HSLA303 - Cylinder under pressure and thermal dilation

Summary:

Calculation is carried out into axisymmetric. The goal of the test is to validate them predeformations (keyword PRE_EPSI).

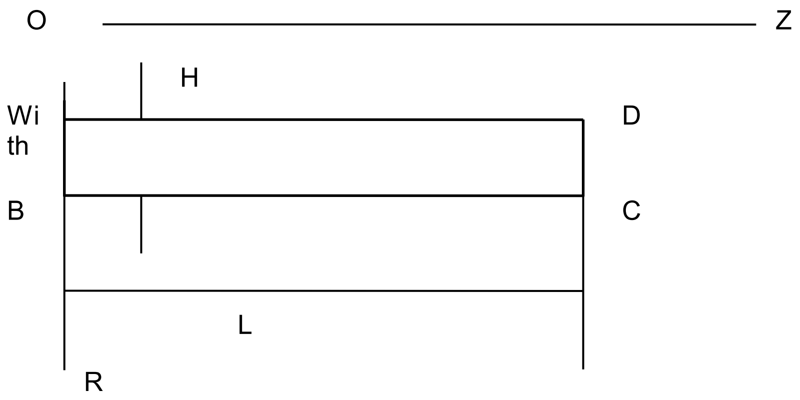
The cylinder is subjected to a homogeneous thermal dilation (ΔT constant).

The followed procedure is the following one:

- that is to say ε_1 the field of deformations resulting from one 1er calculation, the cylinder being subjected to a homogeneous thermal dilation ΔT (U_1 the field of resulting displacements),
- in the second calculation, the cylinder is subjected to an internal pressure, with like predeformations the field of deformations ε_1 (either U_2 the resulting field of displacements),
- one then compares the results with the field U, obtained with cylinder under pressure, but without predeformations. One must have the relation: $U_2 = U + U_1$.

1 Problem of reference

1.1 Geometry



Length: $L=1\,m$
Thickness: $h=0.0025\,m$
External ray: $\mathrm{Re}=0.05\,m$

1.2 Material properties

$E=2.1\times 10^{11}\,Pa$

$\nu=0.3$

$\alpha=0.12\,x\,10^{-4}/°C$

1.3 Boundary conditions and loadings

- Section AB in support (direction z),
- Thermal dilation in the thickness (calculation 1): $\Delta T=100\,°C$
- Internal pressure (calculation 2): $p=2\times 10^{8}\,N/m^{2}$
- Taking into account of the basic effect.

1.4 Initial conditions

Without object for the static analysis.

2 Reference solution

2.1 Method of calculating used for the reference solution

- The deformation due to direct compression is given by:

$$\varepsilon_{zz}=\frac{(1-2\nu)(2R_e-h)}{4Eh}p=3.714\times10^{-3}\ ,\ R_e=\text{ external ray}$$

- Axial displacement due to the pressure is given by:

$$U_z=Z\,\varepsilon_{zz}$$

- The deformations due to the thermal loading are worth:

$$\varepsilon_{rr}=\varepsilon_{\theta\theta}=\varepsilon_{zz}=\alpha\Delta T=1.2\times10^{-3}$$

- Radial displacement due to the thermal loading is worth:

$$U_r=r\,\varepsilon_{rr}=1.2\times10^{-3}r$$

2.2 Results of reference

- Deformation and radial and axial displacement at the points A,B,C,D had with the thermal loading.
- Deformation and axial displacement at the points A,B,C,D had with the pressure.

2.3 Uncertainty on the solution

Analytical solution.

3 Modeling A

3.1 Characteristics of modeling

AXIS, mesh $Q8$

Cutting: 10 elements according to the length
1 element in the thickness

Limiting conditions:

in A , B

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DDL_IMPO = (GROUP_NO = 'WITH', DY = 0. )
DDL_IMPO = (GROUP_NO = 'B', DY = 0. )
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Pressure + basic effect: field U

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PRES_REP:          (GROUP_MA = cont_pr, CLOSE = 2.E8)
FORCE_CONTOUR:     (GROUP_MA = effond  , FY = 1.95E9)
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Thermal dilation: field U_1

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char_no:
CREA_CHAMP         (AFFE = (ALL = 'YES', NOM_CMP = 'TEMP', VALE = 100.))


char_th:
AFFE_MATERIAU      (AFFE_VARC = F (ALL = 'YES', CHAM_GD = CHAR_NO, VALE_REF =
                   0. , NOM_VARC = 'TEMP',  )
```

Predeformations: field U_2

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PRE_EPSI:          (ALL = 'YES', EPXX = 1.2E-3, EPYY = 1.2E-3,
                   EPZZ = 1.2E-3,  EPXY = 0.)
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Names of the nodes:

$A=N1$ $B=N2$ $C=N3$ $D=N4$

3.2 Characteristics of the grid

Many nodes: 53

Many meshs and types: 10 QUAD8, 22 SEG3

3.3 Sizes tested and results

Results concerning the fields U_1 , U_2 , U

Field	Localization	Variables	Reference
Thermal field U_1	A	$Ur(DX)$	5.7 X 10^{-5}
	B	$Ur(DX)$	6 X 10^{-5}
	C	$Ur(DX)$	6 X 10^{-5}
		DY	1.2 X 10^{-3}
	D	$Ur(DX)$	5.7 X 10^{-5}
		$U(DY)$	1.2 X 10^{-3}
	A , mesh $M1$	ε_{rr}	1.2 X 10^{-3}
		$\varepsilon_{\theta\theta}$	1.2 X 10^{-3}
		ε_{zz}	1.2 X 10^{-3}
	B , mesh $M1$	ε_{rr}	1.2 X 10^{-3}
		$\varepsilon_{\theta\theta}$	1.2 X 10^{-3}
		ε_{zz}	1.2 X 10^{-3}
	C , mesh $M10$	ε_{rr}	1.2 X 10^{-3}
		$\varepsilon_{\theta\theta}$	1.2 X 10^{-3}
		ε_{zz}	1.2 X 10^{-3}
	D , mesh $M10$	ε_{rr}	1.2 X 10^{-3}
		$\varepsilon_{\theta\theta}$	1.2 X 10^{-3}
		ε_{zz}	1.2 X 10^{-3}
Field of pressure U	C	$U_\theta(DY)$	3,714 X 10^{-3}
	D	$U_\theta(DY)$	3,714 X 10^{-3}
	C , mesh $M10$	$\varepsilon_{\theta\theta}$	3,714 X 10^{-3}
	D , mesh $M10$	$\varepsilon_{\theta\theta}$	3,714 X 10^{-3}
Field U_2	C	$U_{\theta\theta}$	4,914 X 10^{-3}
	D	$U_{\theta\theta}$	4,914 X 10^{-3}
	C , mesh	$\varepsilon_{\theta\theta}$	4,914 X 10^{-3}
	D , mesh	$\varepsilon_{\theta\theta}$	4,914 X 10^{-3}

3.4 Remarks

- The goal of the test is not to obtain a high degree of accuracy on the level of the results, but simply to check the relation: $U_2=U+U_1$; so calculation was carried out only with one coarse grid.
- It is noted that the required relation is well checked at the loose lead of the cylinder.
- It is checked in addition that the field of deformation resulting from thermal dilation is uniformly equal to 1.2×10^{-3} .

4 Summary of the results

The option PRE_EPSI (predeformations into constant) provides completely satisfactory results.