

Phase I: Model1, Model3 and Some Fracture Mechanics of the Liner

NRC Headquarters, Standard Problem Exercise, April 13 - 14, Washington DC
By: Jukka Kähkönen and Mari Vuorinen

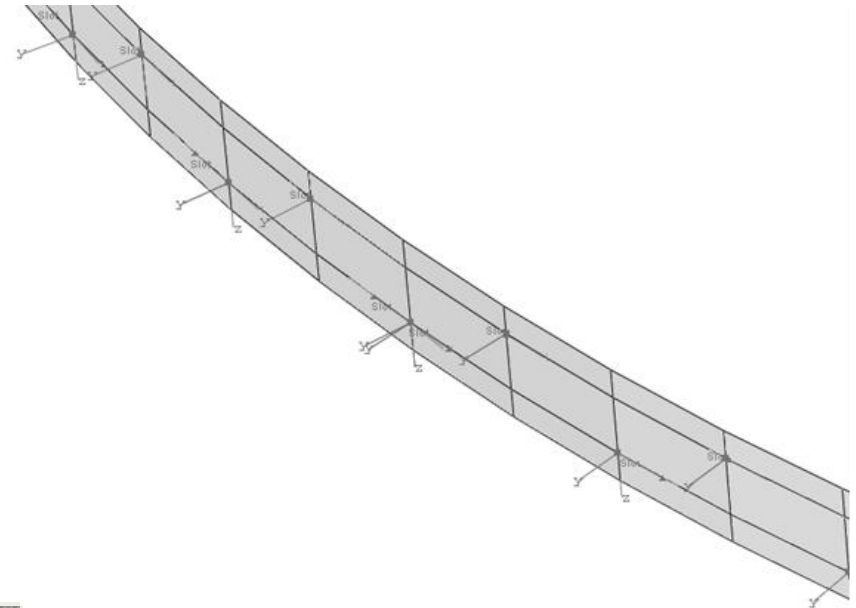
Model1: General

- Modeling with Abaqus-6.10
- Shell model
 - 420 elements
- Reinforcement with rebar layers (shell property)
- Tendons with truss elements
- Liner with "skin" reinforcement.



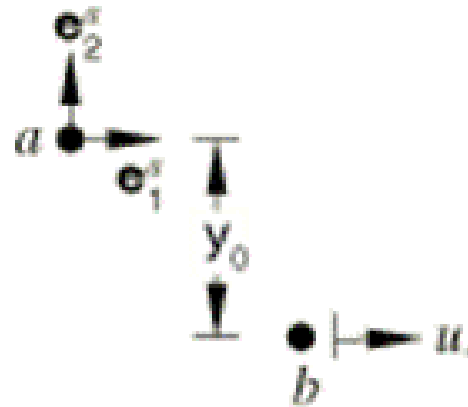
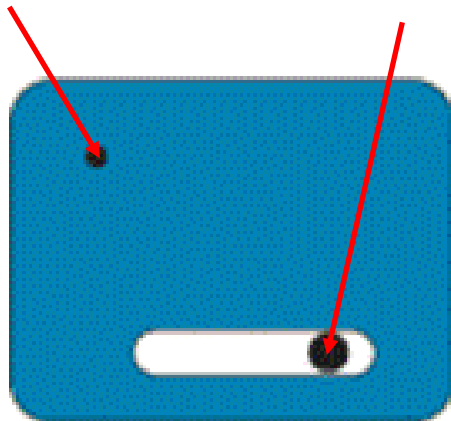
Model1: Tendon-Concrete Interaction

- 140 "slot" connector elements
- Friction factor 0.21
- Prestressing displacement guided.



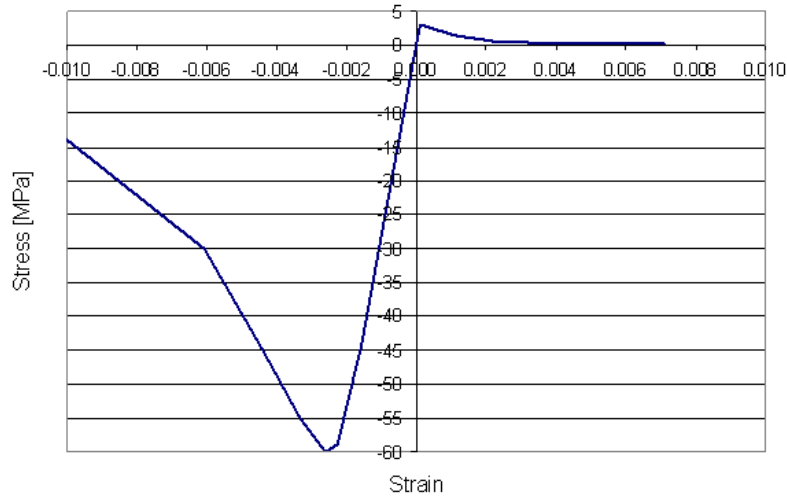
Concrete node

Tendon node

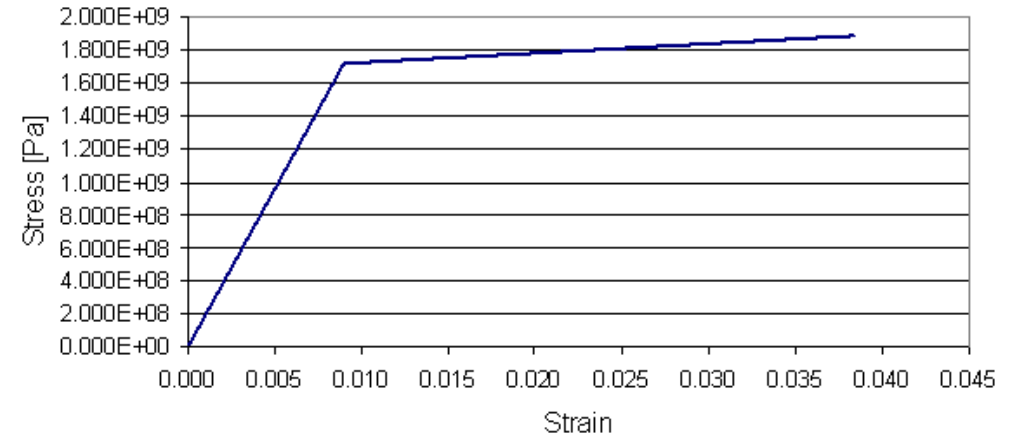


Model1: Material models

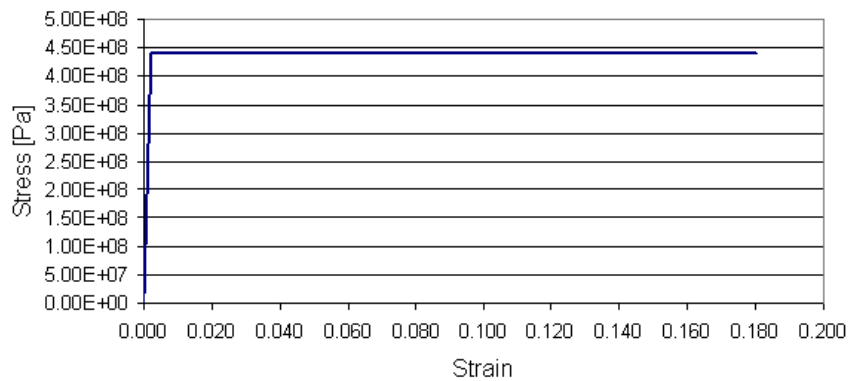
Concrete with Damage Plasticity model



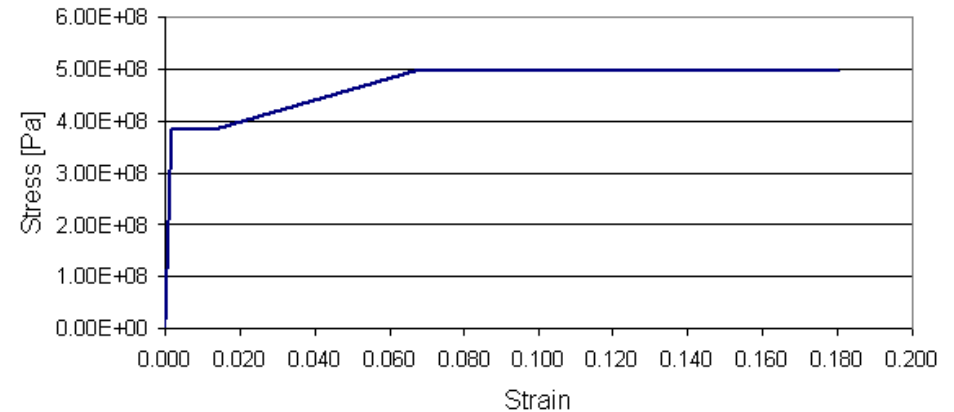
Tendon Steel



Reinforcement Steel

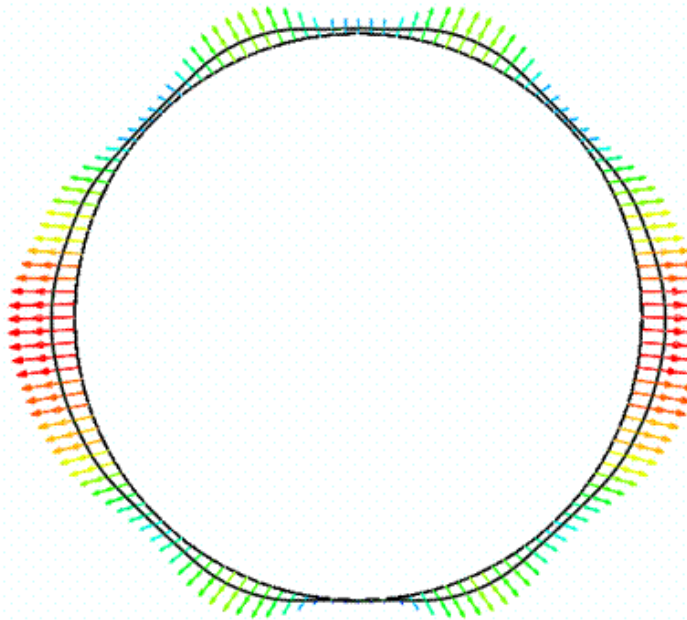
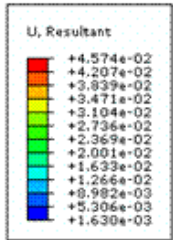


Liner Steel

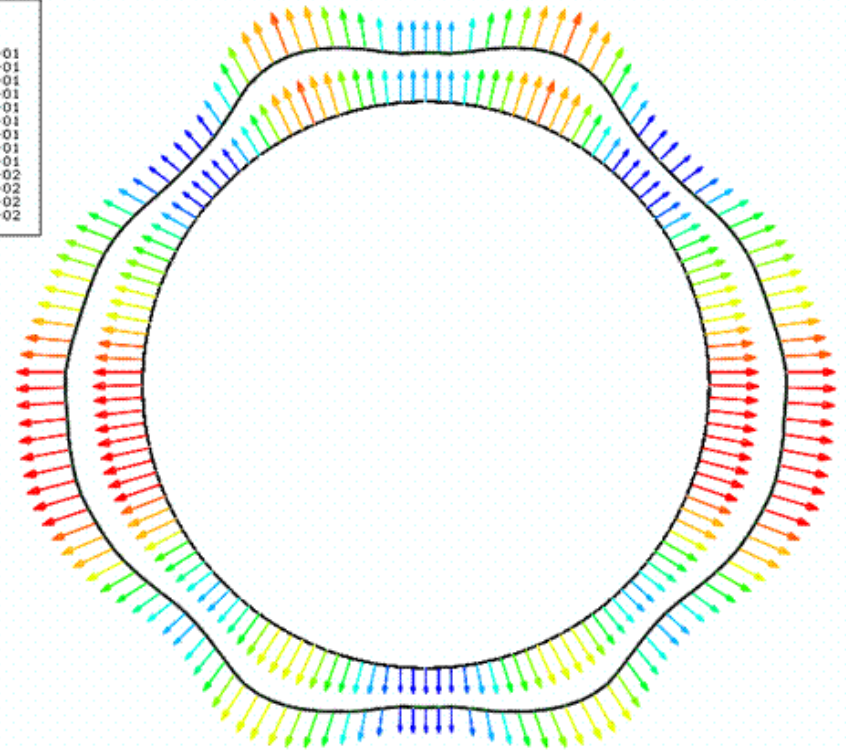
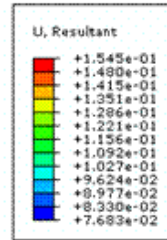


Model1: Results (1/2)

Deformation 3.3xPd
(scale x 10)



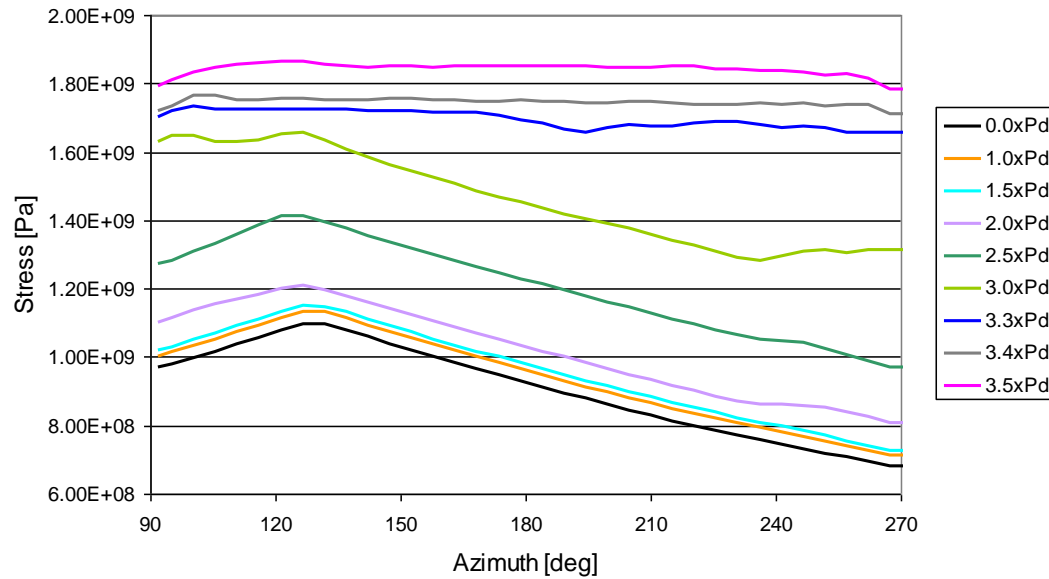
Deformation 3.5xPd
(scale x 10)



Model1: Results (2/2)



Tendon after prestressing



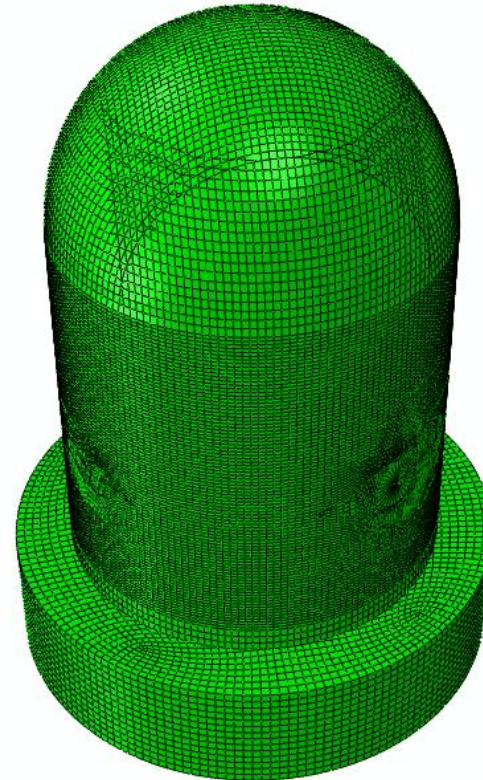
Stress with increasing pressure

Model1: Conclusions

- The behaviour of the model is consistent with the test results.
- Slot connectors are able to model the tendon-concrete interaction.

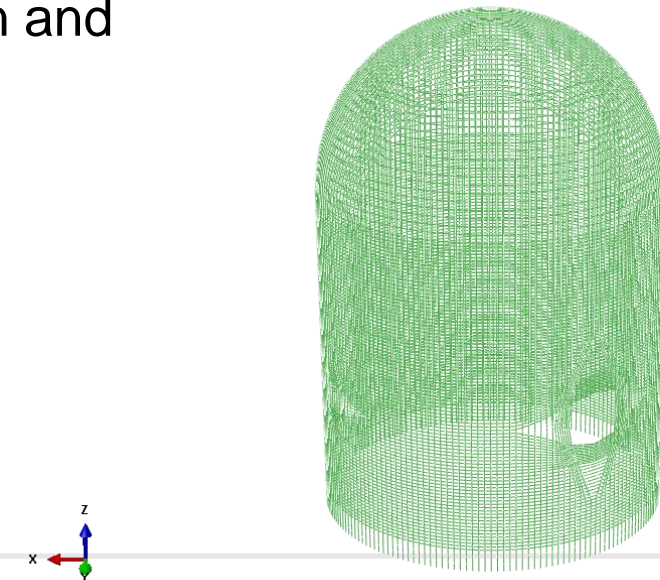
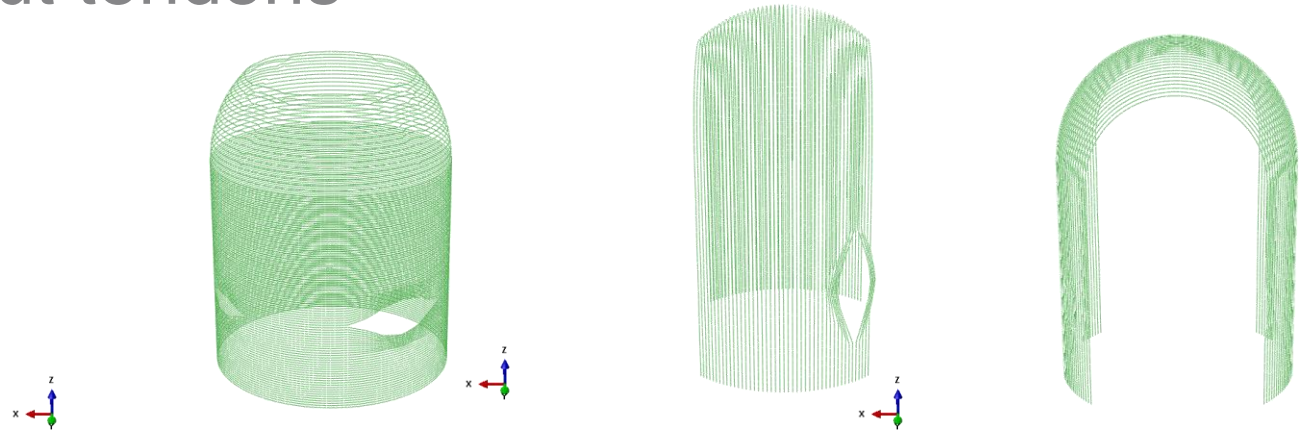
Model3: General

- Modeling with Abaqus-6.10
 - Implicit dynamic analysis. Much better convergence than using static solver.
 - Loads applied slowly (quasi-static).
- 175603 nodes and 257580 elements.
- Containment with shell elements. Basemat with solid elements. Tendons with truss elements.



Model3: About tendons

- 3 parts
 - Horizontal
 - Vertical-1
 - Vertical-2
- Slot connector interaction between tendon and concrete node.



Model3: Rebars and Liner

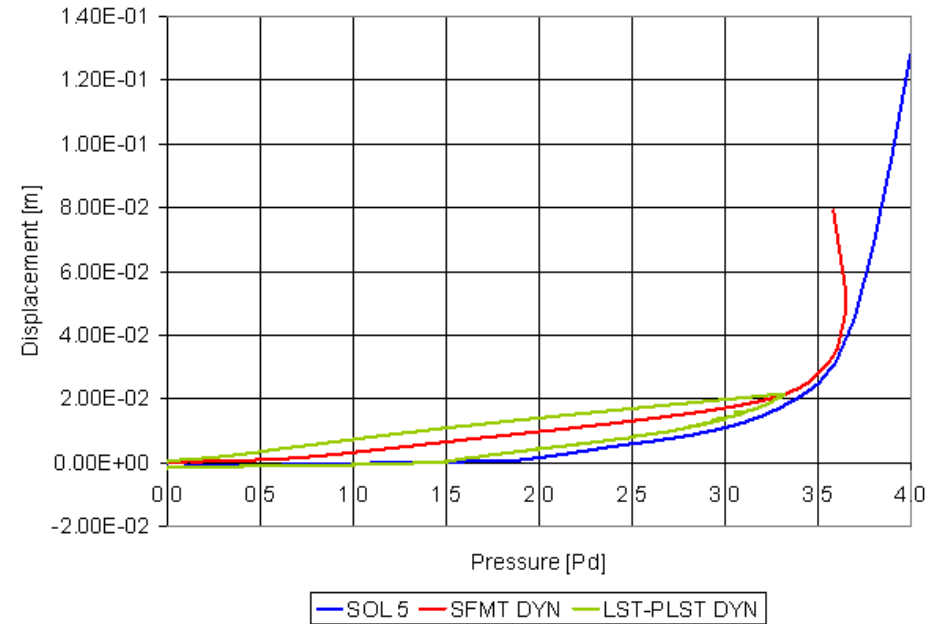
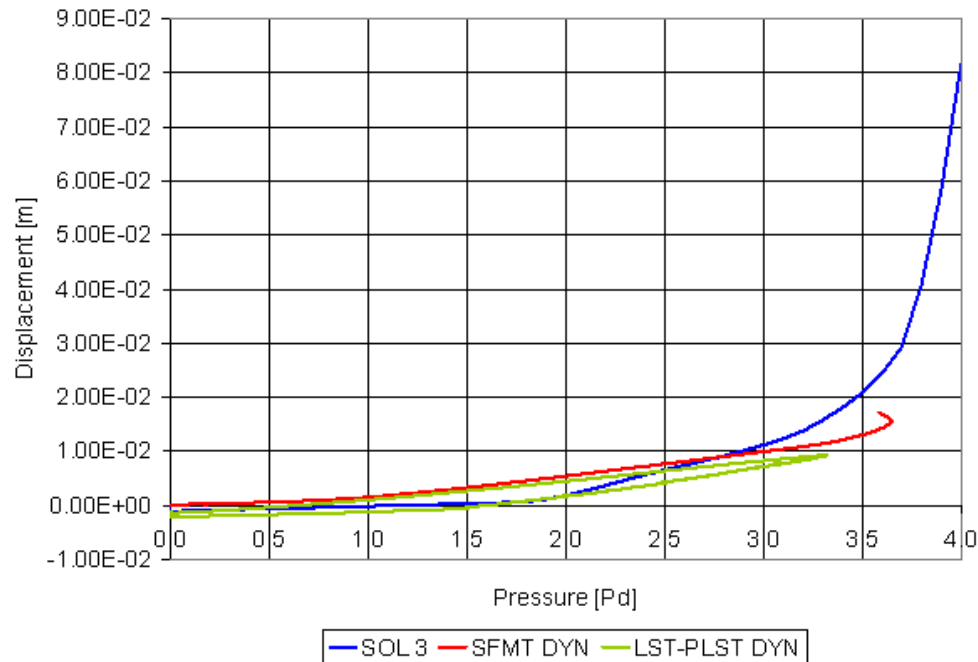
- Rebars with rebar layer shell property.
- Liner as a skin reinforcement.

Model3: Tendon Prestressing

- Force guided pretension and seating loss.
- Locking of the prestressing connectors achieved using temperature dependent connector plasticity:

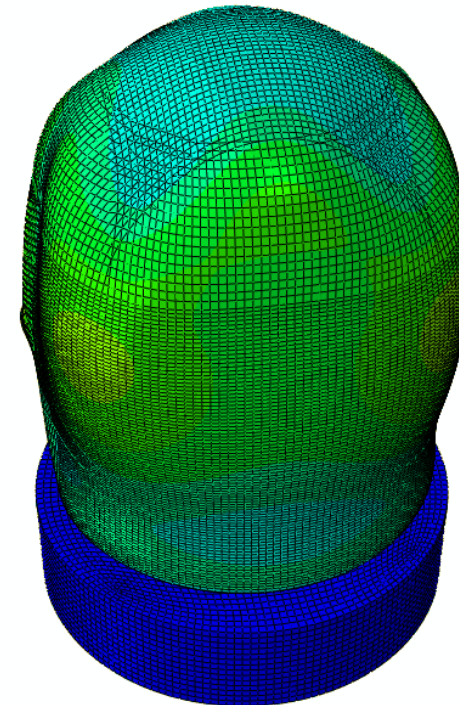
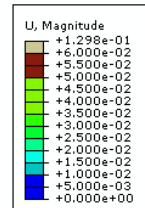
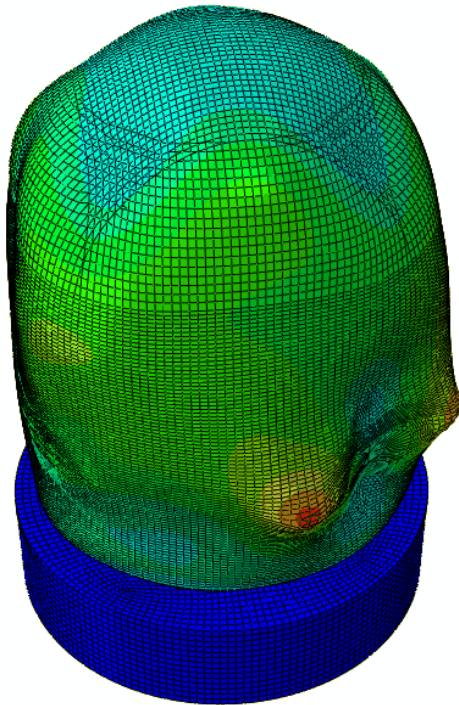
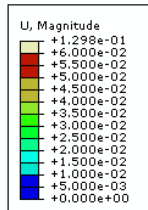
```
*CONNECTOR BEHAVIOR,  
NAME=ZZZV2-CONNSECT-END  
*CONNECTOR ELASTICITY, RIGID  
1  
*CONNECTOR PLASTICITY,  
COMPONENT=1  
*CONNECTOR HARDENING,  
DEFINITION=TABULAR  
1.0E-15, 0.0, 0.0,0.0  
1.0E+15, 0.0, 0.0,1.0
```

Model3: Some Selected Results



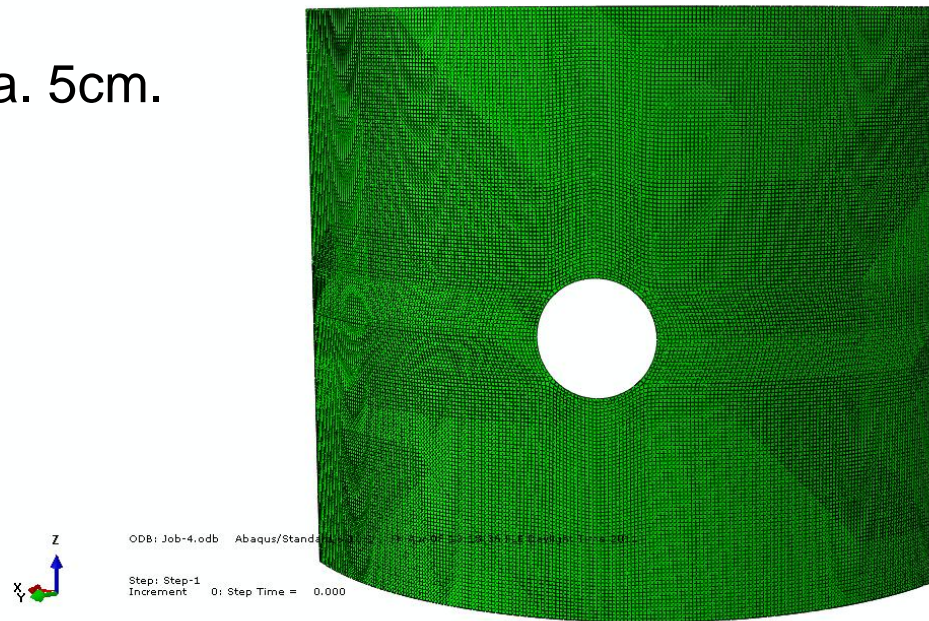
Model3: Results

Global deformation (x 50) at applied pressure $P = 3.5 \times P_d$

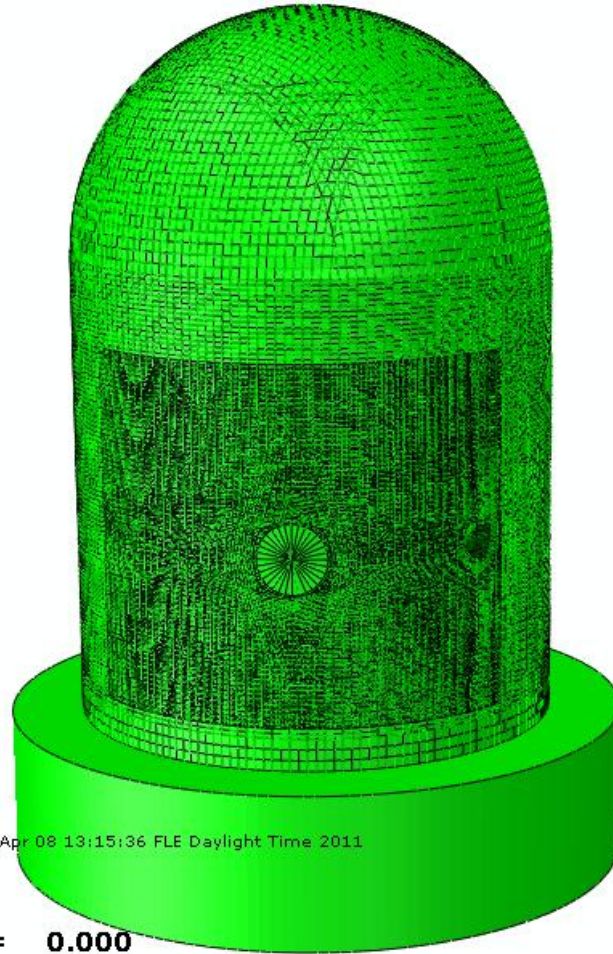


Some Fracture Mechanics of the Liner

- Sub model of the liner.
- Two layers of reduced integrated solid brick-elements.
- Element side length ca. 5cm.



Overlay Plot of the Sub Model

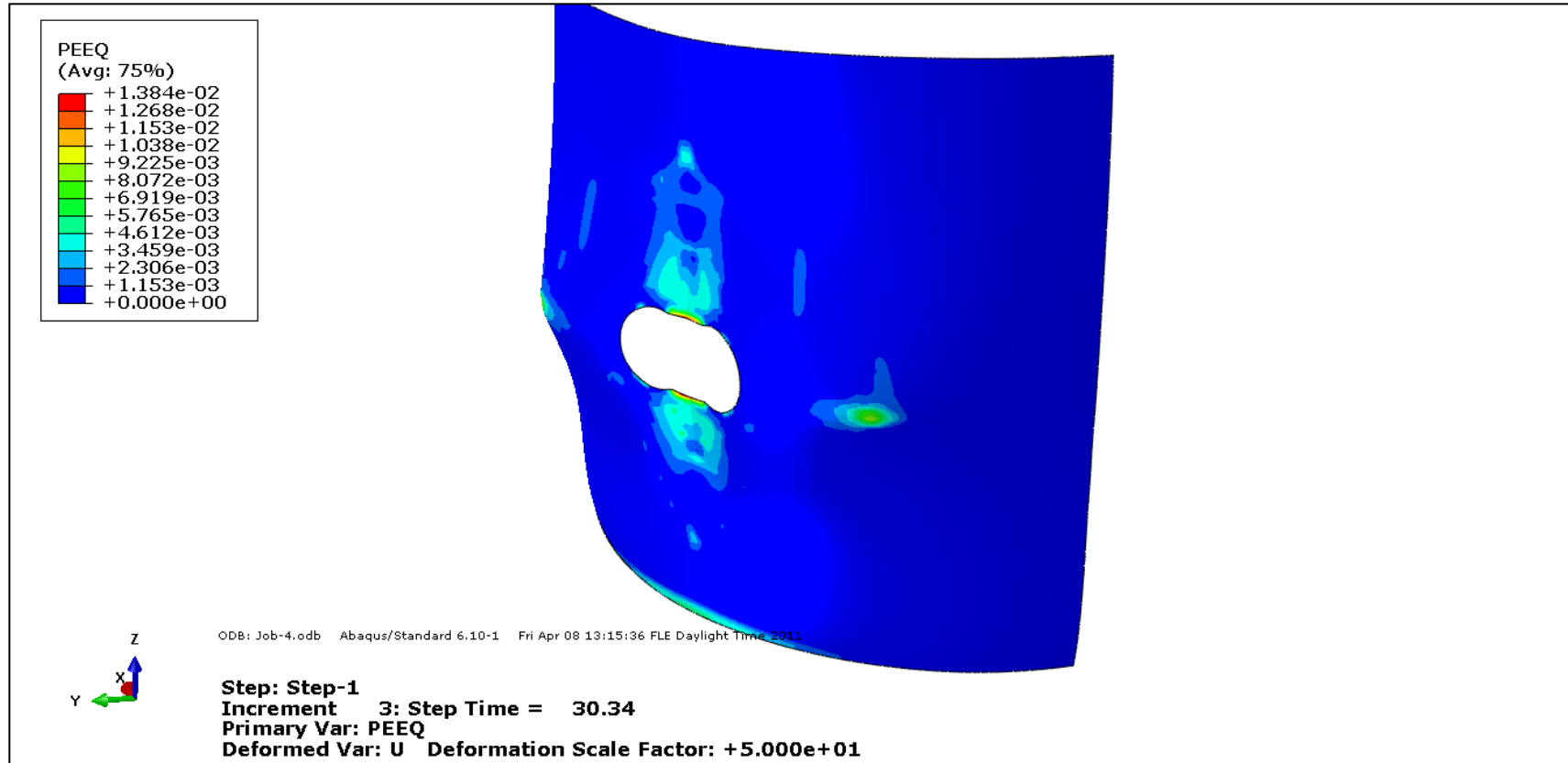


ODB: Job-4.odb Abaqus/Standard 6.10-1 Fri Apr 08 13:15:36 FLE Daylight Time 2011

Step: Step-1
Increment 0: Step Time = 0.000

Does the Sub Model Work?

$P = 3.034Pd$, Deformation x 50



Setup

- The global model drives all the sub model dofs.
- Use of extended finite element method (XFEM) available in Abaqus.
- Crack initiation when max. principal strain = 0.03.

Crack Growth Criteria (1/2)

Abaqus/CAE 6.10-1 - Model Database: C:\FNSusers\ContainmentSPE_2010\AbaModels\v08_sub_04\v08_sub_04.cae [Viewport: 1]

File Model Viewport View Interaction Constraint Connector Special Feature Tools Plug-ins Help

Assembly defaults

Edit Contact Property

Name: IntProp-1

Contact Property Options

Fracture Criterion

Mechanical Thermal Delete

Fracture Criterion

XFEM-based LEFM (using VCCT)

Direction of crack growth relative to local 1-direction: Maximum tangential stress

Mixed mode behavior: Power

Tolerance: 0.2

Viscosity: 0.01

Power

Use temperature-dependent data

Number of field variables: 0

Mode I critical energy release rate	Mode II critical energy release rate	Mode III critical energy release rate	Exponent am	Exponent an	Exponent ao
61320	61320	61320	1	1	1

OK Cancel

Model Database

Models (1)

Model-1

- Parts (7)
- Materials (1)
- Sections (2)
- Profiles
- Assembly
- Steps (2)
- Field Output Requests (2)
- History Output Requests (1)
- Time Points (1)



Interaction Property Manager

Name

IntProp-1

Create... Edit... Copy...

- Loads
- BCs (1)
- Predefined Fields
- Remeshing Rules
- Sketches (1)
- Annotations
- Analysis
- Jobs (1)
- Adaptivity Processes
- Co-executions

Crack Growth Criteria (2/2)

- Critical energy release rate = $J_{ICr} = 61.32 \text{ kJ/m}^2$
- Same critical energy release rate used for modes II and III.
- Power law assumption: $(J_I / J_{ICr})^1 + (J_{II} / J_{IICr})^1 + (J_{III} / J_{IIICr})^1 \leq 1$

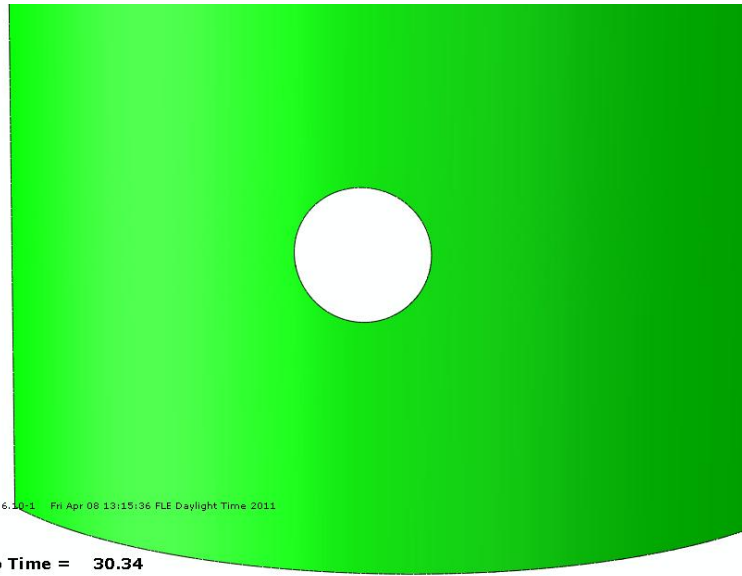
Results: Crack Initiation

$$P = 3.034Pd$$



ODB: Job-4.odb Abaqus/Standard 6.10.1 Fri Apr 08 13:15:36 FLE Daylight Time 2011

Step: Step-1
Increment 3: Step Time = 30.34

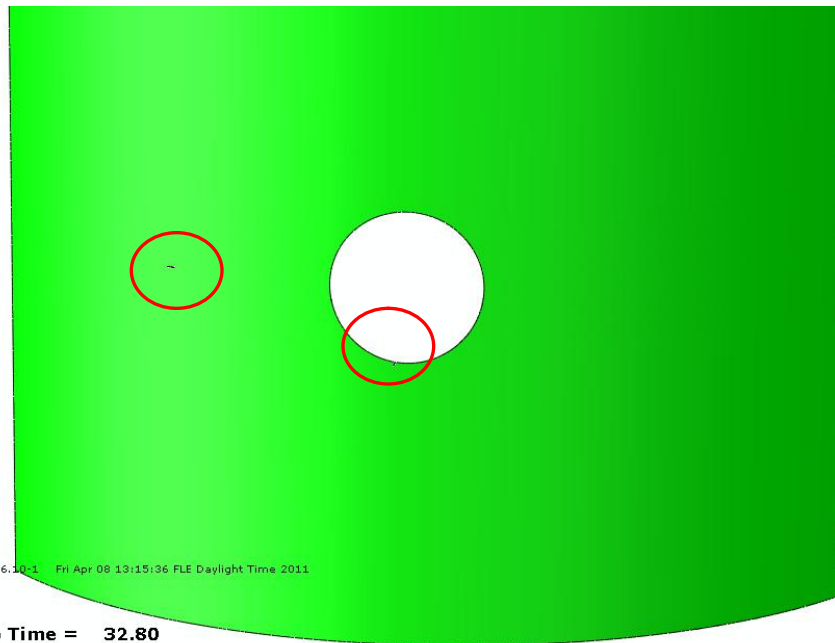


$$P = 3.28Pd$$



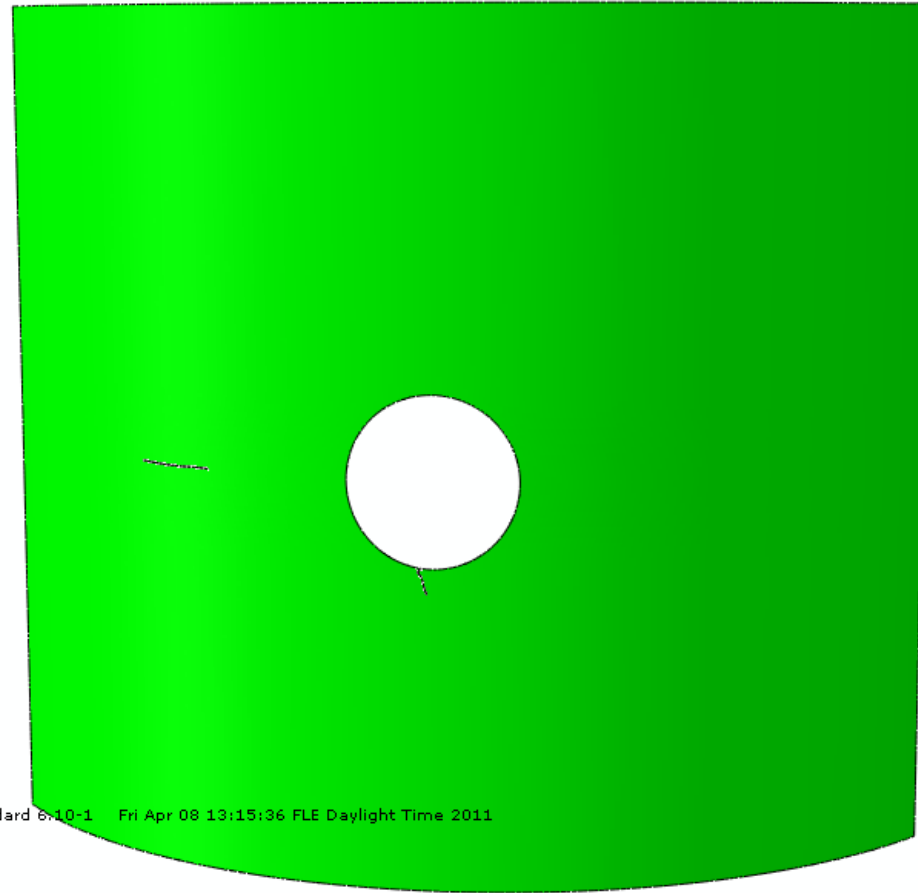
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Step: Step-1
Increment 4: Step Time = 32.80

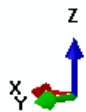


Results: Crack Propagation (1/2)

$$P = 3.284Pd$$



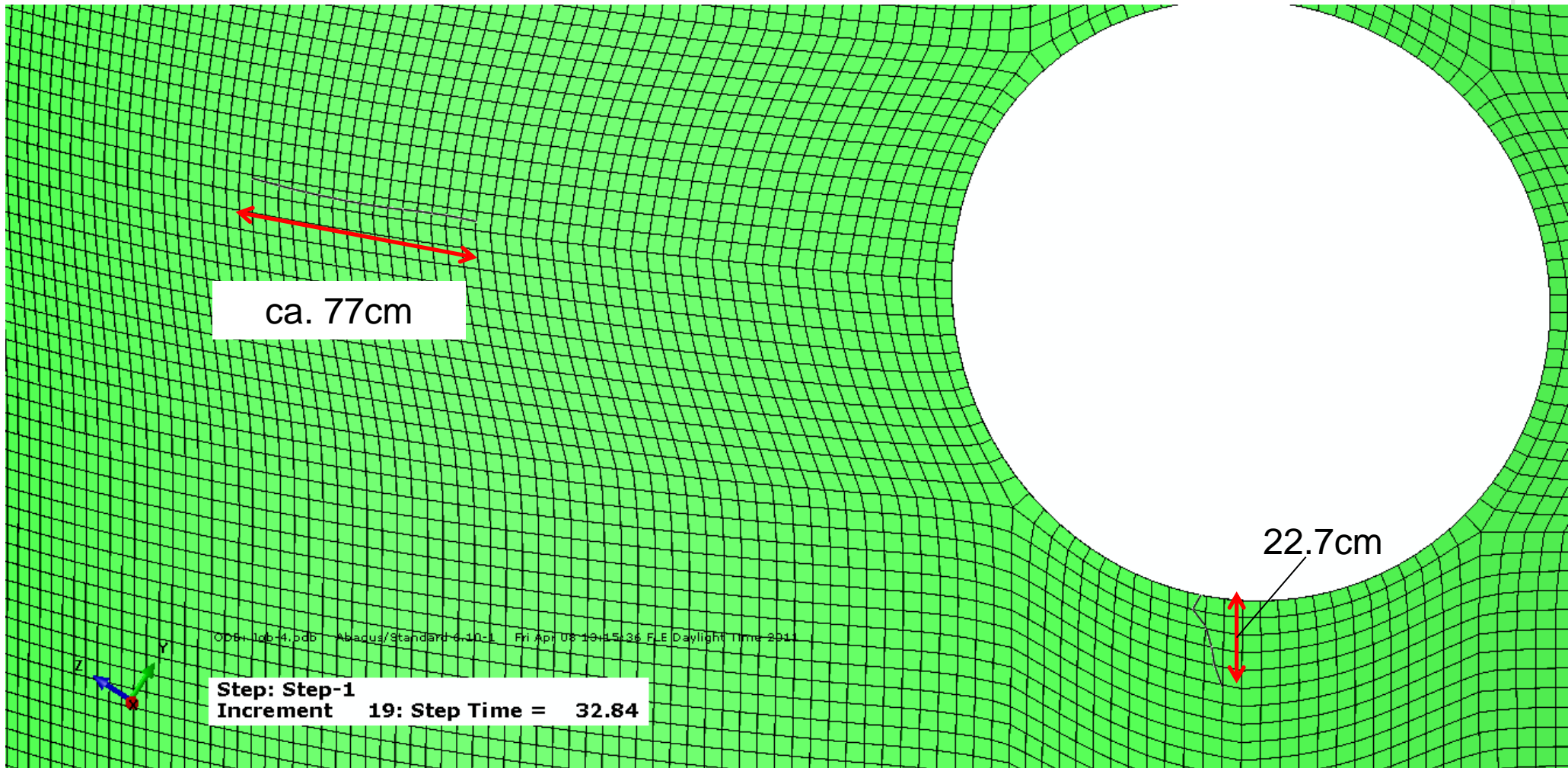
ODB: Job-4.odb Abaqus/Standard 6.10-1 Fri Apr 08 13:15:36 FLE Daylight Time 2011



Step: Step-1
Increment 19: Step Time = 32.84

Results: Crack Propagation (2/2)

$$P = 3.284Pd$$



Thank you for your attention !