LE3: Hemispherical shell with point loads

This problem provides evidence that Abaqus can reproduce the result from the benchmark defined by NAFEMS and cited as the reference solution.

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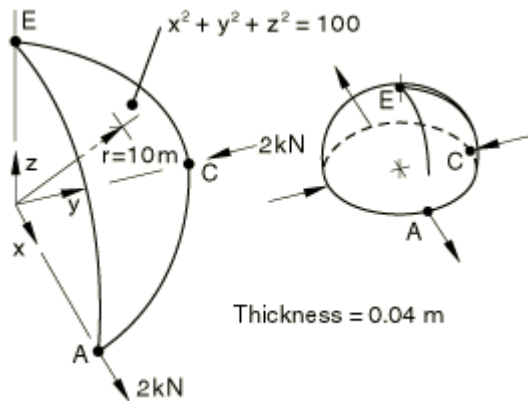- [Input files](#)

ProductsAbaqus/StandardAbaqus/Explicit

Elements tested

- S3
- S3R
- S4
- S4R
- S4R5
- S8R
- S8R5
- S9R5
- STRI3
- STRI65
- SC6R
- SC8R

- SAXA12
- SAXA22

Problem description

Model:

The model is illustrated in the figure above. In addition, two input files are provided for the continuum shell element model to illustrate the use of the STACK DIRECTION=ORIENTATION parameter to define the element thickness (stacking) direction independent of the nodal connectivity using a spherical system.

Material:

Linear elastic, Young's modulus = 68.25 GPa, Poisson's ratio = 0.3.

Boundary conditions:

ux=uy=uz= 0 at point E. Along edge AE, symmetry about the z–x plane. Along edge CE, symmetry about the y–z plane.

Loading:

Concentrated radial loads of 2 kN outward at A, inward at C.

Reference solution

This is a test recommended by the National Agency for Finite Element Methods and Standards (U.K.): Test LE3 from NAFEMS publication TNSB, Rev. 3, "The Standard NAFEMS Benchmarks," October 1990.

Target solution: ux= 185 mm at point A.

Results and discussion

The values enclosed in parentheses are percentage differences with respect to the reference solution.

Element	ux at A (Coarse)	ux at A (Fine)
S3/S3R	0.080 (−57%)	0.161 (−13%)
S4	0.083 (−55%)	0.175 (−5%)
S4R	0.180 (−2.7%)	0.180 (−2.7%)
S4R*	0.072 (−61%)	0.170 (−8.1%)
S4R**	0.058 (–68%)	0.168 (–9.1%)
S4R5	0.190 (2.7%)	0.183 (−1.1%)
S8R	0.101 (−45%)	0.178 (−3.8%)
S8R5	0.179 (−3.2%)	0.185 (0.0%)
S9R5	0.179 (−3.2%)	0.185 (0.0%)
STRI3	0.173 (−1.2%)	0.185 (0.0%)
STRI65	0.169 (−8.6%)	0.182 (−1.6%)
SC6R	0.088 (−52.4%)	0.167 (−9.7%)
SC8R	0.210 (13.5%)	0.188 (1.6%)
SC8R***	0.194(4.9%)	0.185(0.0%)
SAXA12****	0.179 (−3.2%)	
SAXA22****	0.178 (−3.8%)	

* Abaqus/Explicit finite-strain element with enhanced hourglass control.
**Abaqus/Standard finite-strain element with enhanced hourglass control.
*** Abaqus/Explicit continuum shell element with the default "relax stiffness" hourglass control. **** Due to the loading position, only the Mode 2 and Mode 4 elements can be used. Furthermore, due to the symmetries of the problem, only the Fourier interpolator cos2θ contributes to the solution. Thus, the Mode 4 elements produce identical results. Since Mode 4 is the highest-order Fourier term provided, no further circumferential mesh refinement is possible, and only coarse mesh results can be obtained.

The continuum shell element meshes using the STACK DIRECTION=ORIENTATION parameter yield identical results to the continuum shell element meshes in which the thickness direction is defined by the element nodal connectivity.

Input files

Abaqus/Standard input files

nle3xf3x.inp

 S3/S3R elements.

nle3xe4x.inp

 S4 elements.

nle3xf4x.inp

S4R elements.

[nle3xf4x_eh.inp](nle3xf4x_eh.inp)

S4R elements with enhanced hourglass control.

[nle3x54x.inp](nle3x54x.inp)

S4R5 elements.

[nle3x68x.inp](nle3x68x.inp)

S8R elements.

[nle3x58x.inp](nle3x58x.inp)

S8R5 elements.

[nle3x59x.inp](nle3x59x.inp)

S9R5 elements.

[nle3x63x.inp](nle3x63x.inp)

STRI3 elements.

[nle3x56x.inp](nle3x56x.inp)

STRI65 elements.

nle3xntx.inp

SAXA12 elements.

nle3xnxx.inp

SAXA22 elements.

[nle3_std_sc6r.inp](nle3_std_sc6r.inp)

SC6R elements.

[nle3_std_sc8r.inp](nle3_std_sc8r.inp)

SC8R elements.

nle3_std_sc6r_stackdir_sphori.inp

SC6R elements using the STACK DIRECTION=ORIENTATION parameter with a spherical orientation system to define the element thickness direction.

nle3_std_sc8r_stackdir_sphori.inp

SC8R elements using the STACK DIRECTION=ORIENTATION parameter with a spherical orientation system to define the element thickness direction.

nle3_std_sc8r_sgs.inp

SC8R elements using SHELL GENERAL SECTION to define section properties.

Abaqus/Explicit input files

le3_s4r.inp

S4R elements with enhanced hourglass control.

le3_sc8r.inp

SC8R elements with the default "relax stiffness" hourglass control.