SSLV307 - Cylinder obliques under load axial uniform

Summary:

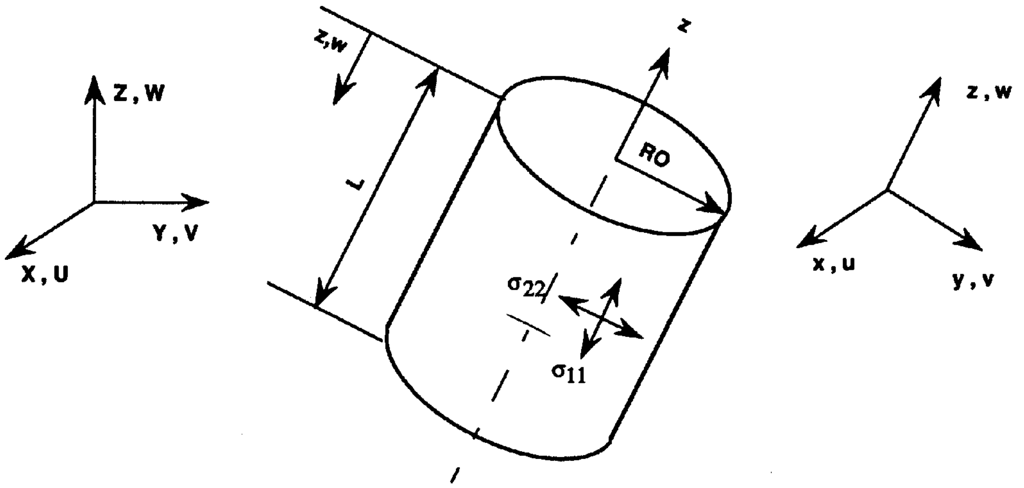
The purpose of the test is to validate the various types of linear relations, defined by the keywords LIAISON_DDL, LIAISON_OBLIQUE, LIAISON_GROUP.

It also makes it possible to test the option “symmetries cyclic” starting from the modeling of a sector of the cylinder.

The analysis is carried out in 3D.

1 Problem of reference

1.1 Geometry



Average radius: $R_o=1\,m$
Thickness: $h=0.02\,m$
Height: $L=4\,m$

Cosine directors of the axis of the cylinder: $(0.0\,,0{,}5\ ,\frac{\sqrt{3}}{2})$

Local axis x parallel with the total axis X.

1.2 Material properties

$E=2.1\times10^{11}\,Pa$

$\nu=0.3$

1.3 Boundary conditions and loadings

- Axial displacement no one at the low end $(w=0)$
  For the other boundary conditions (linear relations), to see paragraph [§3].
- Uniform axial loading per unit of length $q=10000\,N/m$, applied at the high end.

1.4 Initial conditions

Without object for the static analysis.

2 Reference solution

2.1 Method of calculating used for the reference solution

- Radial displacement in local reference mark (x, y, z) :

$$u_r = \frac{q\nu Ro}{Eh} = -\left[U^2 + \left(\frac{\sqrt{3}}{2}V - 0.5\,W\right)^2\right]^{1/2}$$

where U, V, W = component of displacement in the total reference mark (X, Y, Z).

- If $\sigma_{xx}, \sigma_{yy}\ \sigma_{zz} = \sigma_{11}$ are the constraints in the local reference mark, the constraints expressed in the total reference mark are worth:

$$\sigma_{xx} = \sigma_{xx}$$

$$= 3/4\sigma_{yy} + 1/4\sigma_{11} \qquad \sigma_{11} = q/h$$

$$\sigma_{zz} = 1/4\sigma_{yy} + 3/4\sigma_{11}$$

$$\sigma_{yz} = -\frac{\sqrt{3}}{4}\sigma_{yy} + \frac{\sqrt{3}}{4}\sigma_{11}$$

In the local plan $(x, z), \sigma_{yy} = 0$ (circumferential constraint),

from where $\sigma_{yy} 1/4\ \sigma_{11}, \sigma_{zz} = 3/4\ \sigma_{11}$

2.2 Results of reference

- Radial displacement: $u_r = -7.14\times10^{-7}\,m$
- In the local plan (x, z), $\sigma_{yy} = 1.25\times10^5\,Pa$, $\sigma_{zz} = 3.75\times10^5\,Pa$

2.3 Uncertainty on the solution

- Analytical solution

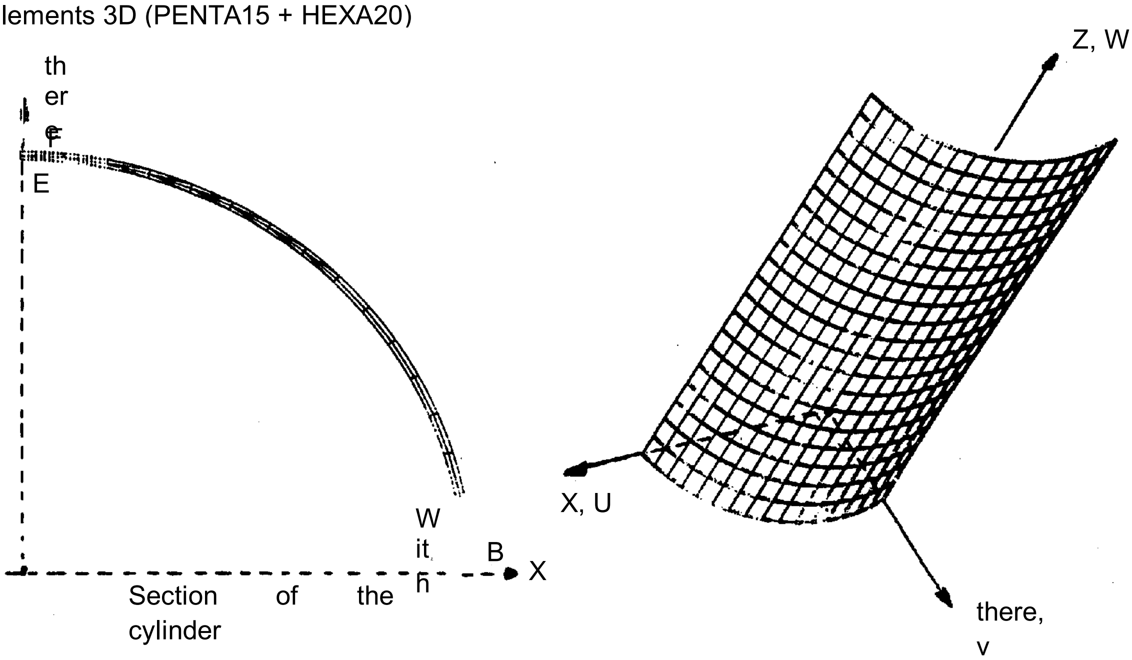
2.4 Bibliographical references

1) R.J. ROARK and W.C. YOUNG: Formulated for stress and strain, 5 è edition. New York, Mc Graw-Hill, 1975

3 Modeling A

3.1 Characteristics of modeling

Elements 3D (PENTA15 + HEXA20)



Modeling:

1/4 of the cylinder following the circumference
2 zones: zone 1 = lower part $(0 \le z \le L/2)$
zone 2 = upper part $(L/2 \le Z \le L)$

Cutting:

20 elements according to the length
16 elements according to the circumference
2 elements in the thickness

Coordinates of the points (r, θ, z)

	Wit h	G	B	E	G1	F	A2 A' 2	H H'	B2 B' 2	E2 E' 2	H1 H' 1	F2 F' 2	A3	I	B3	E3	I1	F3
r	IH	R	Re	IH	R	Re	IH	R	Re	IH	R	Re	IH	R	Re	IH	R	Re
θ	0.	0.	0.	90.	90.	90.	0.	0	.0.	90.	90.	90.	0.	0.	0.	90.	90.	90.
z	0.	0.	0.	0.	0.	0.	L/2	L/2	L/2	L/2	L/2	L/2	L	L	L	L	L	L

Ri = interior ray
Re = external ray

points $A2, H, B2, E2, H2, F2$ are in the section $z = L/2$ zone 1
points $A'2, H', B'2, E'2, H'2, F'2$ are opposite respective in zone 2

Boundary conditions:

- Conditions of support $w=0$ at the base (section $z=0.$) introduced by the keyword `LIAISON_OBLIQUE`
- Conditions of symmetry $v=0.$ on the face AB introduced by the keyword `LIAISON_OBLIQUE`
- Conditions of symmetry $u=0.$ on the face EF introduced by the keyword `LIAISON_OBLIQUE`
- Identification of the nodes common to the 2 zones (section $z=L/2$) by the keyword `LIAISON_GROUP`.

Loading:

Density of surface charge $p=q/h=500000\,N/m2$, along the axis, that is to say in total reference mark:

$$Fx=0.$$

$$Fy=p/2$$

$$Fz=p\frac{\sqrt{3}}{2}$$

Name of the nodes:

plan $z=0.$	$A=N\,1$	$B=N\,321$	$E=N\,1740$	$F=N\,1541$	$G=N\,1540$	
plan $z=2$ (zone 1)	$A2=N\,961$	$B2=N\,993$	$E2=N\,2141$	$F2=N\,2122$	$H=N\,962$	$H1=N\,2121$
plan $z=2$ (zone 2)	$A'2=N\,3361$	$B'2=N\,3364$	$E'2=N\,2159$	$F'2=N\,215$[illegible]	$H'=N\,3360$	$H'1=N\,2156$
plan $z=4$	$A3=N\,3359$	$B3=N\,3355$	$I=N\,3356$	$E3=N\,2151$	$F3=N\,2154$	$I1=N\,2150$

3.2 Characteristics of the grid

Many nodes: 4298

Many meshs and types: 160 HEXA20, 320 PENTA15

3.3 Values tested

Values of displacements U, V, W read on file

Localization	Type of value	Reference
Not G	$U(m)$	$-7{,}143 \times 10^{-7}$
	$V(m)$	0.
	$W(m)$	0.
Not H, H'	$U(m)$	$-7{,}143 \times 10^{-7}$
Not I	$U(m)$	$-7{,}143 \times 10^{-7}$

Not $G1$	$U(m)$	0.
Points $H1, H'1$	$U(m)$	0.

Values of displacements u, v, u_r in local reference mark calculated from U, V, W

Localization	Type of value	Reference
Not G	$u_r(m)$	$-7,143 \times 10^{-7}$
	$v(m)$	0.
Not H, H'	$u_r(m)$	$-7,143 \times 10^{-7}$
	$v(m)$	0.
Not I	$u_r(m)$	$-7,143 \times 10^{-7}$
	$v(m)$	0.
Not $A2, A'2$ Points $B2, B'2$	$v(m)$	0.
Not $G1$	$u(m)$	0.
	$u_r(m)$	$-7,143 \times 10^{-7}$
Points $H1, H'1$	$u(m)$	0.
	$u_r(m)$	$-7,143 \times 10^{-7}$
Not $I1$	$u(m)$	0.
	$u_r(m)$	$-7,143 \times 10^{-7}$
Points $E2, E'2$	$u(m)$	0.
Points $F2, F'2$	$u(m)$	0.
Points A, B, G $A2, B2, H$ $A'2, B'2, H'$ $A3, B3, I$	$\sigma_{YY}(Pa)$	1.25×10^{5}
Points A, B, G $A2, B2, H$ $A'2, B'2, H'$ $A3, B3, I$	$\sigma_{ZZ}(Pa)$	3.75×10^{5}

3.4 Remarks

- Radial displacement ur is obtained with a good precision.

- Conditions of symmetry on the face AB ($v=0$ locally, that is to say $\frac{\sqrt{3}}{2}V-05W=0$) are checked at the points $A2, A'2, G, B2, B'2, H, H', I$ considered.

In the same way, conditions of symmetry on the face EF ($u=U=0$) are checked at the points $E2, E'2, F2, F'2, G1, H1, H'1, I1$ considered.

The keyword LIAISON_OBLIQUE is thus validated.

- Identification of the nodes common to the 2 zones by the keyword LIAISON_GROUP is also validated: displacements U, V, W are identical to the points $A'2, B'2, H', E'2, F'2, H'1$ in comparison with displacements with opposite respective $A2, B2, H, E2, F2, H1$.