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Note: **ME-6**

KLOE BE CHAMBER: RF SHIELD MECHANICAL DESIGN

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Abstract

The KLOE's Be pipe has a bulb like shape with a very thin (50 µm) Beryllium inner shield to prevent RF losses. This shape is needed to avoid K_S regeneration effects. It is necessary to design the Beryllium shield so that it absorbs the thermal strain without breaking and without undergoing excessive deformation.

1. Introduction

The KLOE vacuum chamber is a shaped tube made of Beryllium (Fig. 1). The choice of this material is due to its low Z, and its shape avoids K_s regeneration [1].

To minimize RF losses a very thin (50 µm) beryllium shield has to be assembled between the interaction point and the bulb. The shield must leave an equatorial slot of ~ 3 mm on the pipe, for vacuum purposes.

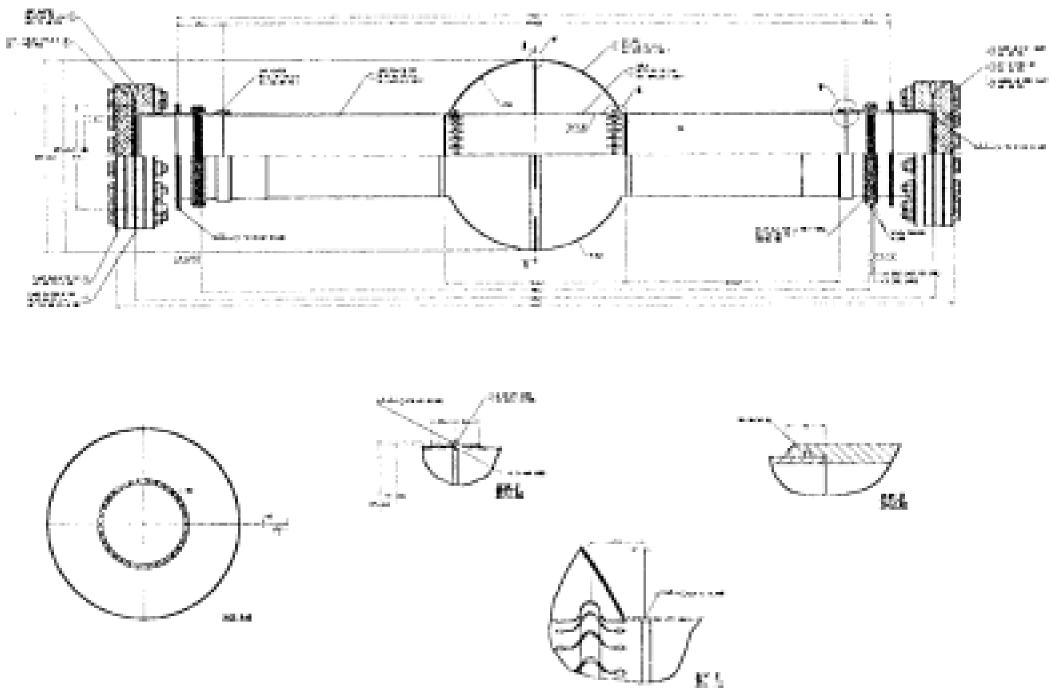

Fig. 1 - Details from the KLOE Be chamber assembly drawing.

2. General review

The dissipated power, if the shield pipe were perfectly cylindrical, is ~ 4 W at full design current [2]. This power quickly increases as the geometry of the pipe undergoes critical change.

The heat increases the shield temperature and, being connected with the pipe, is stressed by an axial force.

The deformation induced by this stress increases the RF loss, and it is necessary to reach rapidly an equilibrium point to avoid a "positive feedback".

The basic idea to obtain the shield with a simple cylindrical shape fails because of the small thickness; in fact the system reaches immediately the condition of local instability, with a geometric configuration hardly predictable due to permanent plastic deformation (*curling up*).

Dividing the cylinder into some strips does not solve the instability problem, even if an improvement is guaranteed.

3. First shield design

The first attempt to develop the situation starts from the following assumptions:

a) Possibility of accepting a system which operates in *post-Buckling* configuration.

b) Preference to have a convex volume limited by the shield.

The consequent idea is to realize the shield with an "American football ball" configuration, by means of a proper number of strips with a calculated shape, assembled on the triple welding point at a distance smaller than their natural length, to obtain an outward sag of ≈ 2 mm in the middle (Fig. 2).

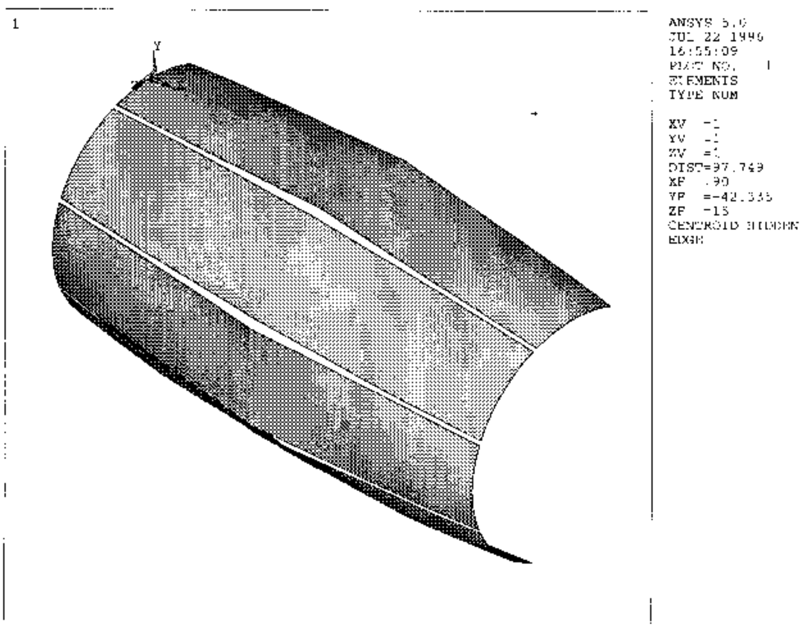

Fig. 2 - First shield: conceptual drawing.

With this option, in order to avoid plastic deformation (out of plane Buckling mode of the strip), due to the change of plane curvature of the strip, it is necessary to divide the shield into about 36 parts [3] (this because the strips would be obtained by flat foil bending, being impossible to perform a "hot forming" process on such strange assembly shape).

Three problems must be solved for this solution:

1) Strip geometry determination.
2) Positioning of the strips before welding in the triple point (axial and circumferential).
3) Control of the thermal strain due to welding on strip's first side.

During the R & D program of the KLOE Be chamber three prototypes were built to establish the proper welding parameters.One of these prototypes included welding of eight strips about 50 mm long, simulating the RF shield (the final shield is about 180 mm long).

From this point of view the prototype failed; only two strips out of eight were completely joined on both sides, the others showing distortions and lack in joining.

The engineering staff of the manufacturer blame it to the thermal strain during welding, because of the small circumferential size of the strips.

4. Second shield design

The test on strips welding showed that it is not possible to handle a shield divided in too many strips. On the other hand with the shield divided into few sectors it is not possible to have an *elastic post-Buckled* configuration; so it is necessary to put springs, or "something" working as a spring, to preserve the cylindrical zone from critical axial forces, and employ wide enough strips to make the welding process easier .

An element that reaches the goal is a bump, that can be carried out directly on the rolling sheet (Fig. 3). The bump geometry determines the shield behavior from the mechanical and RF point of view. Its geometry must be a compromise among these two characteristics and the technological capability of forming a Be foil of 50 μm. A large radius decreases the stress and the forming problems, but increases the RF losses: with a curvature radius of 2 mm the RF losses are ≅ 3 W, while with a curvature of 3 mm losses are ≅ 11W.

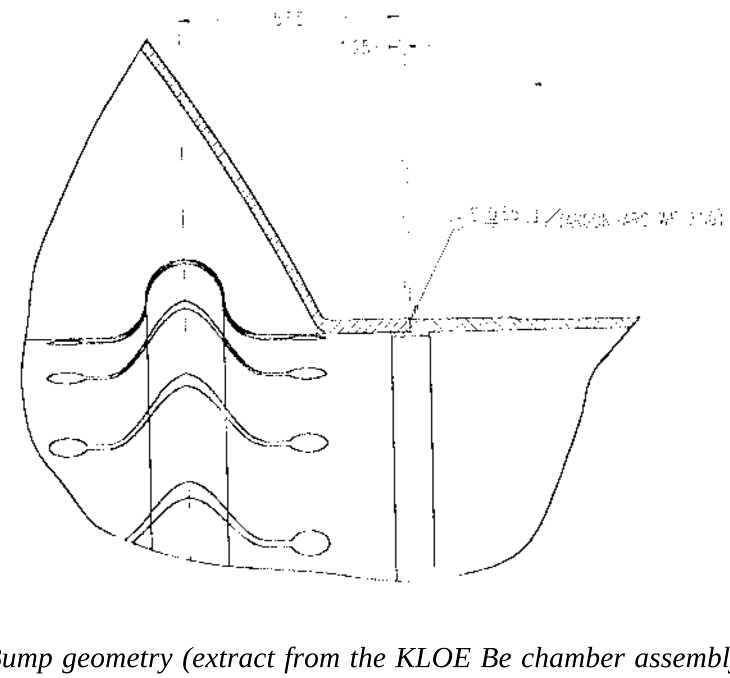

Fig. 3 - Bump geometry (extract from the KLOE Be chamber assembly drawing).

The shield is shown in Fig. 4. Being the axial strain absorbed by the bumps there is now no reason to make the shield in more than two parts; this simplifies the pre-assembling on the support rings, and the welding procedure, preserving from some lack in joint, critical if the strip width is small.

The procedure to realize the shield in this configuration involves two hot forming processes, the first to obtain the bumps, and the second to obtain the cylindrical shape [4].

The two sheets will then be mainly stressed by:

- Bending stress (shield forming)
- Axial force (RF shield heating).

The slots obtained on the bumps are extremely important to decrease the circumferential stress due to foil bending and to RF heating. They facilitate the pumping as well.

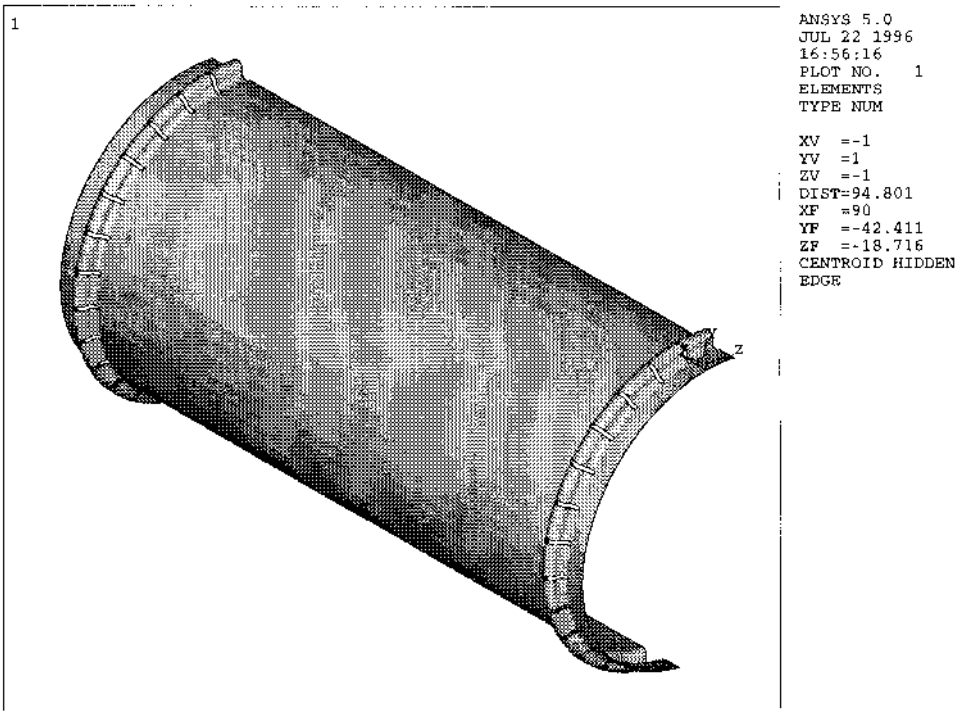

Fig. 4 - Second shield.

5. F.e.a.

We employed the Ansys® code to check the tensional state. Our main goal is to determine the *Buckling* behavior of the shield subject to axial load.

Also an analysis of the stress due to the forming of the flat foil with the bumps has been performed, because at that time it was not known if the cylindrical shape would have obtained by simply bending the sheet with the bumps, or by hot forming (after each forming process a chemical treatment will be performed in order to relax the *residual stress*).

5.1. Buckling Analysis

The Buckling analysis on the shield has been performed considering the system stressed by a thermal load of 8 W, the maximum value of the losses at 120 bunches [2] (the thermal exchange mode considered is only conduction).

We supposed the shield axially fixed-ends, with d.o.f. free in the plane perpendicular to the beam axis. This boundary condition and the conduction mode are both conservative.

The analysis performed is the *non linear Buckling analysis* (the *real Buckling*). The *non linear Buckling analysis* is a non linear static analysis, so it gives directly the stress-strain results as well.

Figures 5÷9 show some of the results of the f.e.a.

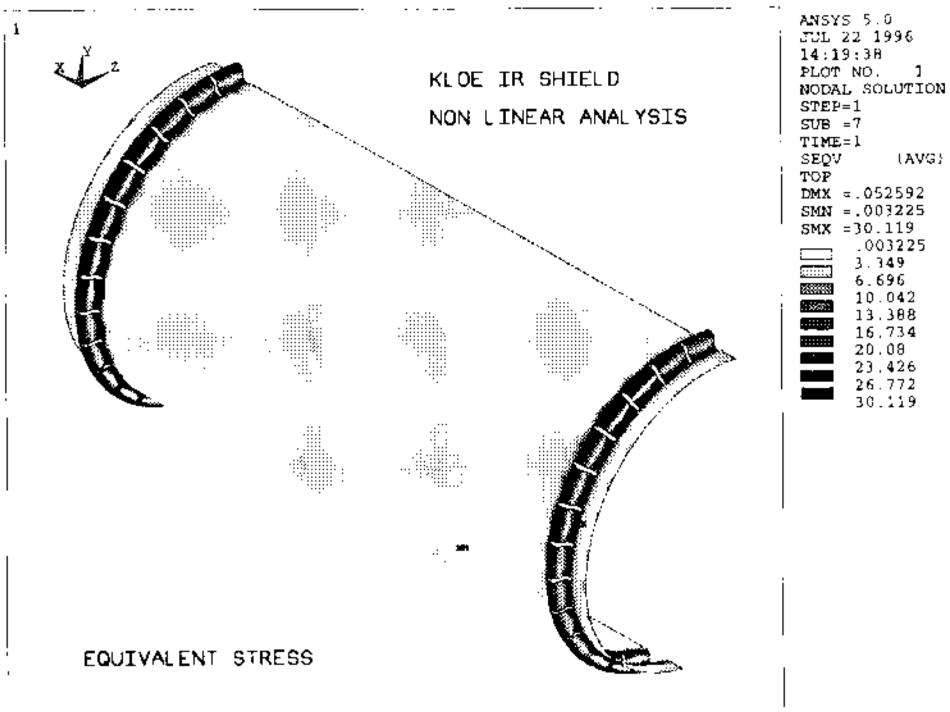

Fig. 5 - Von Mises stress.

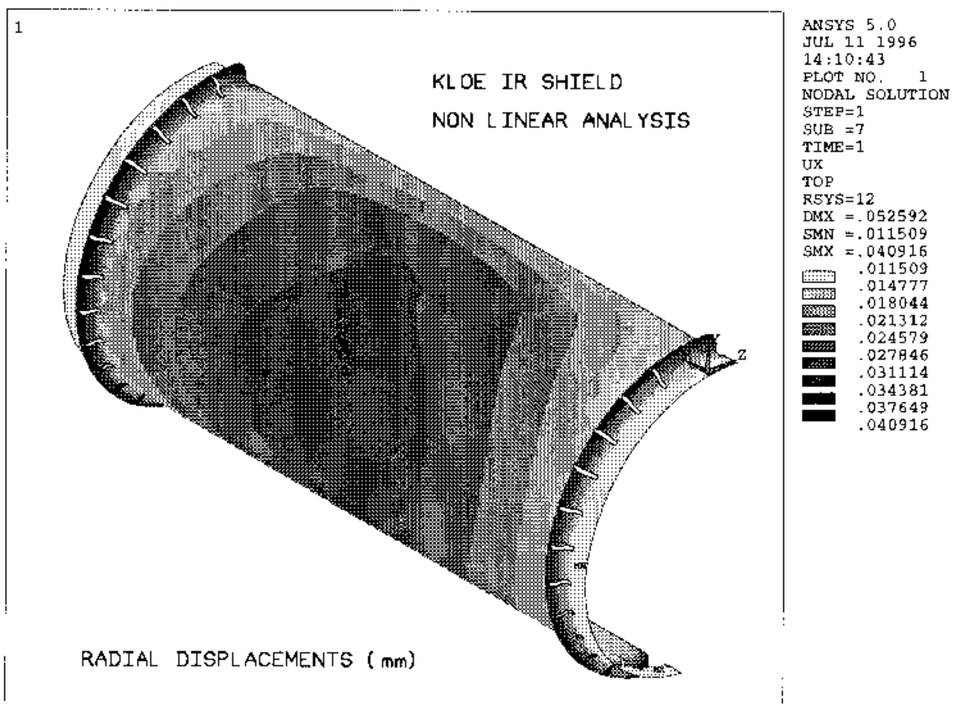

Fig. 6 - Radial displacements.

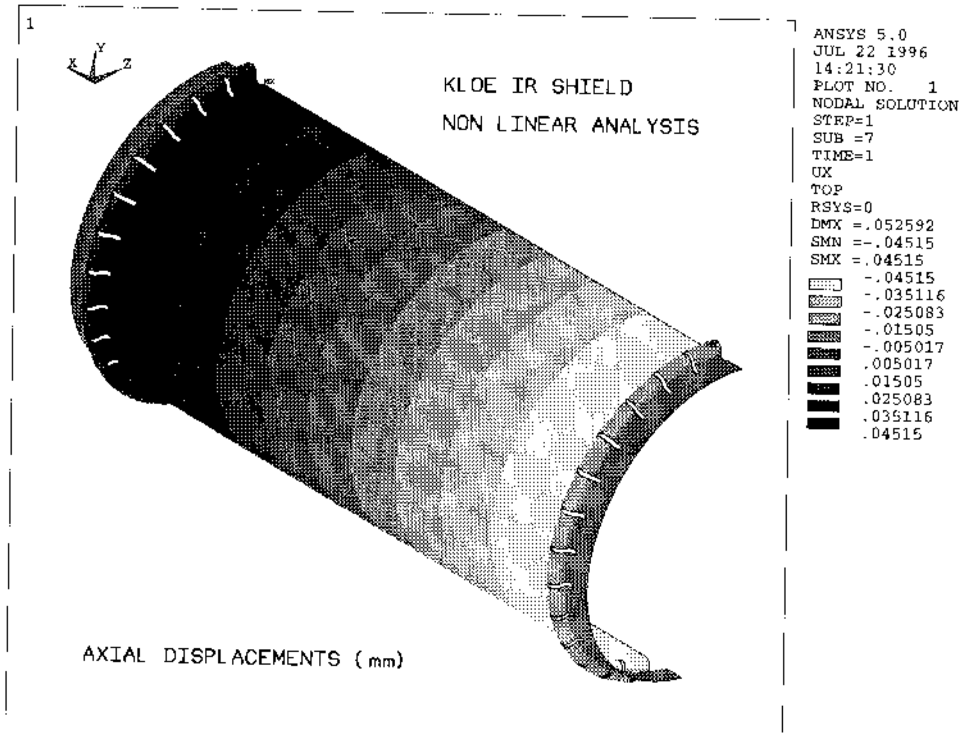

Fig. 7 - Axial displacement

Another proof of the stability properties of the shield comes out from the *Eigenvalue Buckling analysis* (linear), which does not reach the convergence. So it is possible to conclude that the stresses on the shield are not critical.

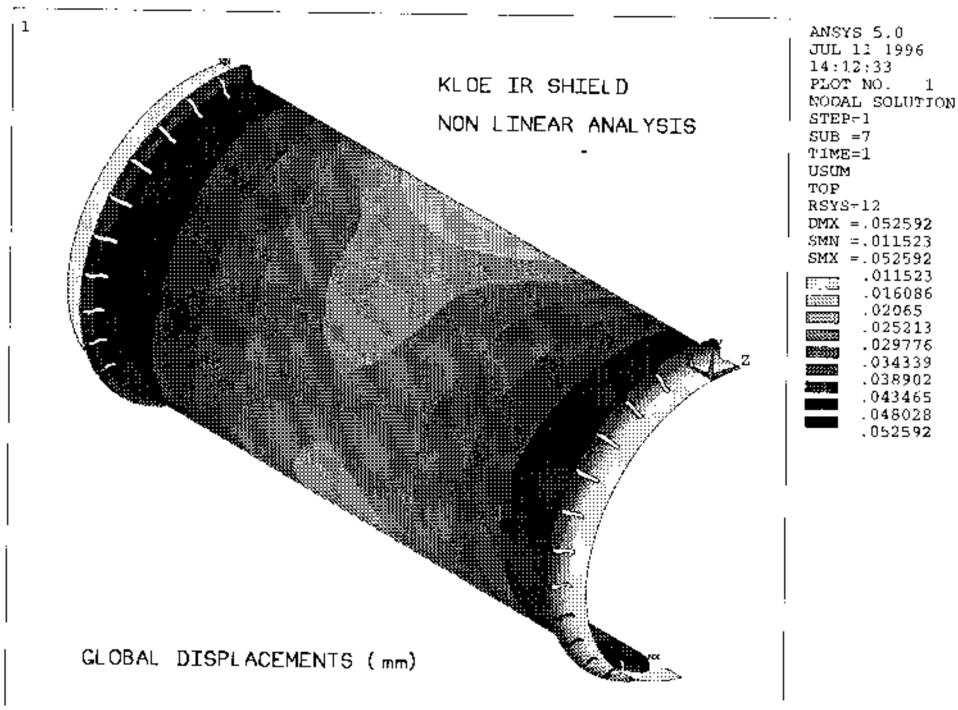

Fig. 8 - Global displacements.

The analysis reaches convergence easily (apart from the entity of calculations due to the large number of d.o.f.).

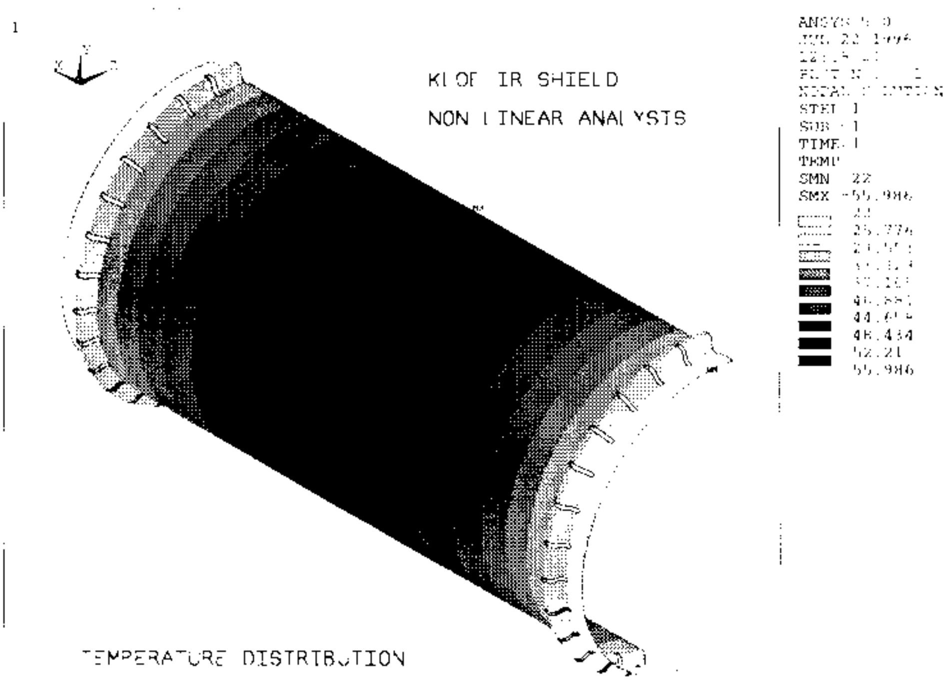

Fig. 9 - Temperature Distribution.

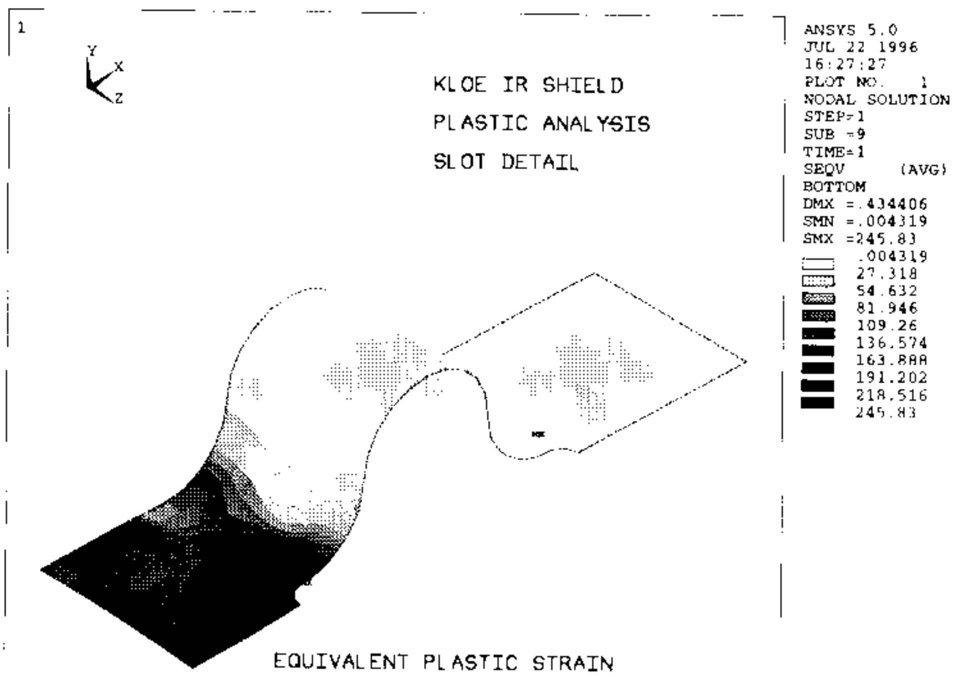

Fig. 10 - Bending analysis. Von Mises stress.

5.2. Bending analysis

The bending analysis has been performed only on an axially limited zone near the bump, because due to the shield geometry the contribution to the stiffness of the remaining part is negligible.

For this detail a plastic analysis has been performed; the selected plasticity criterion is the *Bilinear Isotropic Hardening*. The material characteristics suggested by K-TEK staff (Be grade S-200F) are as follow:

σ_{Yield} = 200 N/mm^2
$\sigma_{Tensile}$ = 300 N/mm^2 (at ε=1%)

A rotation of 13° between the extremities of the detail was set as a load. Figure 10 shows the equivalent stress, Figure 11 the plastic strain.

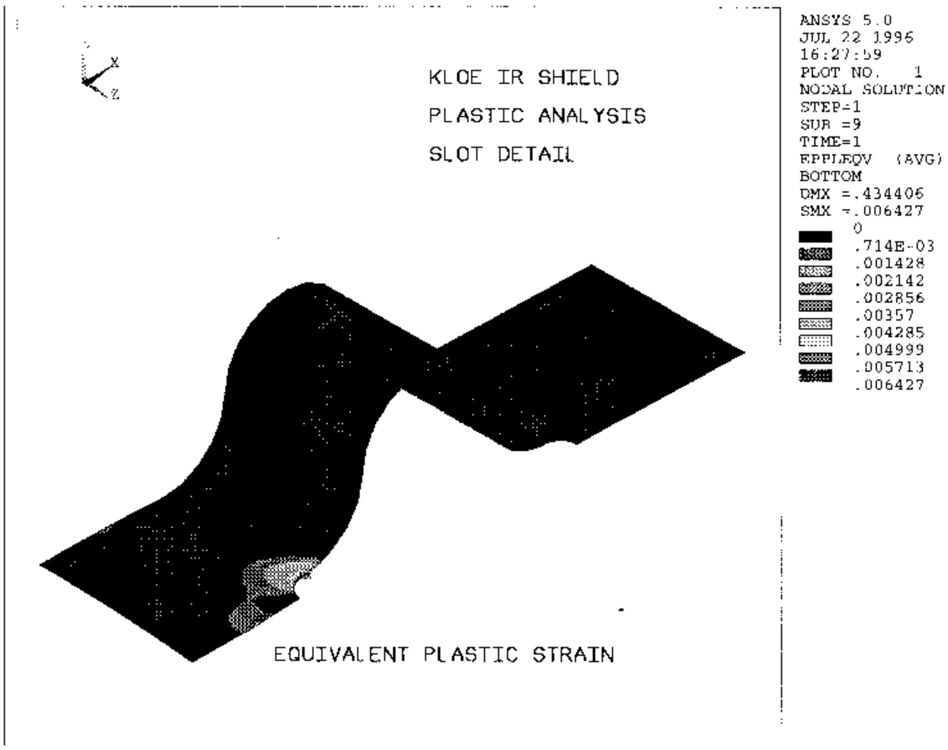

Fig. 11 - Bending analysis. Plastic strain.

6. Conclusions

The f.e. analysis performed show that the shield, as it is designed, can fulfill its structural functions.

The limit of the analysis is in the lack of knowledge about the mechanical properties of such thin Beryllium foils (the value of the Young's modules, yield stress and the hypothesis of isotropic material must be considered only for reference [4]).

Being the shield so critical for the overall success of KLOE experiment, its mechanical behavior will be tested on a prototype.

7. Acknowledgments

The authors wish to thank A. Battisti for carring out the chamber drawings.

8. References

[1] The KLOE Collaboration, "The KLOE Detector: Technical proposal", Frascati Internal Note LNF-93/002, January 1993.

[2] M. Zobov, Private Communication.

[3] G. Raffone, "The DAΦNE 7th Machine Review", July 5-6, 1994.

[4] K-Tek Inc., Private Communication.