

Full Flex Validation using The Standard NAFEMS Benchmarks

Linear Elastic Test

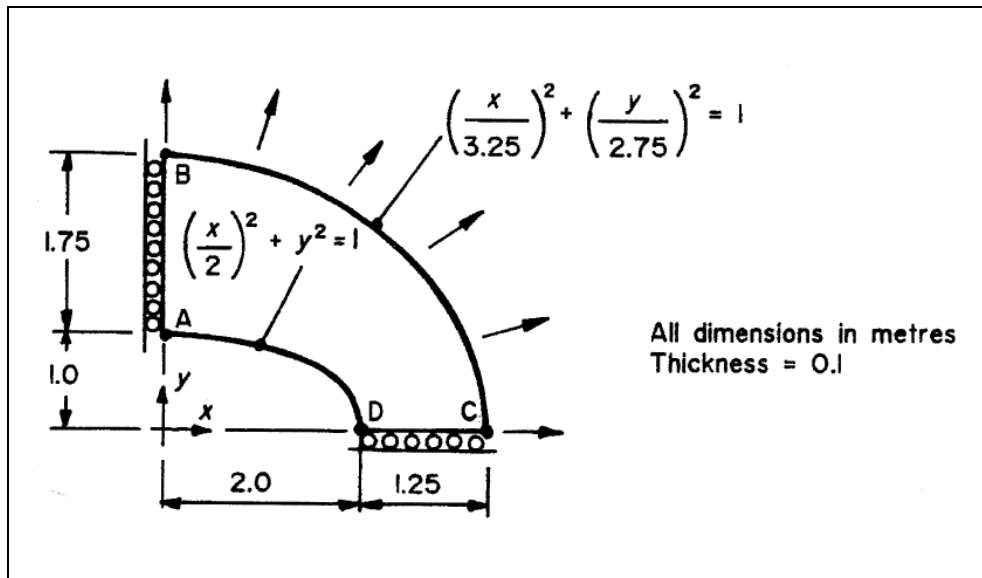
The linear elastic test was performed to validate Full Flex of RecurDyn using The Standard NAFEMS Benchmarks.

Ref. National Agency for Finite Element Methods & Standards (U.K.), The standard NAFEMS benchmarks, TNSB, Rev. 3, October 1990.

LE 01: Elliptic membrane

● Test Description

● Geometry



- Loading Condition
 - Outward pressure of 10MPa (Edge BC)
- Boundary Condition
 - Zero x-displacement (Edge AB)

- Zero y-displacement (Edge CD)
- Material properties
 - Isotropic, $E = 210e3$ MPa, $\nu = 0.3$
- Output
 - Tangential edge stress (σ_{yy}) at D

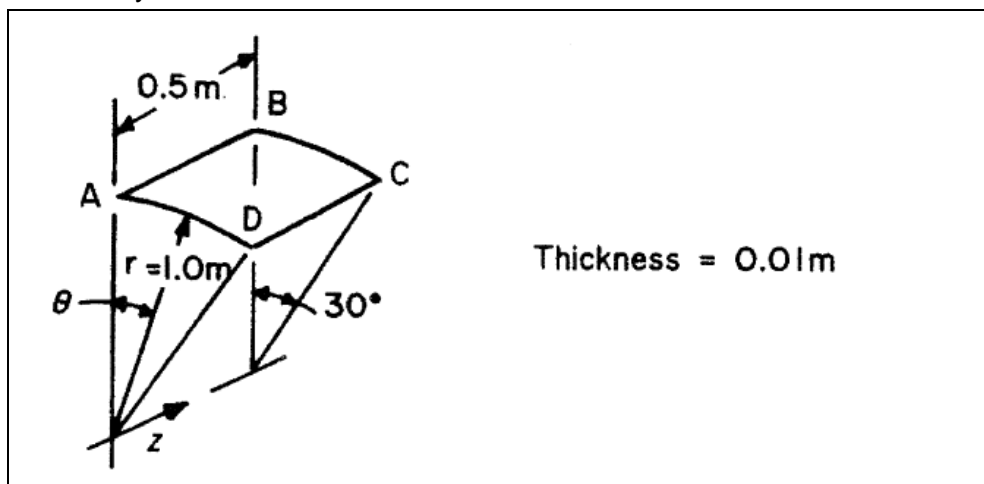
● Results

Element / Mesh	Target value (MPa)	RecurDyn (MPa)	Error (%)
Shell3 - Coarse	92.7	52.94	42.89
Shell3 - Fine		70.83	23.59
Shell4 - Coarse		87.69	5.40
Shell4 - Fine		93.32	0.67
Shell9 - Coarse		90.47	2.41
Shell9 - Fine		100.02	7.90

LE 02: Cylindrical shell patch test

● Test Description

- Geometry



- Loading Condition
 - Case 1: Normal edge moment of 1.0kNm/m (Edge DC)

- Case 2: Outward normal pressure of 0.6MPa (Mid-surface ABCD), Tangential outward normal pressure of 60.0MPa (Edge DC)
- Boundary Condition
 - Zero translation and rotation (Edge AB)
 - Zero z-translation and normal rotations (Edge AD and Edge BC)
- Material properties
 - Isotropic, $E = 210e3$ MPa, $\nu = 0.3$
- Output
 - Outer surface tangential ($\theta - \theta$) stress at point E

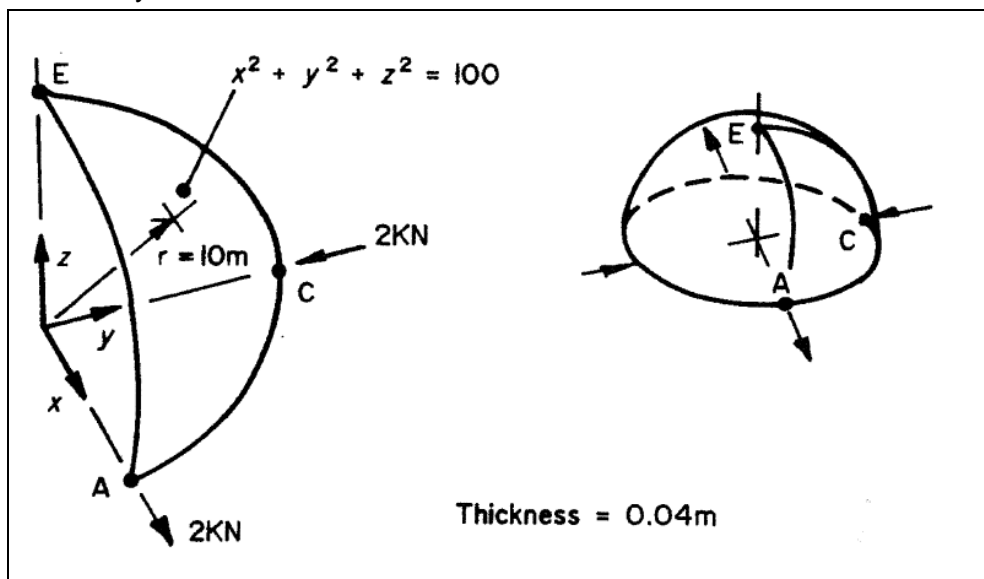
● Results

Element / case	Target value (MPa)	RecurDyn (MPa)	Error (%)
Shell4 – Case1	60.0	56.42	5.97
Shell9 – Case1		32.73	45.45
Shell4 – Case2		78.64	31.07
Shell9 – Case2		76.95	28.25

LE 03: Hemisphere-point loads

● Test Description

- Geometry



- Loading Condition
 - Concentrated radial load of 2kN (Outward at A, Inward at C)
- Boundary Condition
 - Zero z-displacement (Point E)
 - Zero y-displacement and zero normal rotation (Edge AE)
 - Zero x-displacement and zero normal rotation (Edge CE)
- Material properties
 - Isotropic, $E = 68.25 \times 10^3 \text{ MPa}$, $\nu = 0.3$
- Output
 - x-displacement at point A

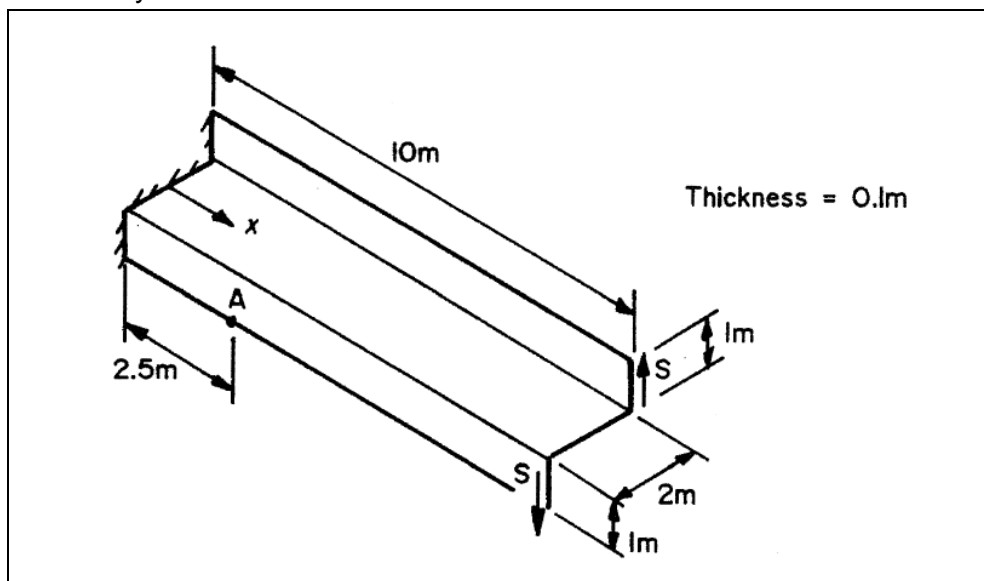
● Results

Element / mesh	Target value (mm)	RecurDyn (mm)	Error (%)
Shell4 – Fine	0.185	0.172	7.03
Shell9 – Fine		0.148	20

LE 05: Z-Section cantilever

● Test Description

- Geometry



- Loading Condition
 - Torque of 1.2MNm applied at $x = 10$ by two uniformly distributed.
- Boundary Condition
 - Zero displacements at edge $x = 0$
- Material properties
 - Isotropic, $E = 210e3$ MPa, $\nu = 0.3$
- Output
 - Axial (x - x) stress at mid-surface, point A

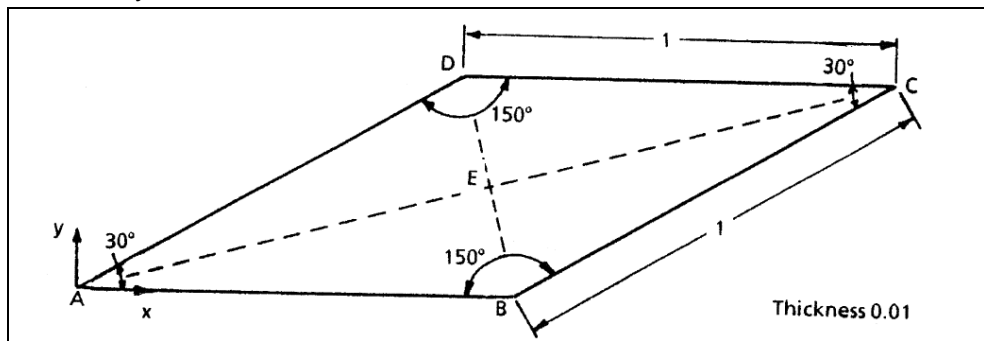
● Results

Element	Target value (MPa)	RecurDyn (MPa)	Error (%)
Shell4	-108	-122.97	13.86
Shell9	-108	-108.65	0.60

LE 06: Skew plate normal pressure

● Test Description

● Geometry



- Loading Condition
 - Normal pressure -0.7kPa in the vertical z -direction
- Boundary Condition
 - Zero z -displacement at all edge (AB, BC, CD, DA)
- Material properties
 - Isotropic, $E = 210e3$ MPa, $\nu = 0.3$

- Output
 - Max. principal stress on the lower surface at point E

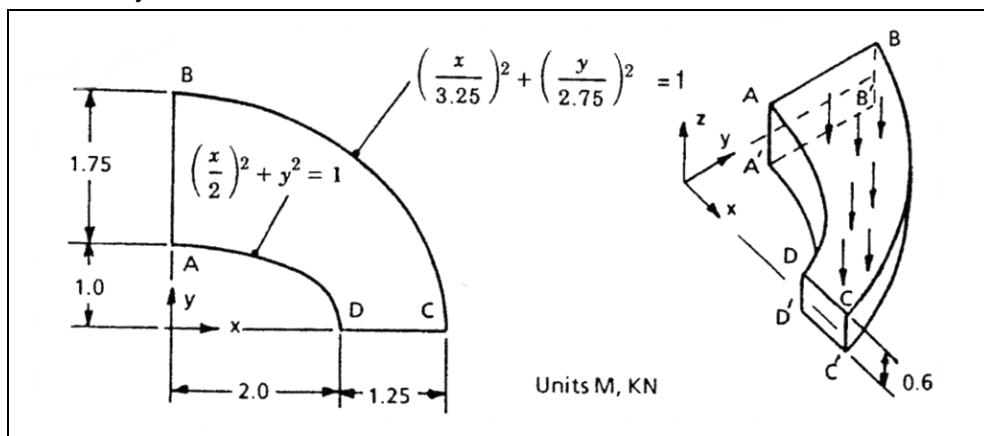
● Results

Element / mesh	Target value (MPa)	RecurDyn (MPa)	Error (%)
Shell3 – Coarse	0.802	0.379	52.74
Shell3 – Fine		0.678	15.46
Shell4 – Coarse		0.153	80.92
Shell4 – Fine		0.788	1.75
Shell9 – Coarse		0.127	84.16
Shell9 – Fine		0.364	54.61

LE 10: Thick plate pressure

● Test Description

● Geometry



- Loading Condition
 - Normal pressure of 1MPa on the upper surface of the plate
- Boundary Condition
 - Zero y-displacement (Face DCD'C')
 - Zero x-displacement (Face ABA'B')

- Zero x, y-displacement, zero z-displacement along mid-plane (Face BCB'C')
- Material properties
 - Isotropic, $E = 210e3$ MPa, $\nu = 0.3$
- Output
 - Direct stress (σ_{yy}) at point D

● Results

Element / mesh	Target value (MPa)	RecurDyn (MPa)	Error (%)
Solid4 – Fine	5.38	2.41	55.20
Solid10 – Fine		5.30	1.49
Solid6 – Coarse		5.45	1.30
Solid6 – Fine		6.09	13.20
Solid8 – Coarse		7.70	43.12
Solid8 – Fine		6.86	27.51
Solid26 – Coarse		6.24	15.99
Solid26 – Fine		6.62	23.05

Linear Thermo-elastic Test

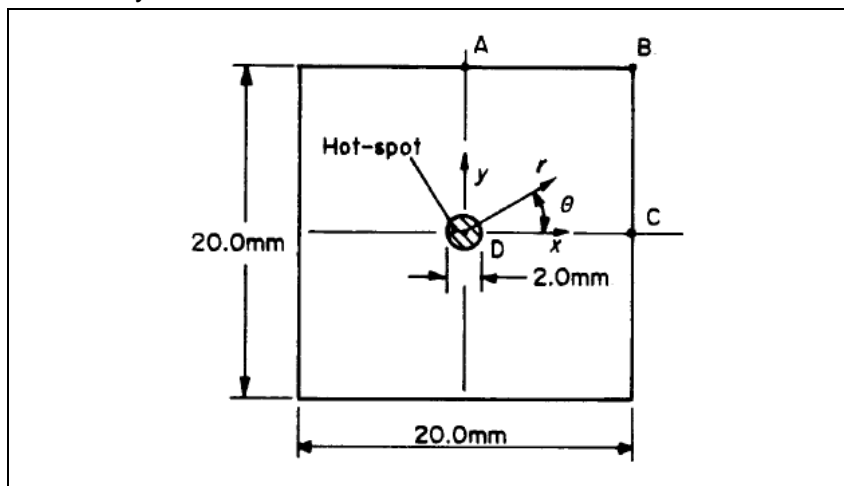
The linear thermo-elastic test was performed to validate Full Flex of RecurDyn using The Standard NAFEMS Benchmarks.

Ref. National Agency for Finite Element Methods & Standards (U.K.), The standard NAFEMS benchmarks, TNSB, Rev. 3, October 1990.

T 01: Membrane with hot-spot

● Test Description

● Geometry



● Loading Condition

- Within hot-spot ($0 \leq r \leq 1.0\text{mm}$); thermal strain (αT) = $1.0\text{e-}3$
- Outboard of hot-spot ($r > 1.0\text{mm}$); thermal strain (αT) = 0

● Boundary Condition

- On quarter model, symmetry condition
- Zero x-displacement (Edge OA)
- Zero y-displacement (Edge OC)

● Material properties

- Isotropic, $E = 100\text{e}3 \text{ MPa}$, $\nu = 0.3$

● Output

- Direct stress (σ_{yy}) at point D, outside hot-spot

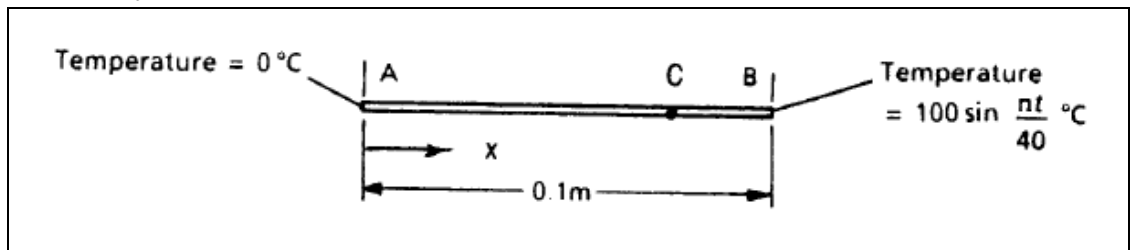
● Results

Element / Mesh	Target value (MPa)	RecurDyn (MPa)	Error (%)
Shell4	50.0	50.74	1.48

T 03: One dimensional transient heat transfer

● Test Description

● Geometry



● Loading Condition

- Zero internal heat generation

● Boundary Condition

- At time $t = 0$, All temperature = $0\text{ }^{\circ}\text{C}$
- At time $t > 0$, Temperature = $0\text{ }^{\circ}\text{C}$ at point A,

$$\text{Temperature} = 100 \sin \frac{\pi t}{40} \text{ }^{\circ}\text{C} \text{ at point B}$$

● Material properties

- Conductivity = $35.0\text{ W/m}^{\circ}\text{C}$
- Specific heat = $440.5\text{ J/kg}^{\circ}\text{C}$
- Density = 7200 kg/m^3

● Output

- Direct stress (σ_{yy}) at point D, outside hot-spot

● Results

Element / Mesh	Target value ($^{\circ}\text{C}$)	RecurDyn ($^{\circ}\text{C}$)	Error (%)
Shell4 - coarse	36.6	54.24	48.20
Shell4 - fine		37.74	3.11

Solid8 - coarse		38.35	4.78
Solid8 - fine		37.74	3.11