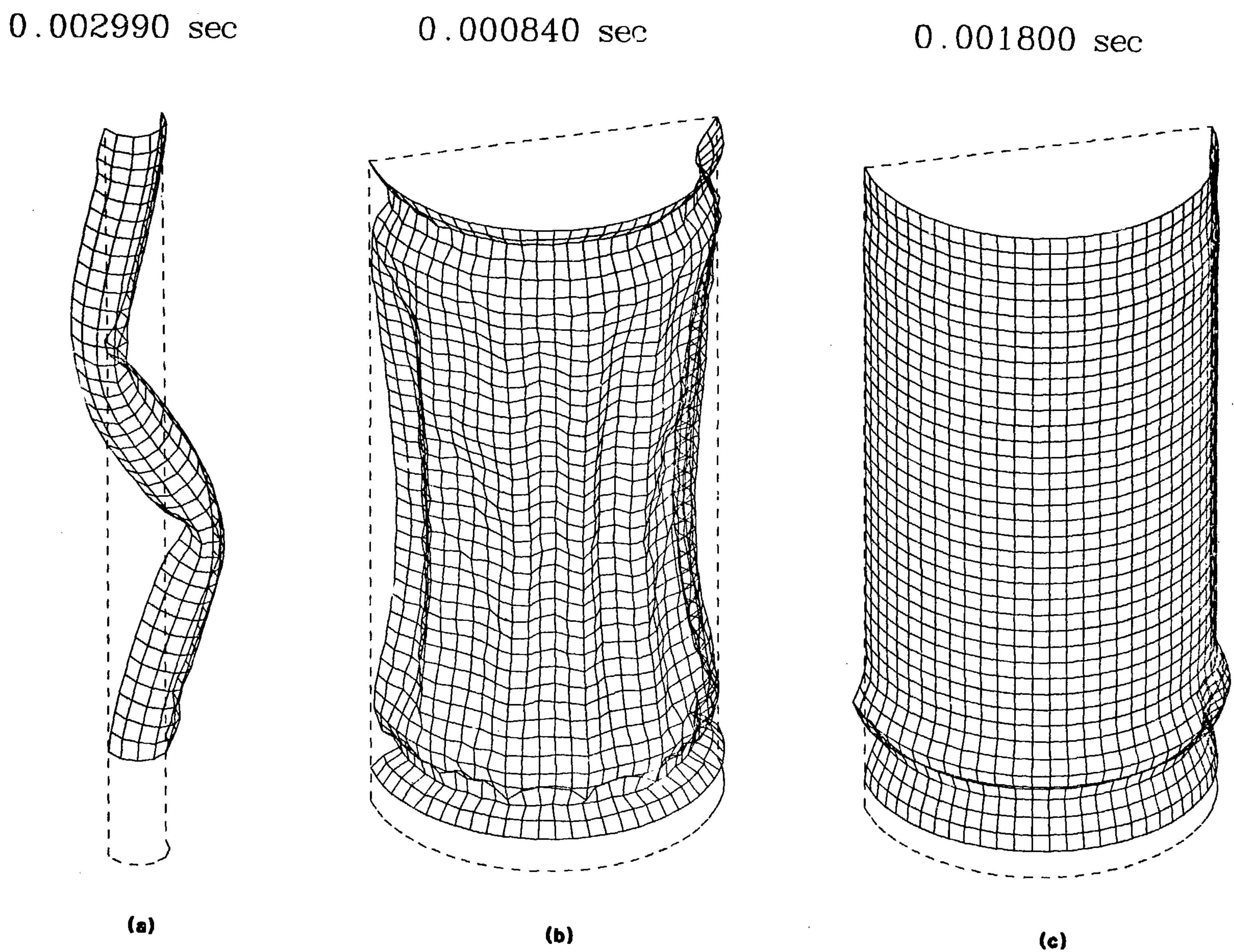

Figure 2. Deformed Shapes of ACS