HSLS01 - Thin square the purpose of plate subjected to a heat gradient in the thickness

Summarized

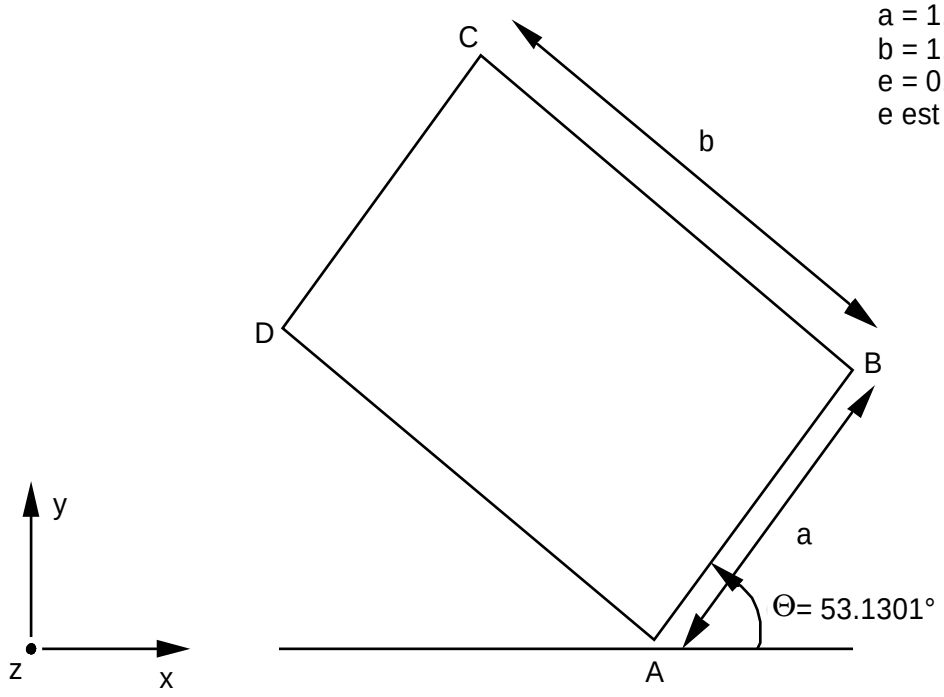
This test is validating thermal thermal expansion in the shell elements, where the temperature is variable in the thickness.

Two modelizations make it possible to test modelizations DKT, DST, Q4G on meshes TRIA3 and QUAD4 and COQUE_3D on meshes the TRIA7 and QUAD9.

1 Problem of reference

1.1 Geometry

a = 1.2 m
b = 1.3 m
e = 0.01 m
e est l'épaisseur de la plaque



1.2 Properties of the materials

Young's modulus: $E=2.10^{11}\,Pa$
Poisson's ratio: $\nu=0.3$
Coefficient of thermal expansion: $\alpha=1.10^{-5}\circ C^{-1}$

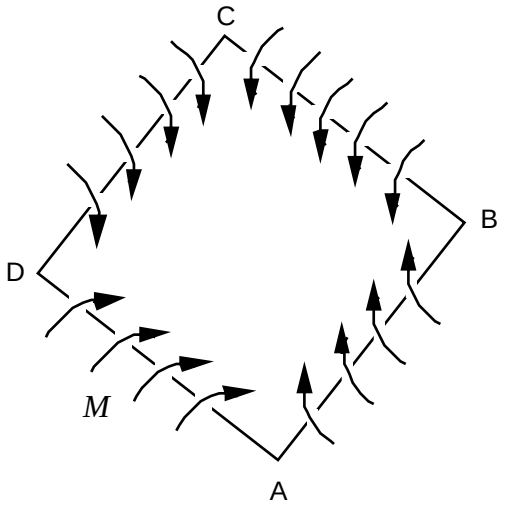
1.3 Boundary conditions and loadings

the sides AB BC, CD and DA are clamped. The temperature is constant on the upper face and is equal to $T_s=100\,^\circ C$.
The temperature is constant on the lower face and is equal to $T_i=0\,^\circ C$; the variation in temperature is supposed to be linear in the thickness.

2 Reference solution

2.1 Method of calculating used for the reference solution

the solution is analytical.



The thermal loading is equivalent to a loading defined by a uniform distribution of moments on edges such as it appears on the figure.

The value of these moments per unit of length is equal to: $M = \alpha \frac{T_s - T_i}{e} \times \frac{E \times e^3 \times (1+\nu)}{12\left(1-\nu^2\right)}$.

That is to say: $M = \alpha \left(T_s - T_i\right) \times \frac{E \times e^2}{12(1-\nu)}$. This led to a uniform distribution of M in the plate.

2.2 Results of reference

One thus has $M = 2380.95238\,N$; the plate being turned of an angle $\theta = 53°.1301$, one has of the components whose absolute value is: $M \times \cos\theta = 1428.5715\,N$ and the $M \times \sin\theta = 1904.76184\,N$

reactions are defined by a distribution of moments equal to the preceding one in absolute value and of contrary sign.

Meshes are squares of which the length is equal to $0.05\,m$, therefore the moments in each node must be equal to $M_1 = M \times \cos\theta \times 0.05 = 71.42857\,N.m$

and $M_2 = M \times \sin\theta \times 0.05 = 95.2381\,N.m$

is $M = \sqrt{M_1^2 + M_2^2}$ = 119.0476 N.m

2.3 Uncertainty on the solution

uncertainty is null.

2.4 Bibliographical references

1) TIMOSHENKO: Theory of punts and shells chapter 2, article 14.

3 Modelization A

3.1 Characteristic of the modelization

The model consists of:

- 1008 elements,
- 675 nodes,

of which:

- 72 éléme nts Q4G,
- 144 elements T3G,
- 84 elements DSQ,
- 84 elements DKQ,
- 312 elements DST,
- 312 elements DKT.

The elements are squares of which the length is equal to $0.05\,m$.

The edges AB BC , CD and DA are clamped.

The plate is subjected to a variation in temperature of $100\,°C$ in the thickness. This gradient is uniform on the plate.

3.2 Quantities tested and results

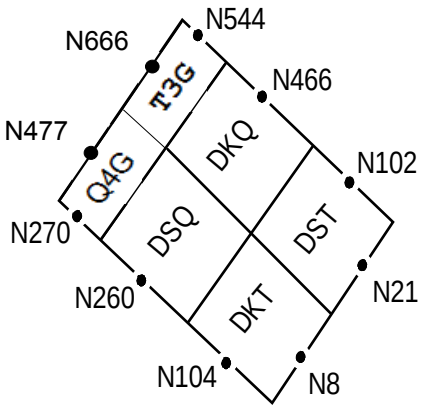
Rx = reaction according to Ox
Ry = reaction according to Oy

Standard	Identification of reference	Reference	Tolerance
$N104$ (on edge AD in the part with a grid in DKT)	"ANALYTIQUE"	$DRx=71.4286$ $DRy=95.2381$	3.10^{-5} 3.10^{-5}
$N260$ (on edge AD in the part with a grid in DSQ)	"ANALYTIQUE"	$DRx=71.4286$ $DRy=95.2381$	3.10^{-5} 3.10^{-5}
$N270$ (on edge AD in the part with a grid in Q4G)	"ANALYTIQUE"	$DRx=71.4286$ $DRy=95.2381$	3.10^{-5} 3.10^{-5}
$N8$ (on edge AB in the part with a grid in DKT)	"ANALYTIQUE"	$DRx=95.2381$ $DRy=71.4286$	3.10^{-5} 3.10^{-5}
$N21$ (on edge AB in the part with a grid in DST)	"ANALYTIQUE"	$DRx=95.2381$ $DRy=71.4286$	3.10^{-5} 3.10^{-5}
$N102$ (on edge BC in the part with a grid in DST)	"ANALYTIQUE"	$DRx=71.4286$ $DRy=95.2381$	3.10^{-5} 3.10^{-5}
$N466$ (on edge BC in the part with a grid in DKQ)	"ANALYTIQUE"	$DRx=71.4286$ $DRy=95.2381$	3.10^{-5} 3.10^{-5}

$N544$ (on edge BC in the part with a grid in T3G)	"ANALYTIQUE"	$DRx=71.4286$ $DRy=95.2381$	3.10^{-5} 3.10^{-5}
$N477$ (on edge CD in the part with a grid in Q4G)	"ANALYTIQUE"	$DRx=71.4286$ $DRy=95.2381$	3.10^{-5} 3.10^{-5}
$N666$ (on edge CD in the part with a grid in T3G)	"ANALYTIQUE"	$DRx=71.4286$ $DRy=95.2381$	3.10^{-5} 3.10^{-5}

3.3 Remarks

the nodes tested are about placed as follows:



4 Modelization B

4.1 Characteristic of the modelization

The modelization is COQUE_3D.

The model consists of:

- 662 elements,
- 2267 nodes,

of which:

- 462 triangles with 7 nodes,
- 200 quadrilaterals with 9 nodes.

The edges AB BC, CD and DA are clamped.

The plate is subjected to a variation in temperature of $100\,°C$ in the thickness. This gradient is uniform on the plate.

4.2 Quantities tested and results

One tests the moments MXX and MYY. These values are given in the local coordinate system to the plate, chosen parallel at the sides.

One thus has: $MXX = MYY = M = -2{,}38095\,10^{3}\,N$ as the moment is uniform in the plate, it is enough to test the values maximum and minimum of the moments and to check that they are both equal to M:

	Standard	identification of reference	Reference	Tolerance (%)
Forces obtained by EFGE_ELNO :	MXX Maximum	"ANALYTIQUE"	– 2,38095 103.0.1	
	MXX Minimum	"ANALYTIQUE"	– 2,38095 103.0.1	
	MYY Maximum	"ANALYTIQUE"	– 2,38095 103.0.1	
	MYY Minimum	"ANALYTIQUE"	– 2,38095 103.0.1	

5 Summary of the results

the perfect adequacy of the results with the analytical reference shows the good taking into account of the variation in the temperature.