LE2: Cylindrical shell bending patch test

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

This page discusses:

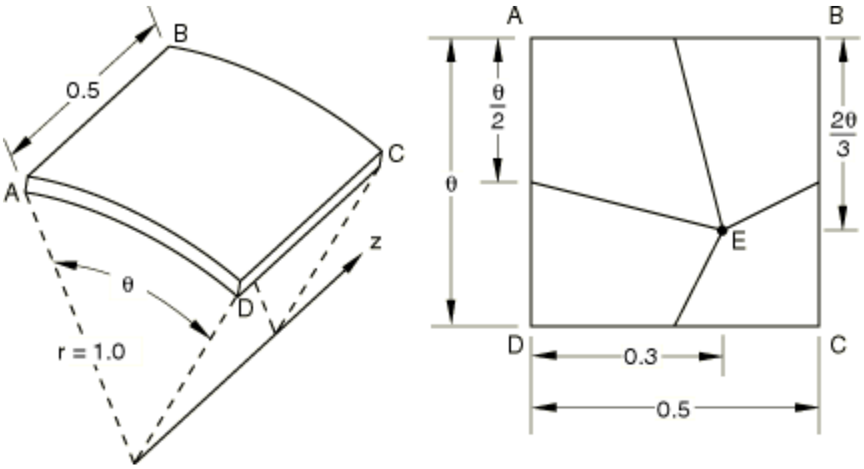
ProductsAbaqus/StandardAbaqus/Explicit

Elements tested

- S3
- S3R
- S3RS
- S4
- S4R
- S4R5
- S4RS
- S4RSW
- S8R
- S8R5
- S9R5

- STRI3
- STRI65
- SC6R
- SC8R

Problem description



Model:

Sector of cylindrical shell with a thickness t= 0.01 m.

Material:

Linear elastic, Young's modulus = 210 GPa, Poisson's ratio = 0.3, density = 7800 kg/m^3.

Boundary conditions:

Edge AB is clamped. Axial displacements are constrained along edges AD and BC.

Loading:

Uniform normal edge moment of 1000/unit length along edge DC. In the explicit dynamic analysis the loading is applied such that a quasi-static solution is obtained.

Reference solution

This is a test recommended by the National Agency for Finite Element Methods and Standards (U.K.): Test LE2 from NAFEMS publication TNSB, Rev. 3, “The Standard NAFEMS Benchmarks,” October 1990.

Stress: Outer surface tangential stress at point E is 60 MPa.

Results and discussion

The results shown in Table 1 through Table 4 are interpolated from the integration points to the required nodal location. The values enclosed in parentheses are percentage differences with respect to the reference solution.

Table 1. Abaqus/Standard analysis, θ= 30°.

Element	**Bottom Surface (MPa)**	**Top Surface (MPa)**
S3/S3R	−44.3 (–26%)	40.6 (–32%)
S4	−63.2 (5%)	54.0 (–10%)
S4R	−58.0 (–3%)	58.0 (–3%)
S4R*	–55.0 (–8%)	55.2 (–8%)
S4R5	−58.6 (–2%)	58.6 (−2%)
S8R	−50.7 (−16%)	50.4 (−16%)
S8R5	−57.8 (−4%)	58.2 (−3%)
S9R5	−57.9 (−4%)	58.3 (−3%)
STRI3	−37.9 (−37%)	36.0 (−40%)
STRI65	−53.6 (−11%)	53.9 (−10%)
SC6R	–43.9 (−27%)	43.9 (−27%)
SC8R	−59.7 (−1%)	59.7 (−1%)
SC8R*	–54.8 (–9%)	–54.8 (–9%)

*Abaqus/Standard results with enhanced hourglass control.

Table 2. Abaqus/Explicit analysis, θ= 30°.

Element	**Bottom Surface (MPa)**	**Top Surface (MPa)**
S3R	−43.2 MPa (−28%)	39.7 MPa (−34%)
S3RS	−44.7 MPa (−26%)	42.2 MPa (−30%)
S4R	−58.2 MPa (−3%)	58.3 MPa (−2.8%)
S4RS	−57.0 MPa (−5%)	56.9 MPa (−5.2%)
S4RSW	−57.3 MPa (−4.5%)	57.4 MPa (−4.3%)

These results vary significantly from the target value since the mesh is too coarse to capture a curvature of θ= 30°. The mesh can be refined easily by reducing the arc angle to θ= 10°. The following results show that such mesh refinement greatly improves the accuracy of the results.

Table 3. Abaqus/Standard analysis, θ= 10°.

Element	**Bottom Surface (MPa)**	**Top Surface (MPa)**
S3/S3R	−60.1 (0.2%)	59.9 (−0.2%)
S4	−60.5 (0.8%)	59.5 (−0.8%)
S4R	−60.0 (0%)	60.0 (0%)
S4R*	–60.0 (0%)	60.0 (0%)
S4R5	−60.0 (0%)	60.0 (0%)
S8R	−59.6 (−0.7%)	59.7 (−0.5%)
S8R5	−59.9 (−0.2%)	60.0 (0%)

Element	Bottom Surface (MPa)	Top Surface (MPa)
S9R5	−59.7 (–0.5%)	60.0 (0%)
STRI3	−60.8 (1.3%)	60.8 (1.3%)
STRI65	−59.6 (−0.7%)	59.7 (−0.5%)
SC6R	–60.2 (0.3%)	60.2 (0.3%)
SC8R	–60.2 (0.3%)	60.2 (0.3%)
SC8R*	–60.2 (0.3%)	60.2 (0.3%)

*Abaqus/Standard results with enhanced hourglass control.

Table 4. Abaqus/Explicit analysis, θ= 10°.

Element	Bottom Surface (MPa)	Top Surface (MPa)
S3R	−60.2 MPa (−0.3%)	59.9 MPa (−0.1%)
S3RS	−60.0 MPa (0%)	59.8 MPa (−0.3%)
S4R	−60.0 MPa (0%)	60.0 MPa (0%)
S4RS	−60.1 MPa (−0.1%)	60.1 MPa (−0.1%)
S4RSW	−60.0 MPa (0%)	59.9 MPa (−0.2%)

Input files

Abaqus/Standard input files

θ = 30°:

nle2xf3c.inp

S3/S3R elements.

nle2xe4c.inp

S4 elements.

nle2xf4c.inp

S4R elements.

nle2xf4c_eh.inp

S4R elements with enhanced hourglass control.

nle2x54c.inp

S4R5 elements.

nle2x68c.inp

S8R elements.

nle2x58c.inp

S8R5 elements.

nle2x59c.inp

S9R5 elements.

nle2x63c.inp

STRI3 elements.

nle2x56c.inp

STRI65 elements.

nle2_std_sc6r_30.inp

SC6R elements.

nle2_std_sc8r_30.inp

SC8R elements.

nle2_std_sc8r_30_eh.inp

SC8R elements with enhanced hourglass control.

$\theta = 10°$:

nle2xf3f.inp

S3/S3R elements.

nle2xe4f.inp

S4 elements.

nle2xf4f.inp

S4R elements.

nle2xf4f_eh.inp

S4R elements with enhanced hourglass control.

nle2x54f.inp

S4R5 elements.

nle2x68f.inp

S8R elements.

nle2x58f.inp

S8R5 elements.

nle2x59f.inp

S9R5 elements.

nle2x63f.inp

STRI3 elements.

nle2x56f.inp

STRI65 elements.

nle2_std_sc6r_10.inp

SC6R elements.

nle2_std_sc8r_10.inp

SC8R elements.

nle2_std_sc8r_10_eh.inp

SC8R elements with enhanced hourglass control.

Abaqus/Explicit input files

$\theta = 30°$:

le2_s3r_c.inp

S3R elements.

le2_s3rs_c.inp

S3RS elements.

le2_s4r_c.inp

S4R elements.

le2_s4rs_c.inp

S4RS elements.

le2_s4rsw_c.inp

S4RSW elements.

$\theta = 10°$:

le2_s3r_f.inp

S3R elements.

le2_s3rs_f.inp

S3RS elements.

le2_s4r_f.inp

S4R elements.

le2_s4rs_f.inp

S4RS elements.

le2_s4rsw_f.inp

S4RSW elements.