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Finite Element Analysis for KTev Thin Window with a Diameter of 1.7 m/1.8 m

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This note contains an finite element analysis for a large cloth-type thin window used for the Ktev experiment. It starts with an assumption that the window material will be the same as one used in design report written by S. Sobczynski " E731/E621 Cloth Vacuum Window"[1]. Since the thickness of window is so small, two type shell elements, membrane shell (STIF 41) and axisymmetric element (STIF 51), have been used to find the maximum stress and maximum deflection. The thickness of the shell is estimated based on the equivalent membrane stiffness concept. A poisson's ratio is modified into a small number to simulate an individual fiber behavior. A calculation result for these two elements is shown in Table-1. The difference is negligible since the bending stiffness in structure is so small compared with its membrane stiffness. This result justified that using equivalent membrane stiffness to estimate shell thickness is a reasonable approach.

Table -1 Comparison of two type element

Material	Thickness	Maximum deflection	Maximum stress	element type
Kevlar	t_o	4.88"	1.57E5 psi	STIF 41
Kevlar	t_o	4.89"	1.56E5 psi	STIF 51

In order to gain more confidence regarding this finite model, a same geometry from reference 1 is taken to calculate the window deflection, and compared it with the experiment data [1] for both E621(24") and E621 (48") window as shown in Fig 1 and Fig. 2. It shows that the shell element fits experiment data very well for 24" window but cable element . For the larger window, the shell element solution is still much closer to experiment data compared with cable element again. Since the experiment measurement is sometimes depend on the initial flatness of window or how good it claims to the fixture specially for the larger window size, a calculation is done for the increment pressure ΔP vs the increment deflection ΔD in order to eliminate these effects (Fig. 3). The agreement is improved. The conclusion is that the shell element might be a better approach to simulate the window behavior.

A similar calculation is done for the window size 1.7 m and 1.8 m as shown in Fig 4 and Fig 5 for a maximum deflection and safety factor as a function of the thickness ratio. The t_o is defined as a kevlar thickness, which is the same as for E731(48")[1]. The safety factor is defined as ratio of the tensile strength of Kevlar respected to the maximum calculated stress. Results show that the window deflection decreases as its thickness increases. For the same thickness the larger window gives a bigger deflection. Also, it can be seen that the thicker window has a larger safety factor. The analysis is done by ANSYS and thickness calculation is included in Appendix

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REFERENCE:

1) "E731/E621 Cloth Vacuum Window Design Report" , Stan Sobczynski, RD/Mechanical Department, Jan. 28, 1985

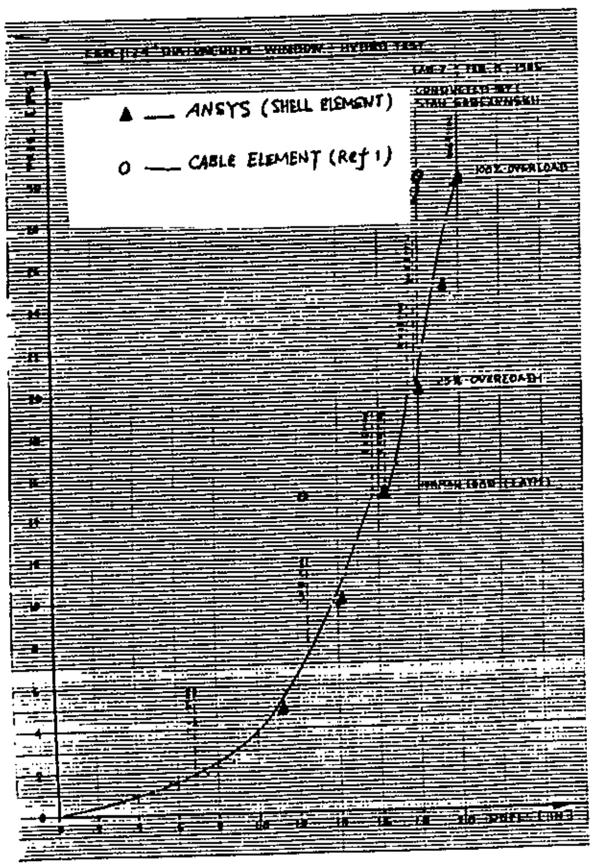


Fig. 1 Comparison for 24" window

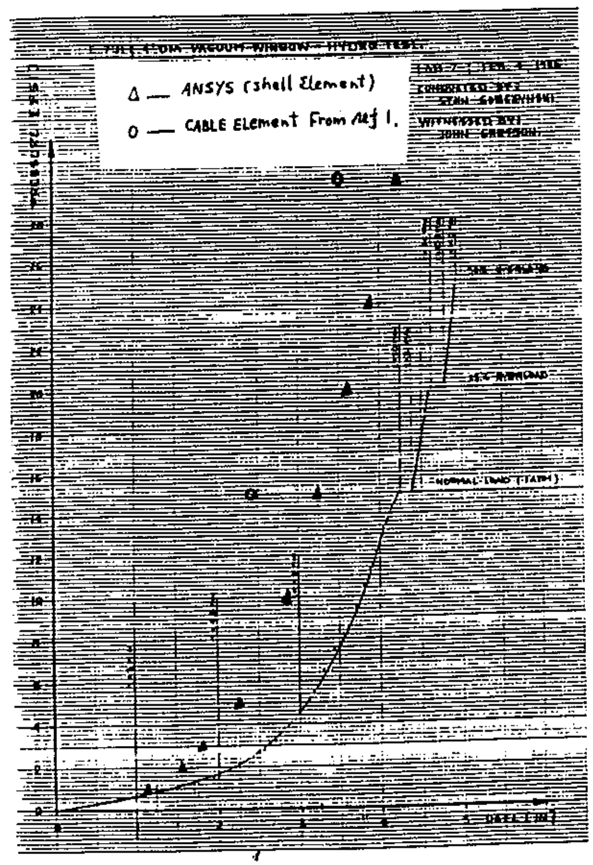


Fig. 2 Comparison for 48" window

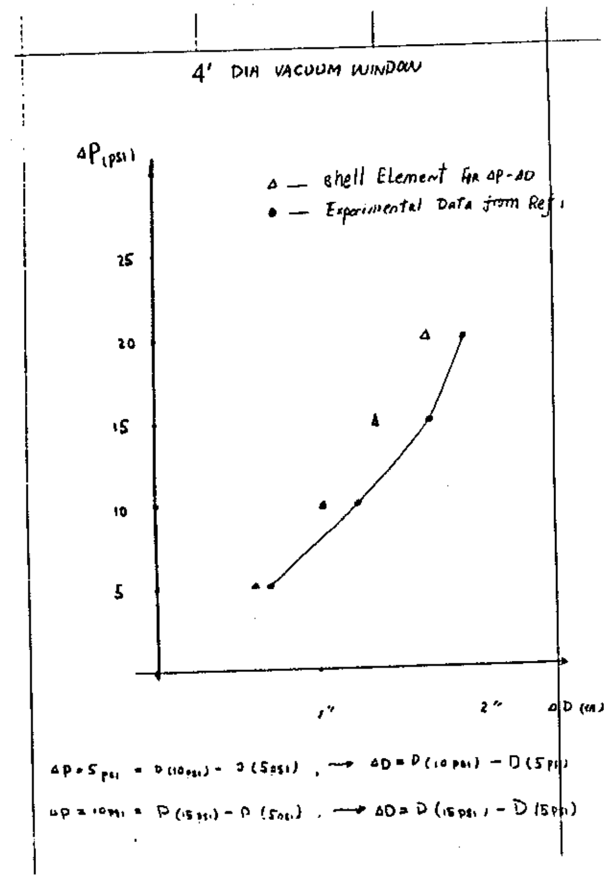


Fig. 3 Comparison for 48" window (ΔP vs ΔD)

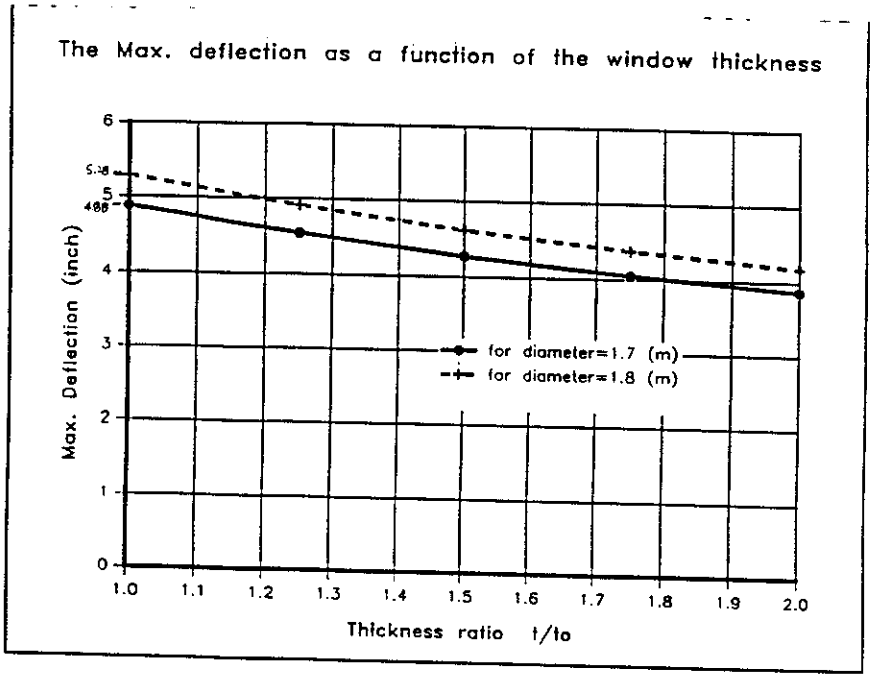


Fig. 4 The Max deflection as a function of the window thickness

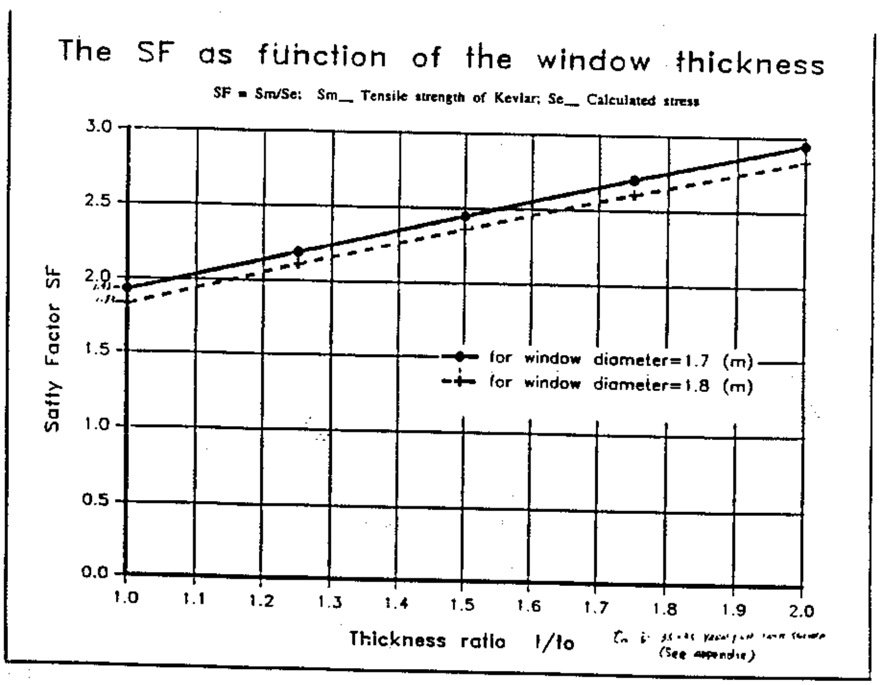
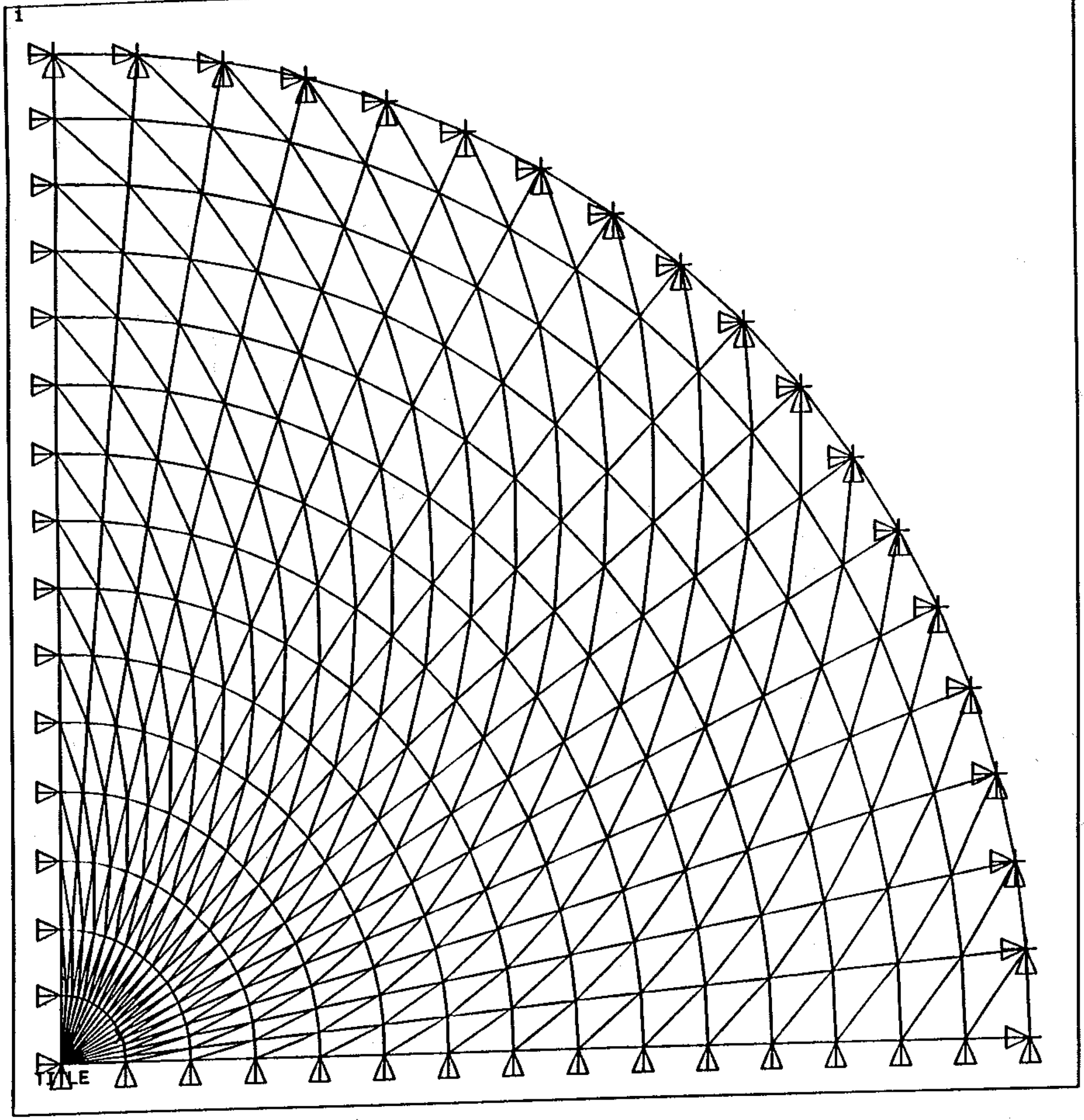


Fig. 5 The SF as a function of the window thickness



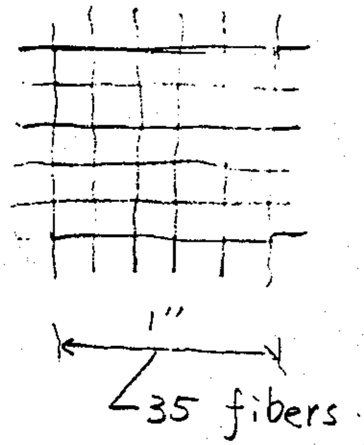
13:42:28
PLOT NO. 1
POST1 ELEMENTS
TYPE NUM
TDIS

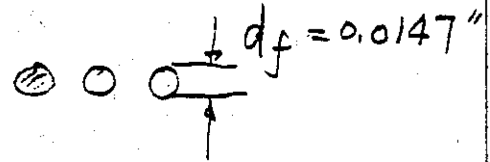
ZV =1
DIST=0.4675
XF =0.425
YF =0.425

Fig. 6

Appendix

Shell Thickness Estimation





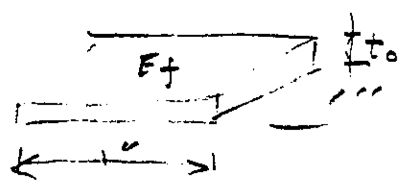
1) Cross-section area of fiber for 1'' width

$$A_f = 35 \times \frac{\pi}{4} \times (0.0147'')^2 = 5.94 \times 10^{-3} \ \text{in}$$

∴ Membrane stiffness will be

$$E_f \cdot A_f .$$

2): Assuming a plate with same material (E_f) and 1'' width, the membrane stiffness



$$E_f \cdot t_o \cdot 1$$

3): If:

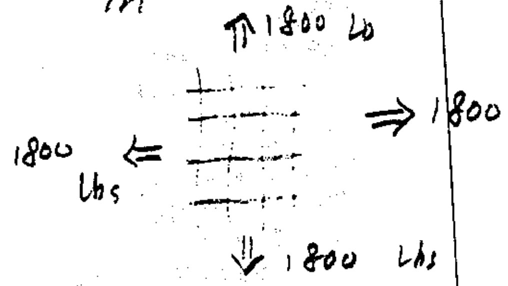
$$E_f A_f = E_f \cdot t_o . \quad (\text{Equivalent Membrane}$$

Appendix

Safety Factor

1. Kevlar material has $1800 \frac{Lbs}{in} \times 1821 \frac{Lbs}{in}$

Tensile strength.



∴ Max. stress of MATERIAL S_m is Define

$$S_m = \frac{1800\ Lb}{A_f} = \frac{1800\ lbs}{35 \times \frac{\pi}{4} \times 0.0147''} = 303{,}03$$

20 20

∴ Safety Factor (SF)

$$SF = \frac{S_m}{S_e}$$

where: Se is maximum calculated stress from ANSYS, $E_{kevlar} = 9.0 \times 10^9$ (PSI)

SAMPLE INPUT FILE

WIN-3W.dat

```
C**************this file for 1.7 (m) diameter window design 9/16/91
/PREP7
KAN,0
KAY,3,0
KAY,6,1
KAY,8,1
KAY,9,0
C*************kevlar 1 layer
ET,1,41,2,,,,1
EX,1,9.0e6
EY,1,9.0e6
C*************
NUXY,1,0.0001
ALPX,1,0.001
R,1,1.508e-4/25.4e-3
C************mylar with 5 mils
ET,2,41,2,,,,1
EX,2,5.5e5
EY,2,5.5e5
ALPX,2,0.001
R,2,5*1e-3
C**************
CSYS,1
N,1
N,16,33.4645
FILL
NGEN,19,16,1,16,,,5
E,1,2,18,
EGEN,15,1,1
EGEN,18,16,1,15
E,2,19,18
EGEN,14,1,271
EGEN,18,16,271,284
C****************
TYPE,2
REAL,2
MAT,2
E,1,2,18
EGEN,15,1,523
EGEN,18,16,523,537
E,2,19,18
EGEN,14,1,793
EGEN,18,16,793,806
C***************
D,16,ALL,,, 304,16
SYMBC,,1
SYMBC,,2
CSYS,1
WSOR,Y
C***************
TREF,0
TUNIF,-1
ITER,1,1
LWRI
C******************
EP,1,6,15,,522
ITER,-10,10
LWRI
C***************
```

Sample Input File

```
C**************this file for 1.7 (m) diameter window design 9/16/91
/PREP7
 AN,0
KAY,3,0
KAY,6,1
KAY,8,1
KAY,9,0
C*************kevlar 1 layer
ET,1,51
EX,1,9.0e6
EY,1,9.0e6
C*************
NUXY,1,0.0001
ALPX,1,0.001
R,1,5.94e-3*1.25
C**************mylar with 5 mils
ET,2,51
EX,2,5.5e5
EY,2,5.5e5
ALPX,2,0.001
R,2,5*1e-3
C*************
N,1.0.001
N,31,35.43
FILL
e,1,2
egen,30,1,1
C****************
 YPE,2
 EAL,2
MAT,2
E,1,2
EGEN,30,1,31
C***************
D,31,ux,0,,,,uy,uz
C***************
TREF,0
TUNIF,-1
ITER,1,1
LWRI
C*****************
esel,type,1
nele
EP,all,2,15
nall
eall
ITER,-20,10
LWRI
C*****************
afwrite
fini
/input,27
fini
```

Extra Attachment from Ref. 1

2. TESTING OF FABRIC AND FABRIC CLAMPING

Tensile testing of fabric-mylar laminate was done in order to correlate the theoretical and actual properties of Kevlar 29, dacron and mylar, and to test various clamping techniques.

A clamping fixture was designed so as to match closely the behavior of the actual clamping flanges, their bolt pattern, surface finish, "o-ring" groove, etc. (See drawings MD-177035, and MC-177037 in the Appendix).

All initial tests were done with dacron, and without use of the aluminum wire. Mode of failure was the premature pull-out from the clamp. Installation of the aluminum wire solved this problem and shifted the mode of failure to the fabric. Dacron-mylar test sample was failing at approximately half the tensile strength listed for this fiber. The mylar failed also, just prior to the rupture of the fabric.

Due to unsatisfactory behavior of dacron (poor strength and excessive elasticity), Kevlar 29 became the focal point for further tests.

Based on preliminary analysis, the following fabric was purchased for evaluation:

- Style 735
- MIL-C-44050 (Military Spec.)
- 1500 Denier, Kevlar 29
- 2 x 2 Basket Weave
- 35 x 34 Count
- 1800 lb. x 1821 lb. Tensile Strength
- Vendor:

    Clark-Schwebel Fiber Glass Corp.
    5 Corporate Park Drive
    P. O. Box 851C
    White Plains, New York 10603
    J. E. McAdams - Sales

Test results are outlined in the following section.