DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, Jan. 28, 1993

Note: **ME-1**

ANALYSIS OF AN ELLIPTICAL VACUUM CHAMBER STIFFENED WITH TRANSVERSAL RIBS

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Abstract

Structural and buckling analysis of the vacuum chamber for the pulsed bending magnets in DAΦNE transfer line is presented. The segment is an elliptical cylinder stiffened with transversal rectangular ribs.

The analysis has been done by the ANSYS finite element code.

Introduction

The vacuum chamber considered is placed in the transfer line under the expansions of the bender magnet DHPTT01. This chamber follows a curve with a radius of 1.417 m (55.79 in) for an angle of 45° and is realized by four straight segments, jointed with flanges.

Each segment is a very thin elliptical cylinder. To improve the strength of the chamber without affecting its thickness, a series of regularly spaced transversal ribs has been provided at the exterior.

The geometric data of the structure are in Fig. 1.

Scope of the work is to verify such design, both from a static and a buckling point of view.

Methods

The analyses have been done by means of the ANSYS general purpose finite element code. Two different approaches have been followed in the modelization.

The first finite element model employs thin walled elements with bending capabilities.

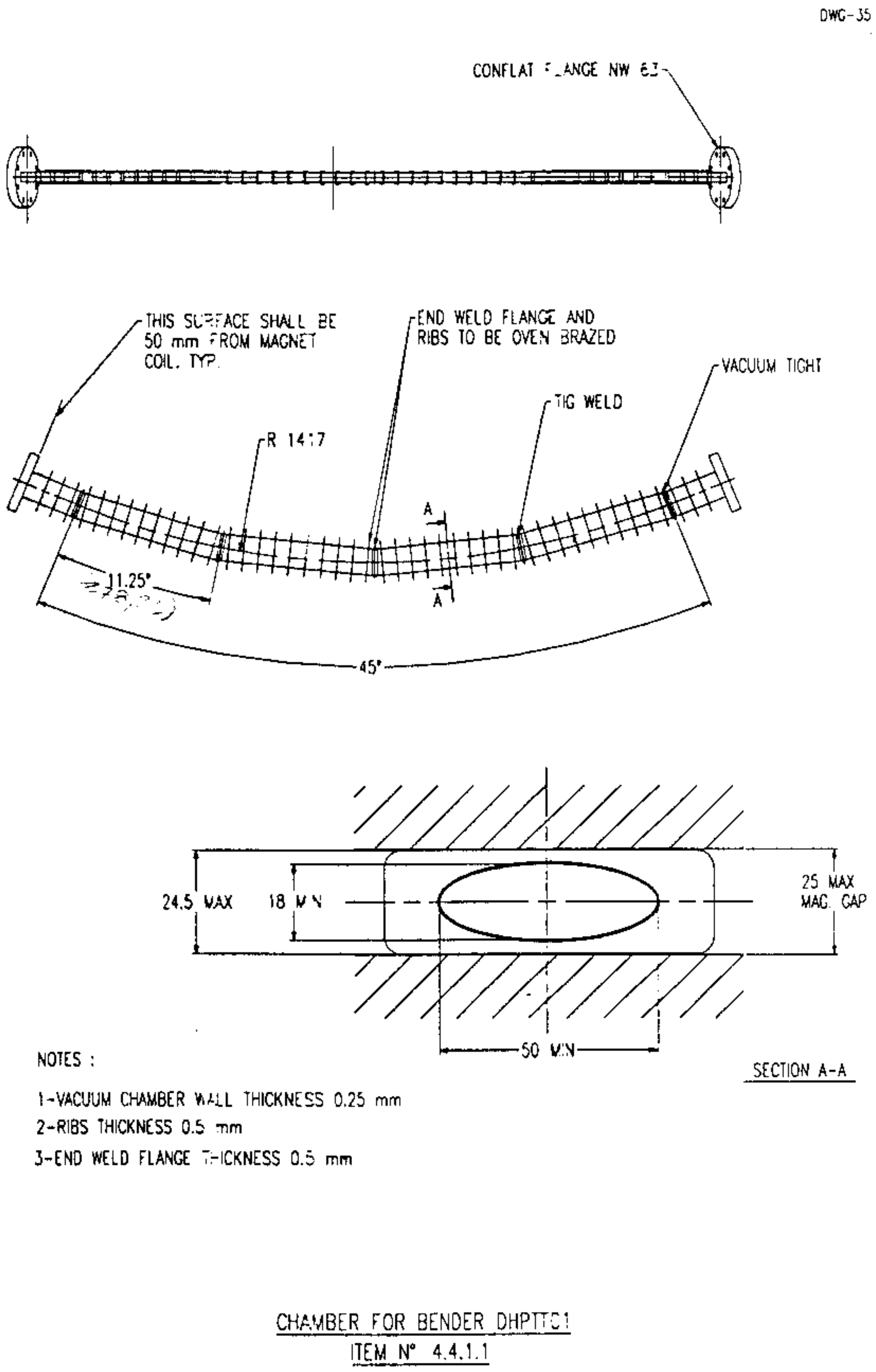

Fig. 1 - Vacuum chamber geometry.

The mesh for the static analysis has been realized with a self adaptive automatic method, to minimize the computation error in the most critical zone (i.e., the joint region between rib and chamber).

For the buckling analysis a simpler mesh has been adopted, to save computation time (in this case the results are not affected by the precision of the stress values in the joint zone).

According to simple symmetry considerations, only a portion of the chamber has been modeled. The portion corresponds to a whole module in the axial direction with a rib in the middle, and to a quarter in the transversal section.

Neither analytic nor numerical methods has been found in literature about buckling of elliptical cylinder with external pressure. Thus, a rough verification of the computer analysis has been done by hand calculations for a long circular cylinder with stiffening rings [1], taking the radius equal to the major semi-axis of the ellipse.

A further finite element model has been realized to obtain more precise results in the joint zone between rib and chamber. This second model employs brick elements.

Results

The static analysis has been done for an inter-rib span of (a) 0.028 m (1.10 in) and (b) 0.020 m (0.79 in). Only the latter span has been considered in the buckling analysis.

Static analysis - shells model

(a) for the 0.028 m span model, the highest equivalent stress is 0.18 GPa (26.1 ksi), and the highest displacement is 0.92 10^{-4} m (3.62 10^{-3} in).

(b) for the 0.020 m span model, the highest equivalent stress is 0.13 GPa (18.85 ksi), and the highest displacement is 0.66 10^{-4} m (2.60 10^{-3} in).

Static analysis - bricks model

For the 0.020 m span model, the highest equivalent stress is 0.105 GPa (15.225 ksi), and it is localized in the joint of the rib to the chamber. The highest displacement is 0.47 10^{-4} m (1.85 10^{-3} in).

Buckling analysis

For the 0.020 m span model, ANSYS gives a ratio of the critical load to the real one equal to 10.91.

For a comparable circular cylinder, the following formula has been employed [1]:

$$q_{cr} = 0.807 \frac{Et^2}{lr} \sqrt[4]{\left(\frac{1}{1-\nu^2}\right)^3 \frac{t^2}{r^2}}$$

where
q_{cr} = critical pressure
E = Young modulus
ν = Poisson ratio
r = ext. radius
t = thickness
l = inter-rib length

The formula gives a critical pressure of 2.165 MPa (314.0 psi), which corresponds to a ratio 21.37 (the circular shape is less critical than the elliptical).

Selected graphic displays of the results about the bricks model are shown in Figs. 2 to 8.

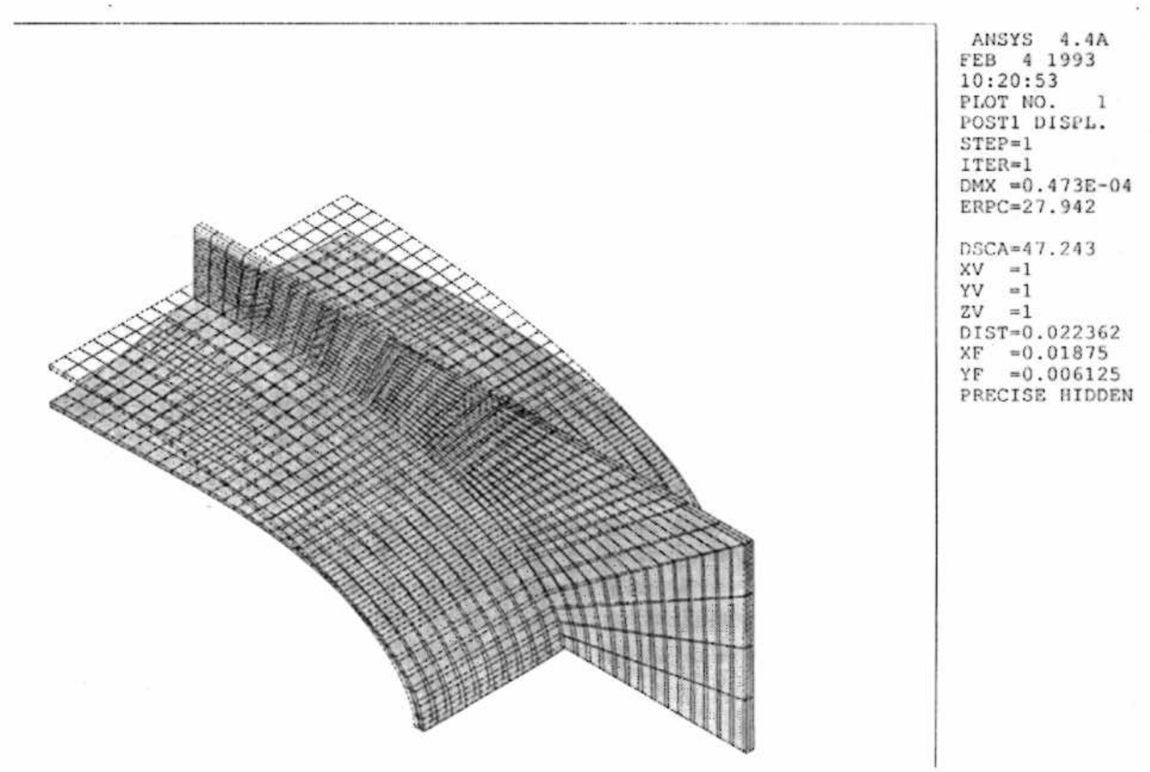

Fig. 2 - Deformed structure versus undeformed.

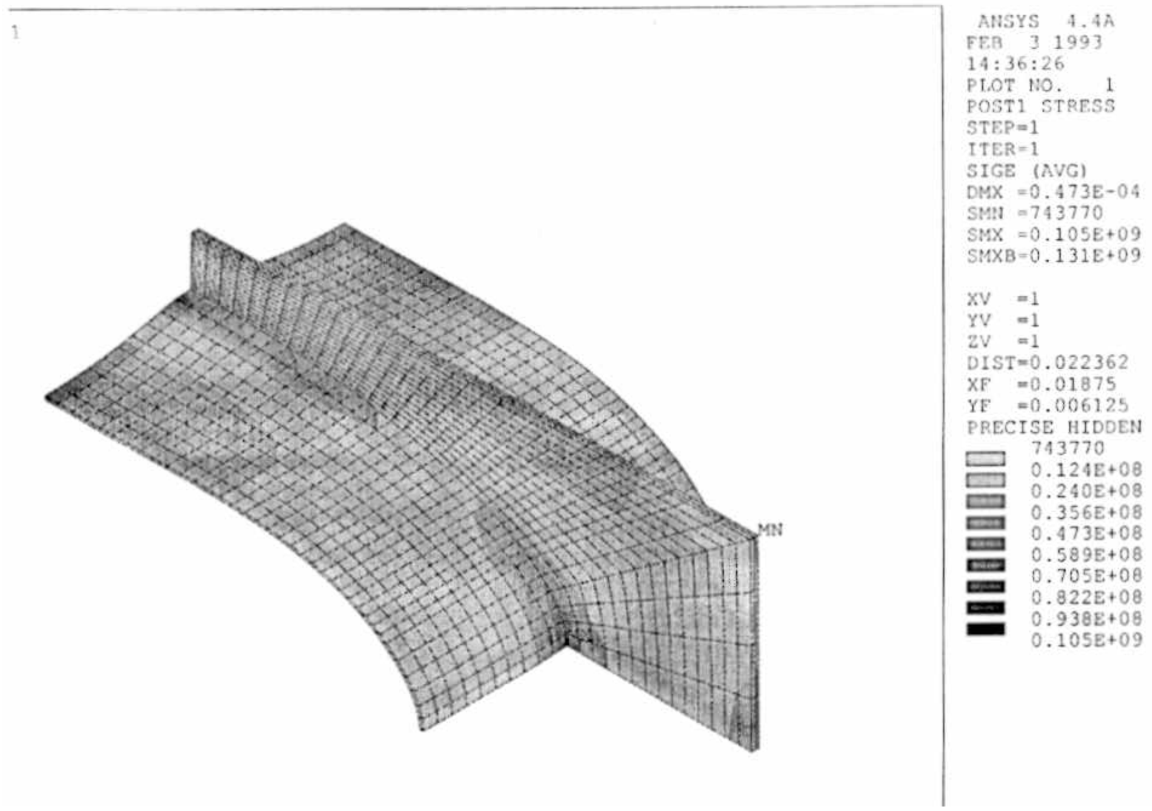

Fig. 3 - Equivalent stresses (Pa) for the 0.020 m span case.

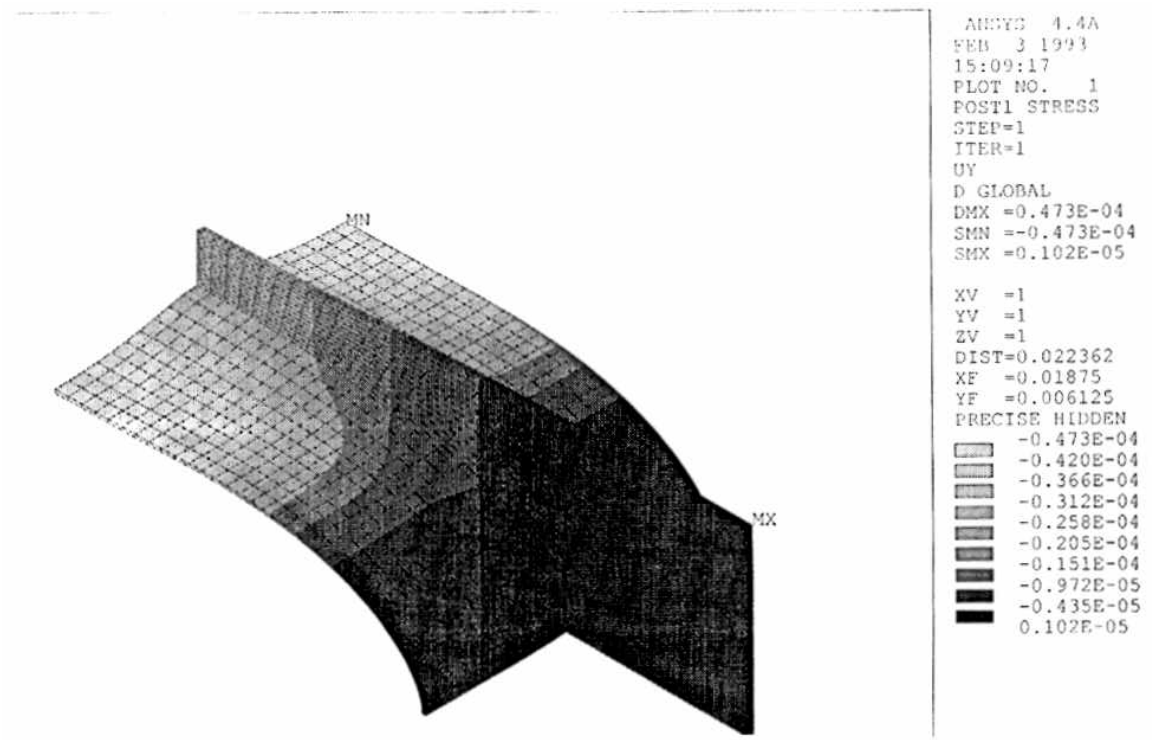

Fig. 4 - Vertical displacement (m) for the 0.020 m span case.

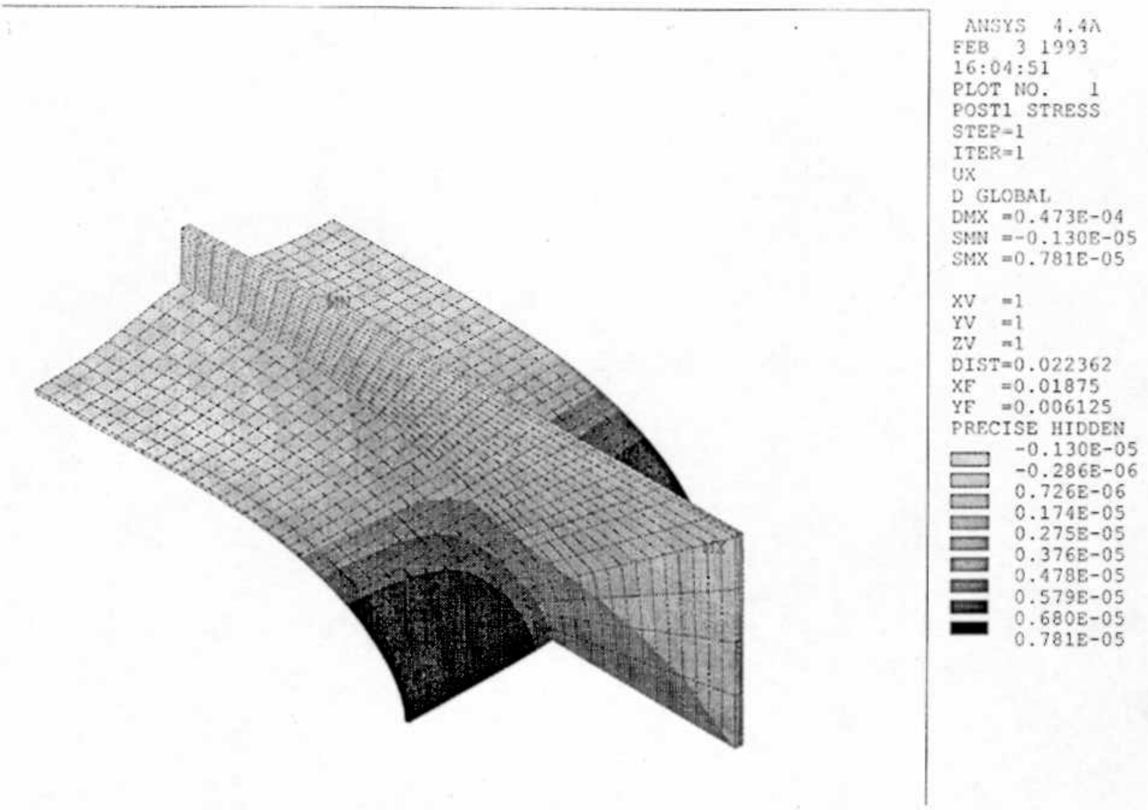

Fig. 5 - Horizontal displacement (m) for the 0.020 m span case.

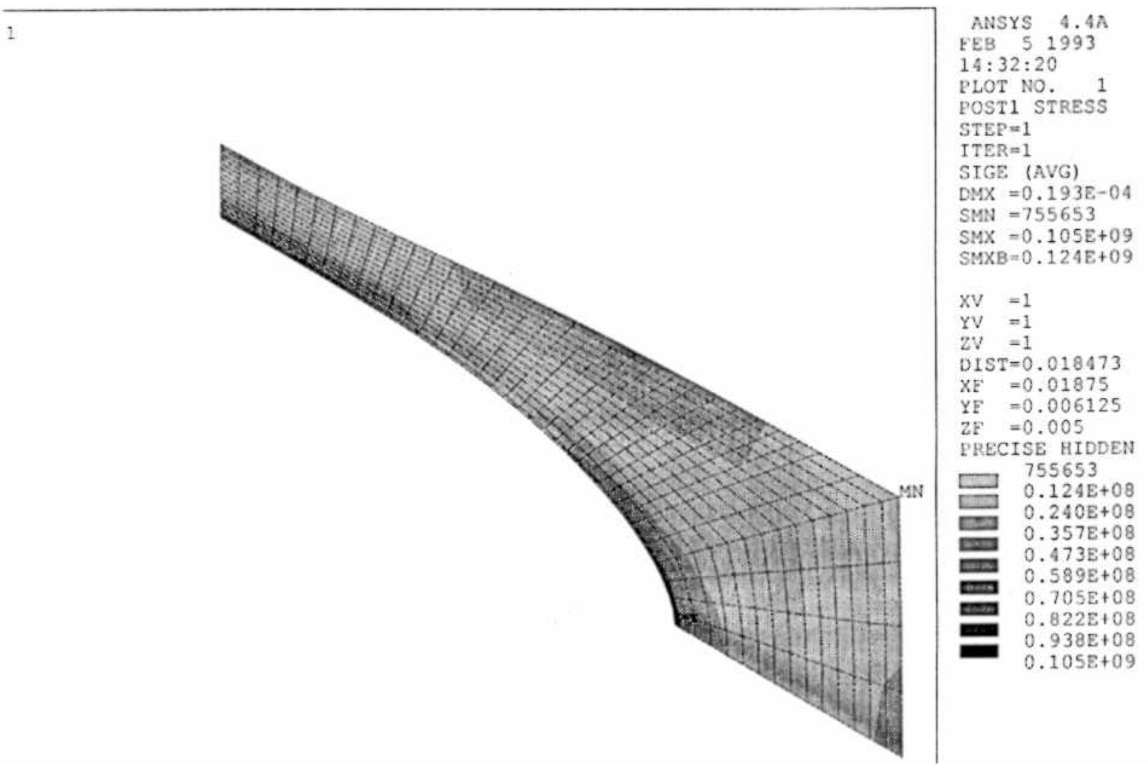

Fig. 6 - Equivalent stresses (Pa) in the joint zone for the 0.020 m span case (mid-section of the rib-bricks model).

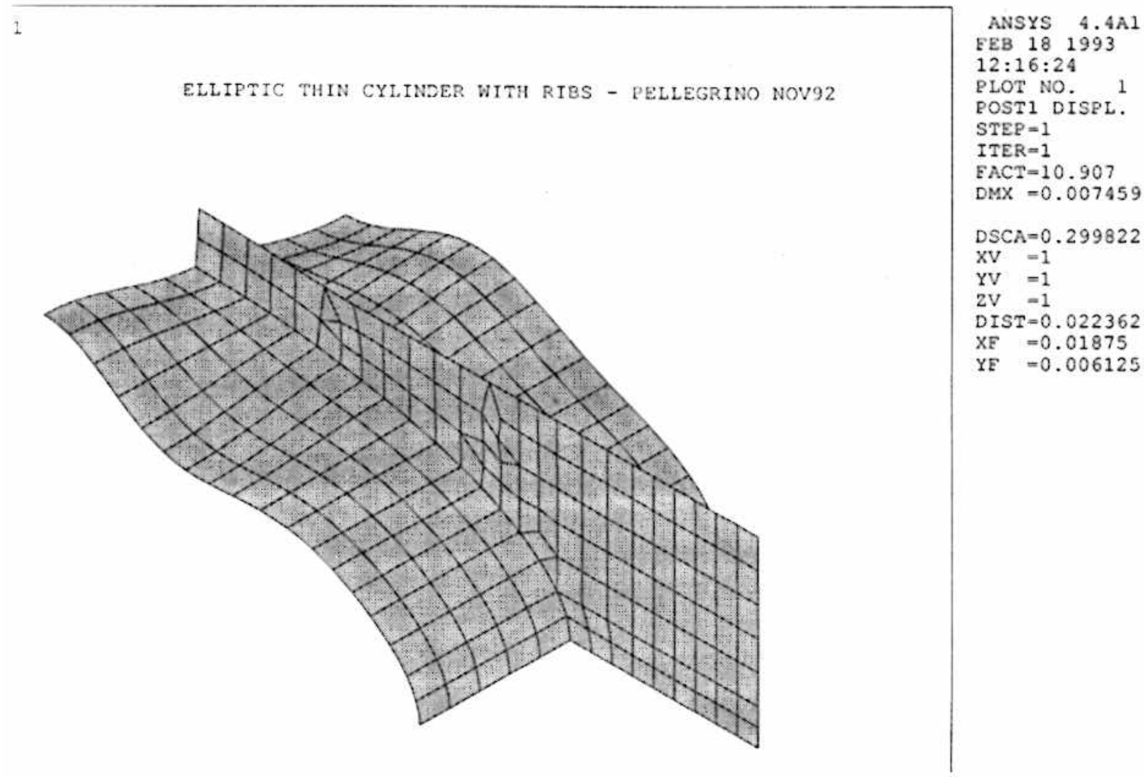

Fig. 7- Buckled structure for the 0.020 m span case.

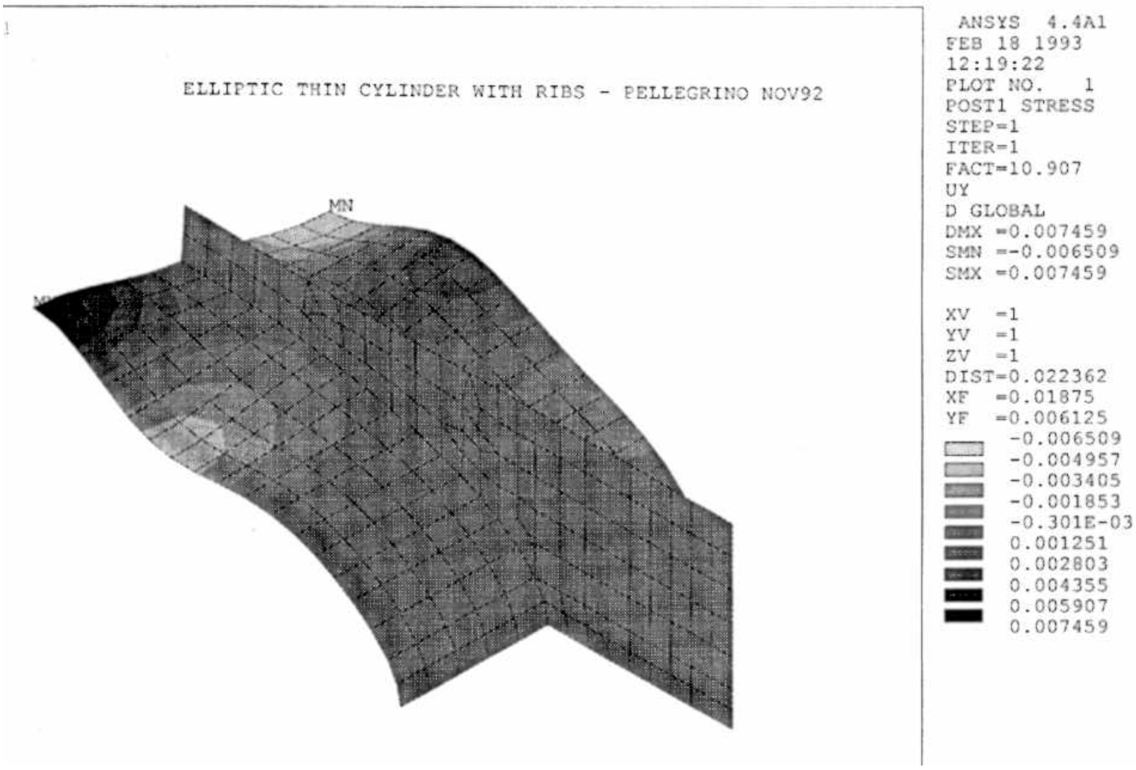

Fig. 8 - Buckling: relative vertical displacement for the 0.020 m span case.

Conclusion

The buckling behavior of a structure is a very delicate matter indeed. However, the hand calculation shows a similar result, reinforcing the ANSYS evaluations.

Note in the pictures the stress concentration in the joint zone between cylinder and rib in correspondence of the minimum curvature radius (this zone corresponds to the most critical for the computation, too).

There is good agreement between the results obtained from the two models employed (the first is slightly more conservative).

In conclusion, the results show that the major constraint is represented by the structural strength of the stiffened chamber, while the buckling threshold is not critical. The stress in the joint is 0.105 GPa (15.225 ksi). An inter-rib span of 0.020 m seems to be adequate.

References

[1] Raymond C. Roark, Warren C. Young, Formulas for stress and strain, Mc Graw-Hill, 1985.

[2] Stephen P. Timoshenko, James M. Gere, Theory of elastic stability, Mc Graw-Hill, 1961.

[3] Stephen P. Timoshenko, S. Woinowsky-Krieger, Theory of plates and shells, Mc Graw-Hill, 1987.

[4] Annaratone, Recipienti in pressione, CLUP.