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Material calibration

Urea freezing simulations

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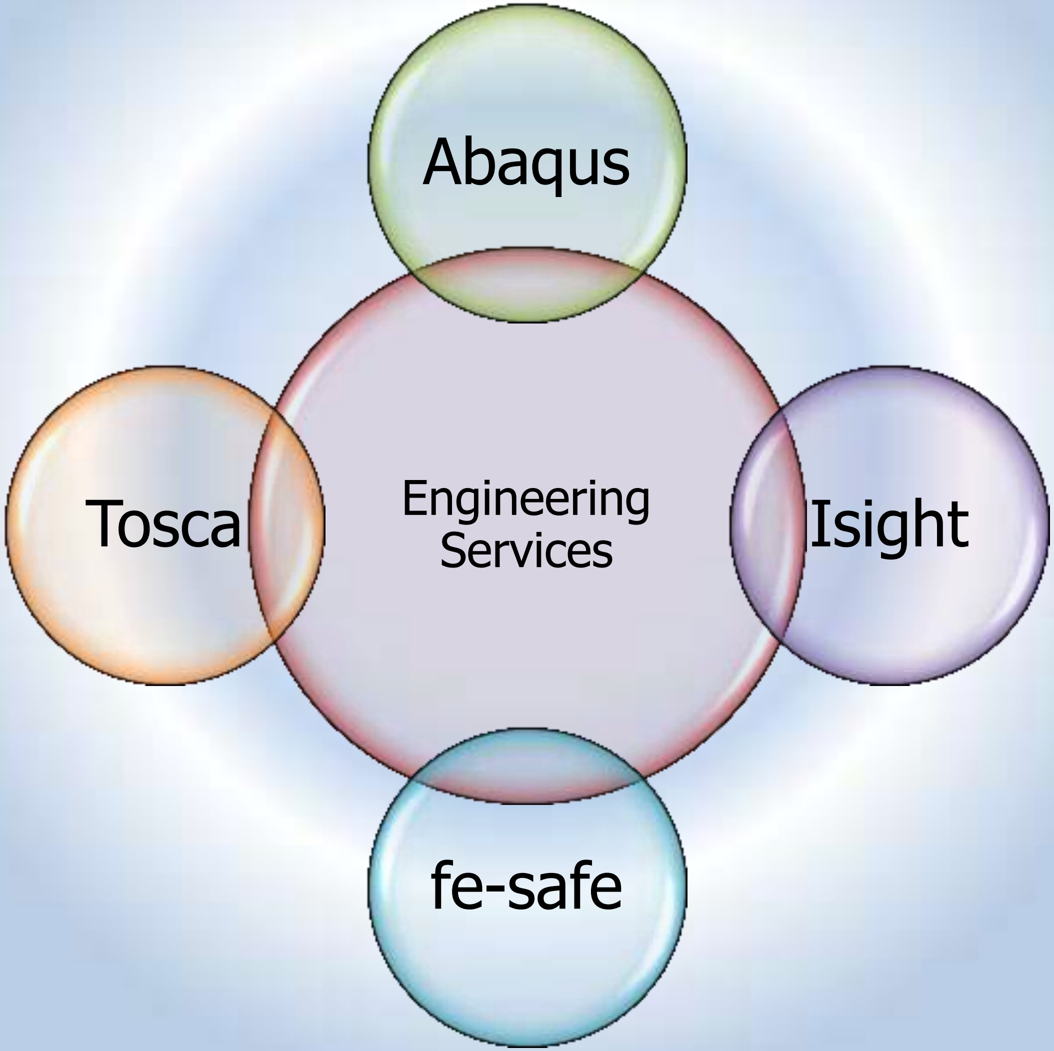
SOLUTIONS PARTNER 2013 SIMULIA



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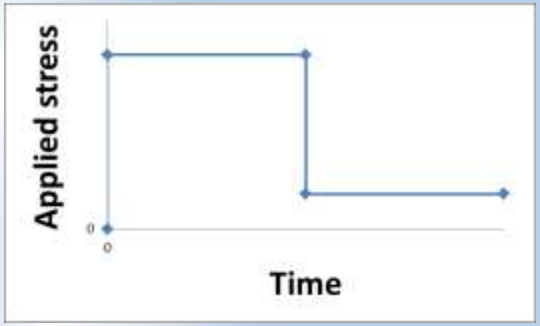
Inergy Automotive Systems Research

Material calibration

Urea freezing simulations

Introduction

- Material behavior of a Polymer (material name is confidential)
- Physical tests (creep) performed in 2006



- Still no correlated material model today
  - Unstable UMAT used for supposedly nonlinear viscoelastic-plastic behavior
- Request to 4RealSim
  - Obtain calibrated material data with the new PRF-model (nonlinear viscoelasticity) in 6.13

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Project steps

- Simple 1-element model with the nonlinear viscoelastic material model

```
** MATERIALS
**
*Material, name=prf-fit
*Hyperelastic, neo hooke, moduli=instantaneous
0.1, 0.01
*Viscoelastic, nonlinear, networkid=1, sratio=1, law=strain
** A, n, m
** A>0, n>0, -1<m<0
1,1,-1
```

Fit-parameters

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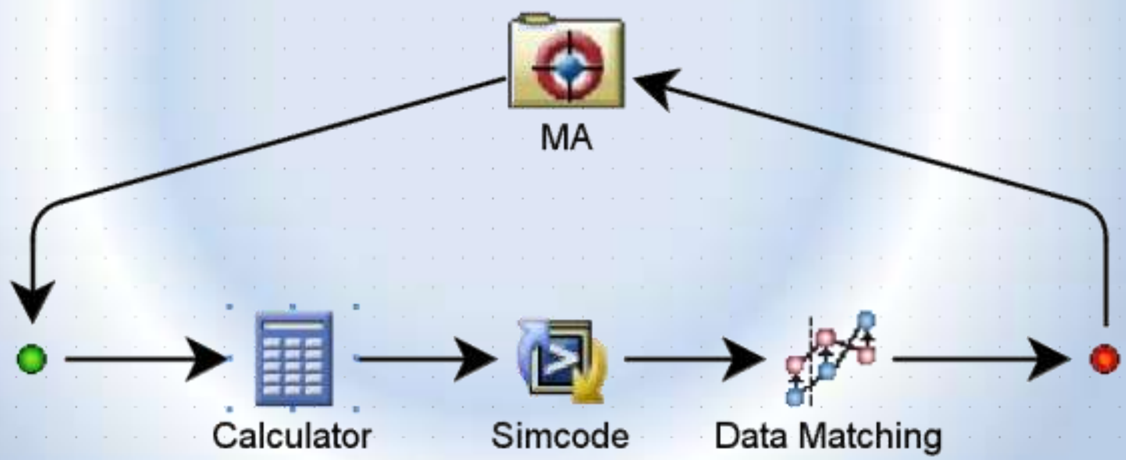
Project steps

- Simple 1-element model with the nonlinear viscoelastic material model
- Automate and optimize the simulation process with Isight



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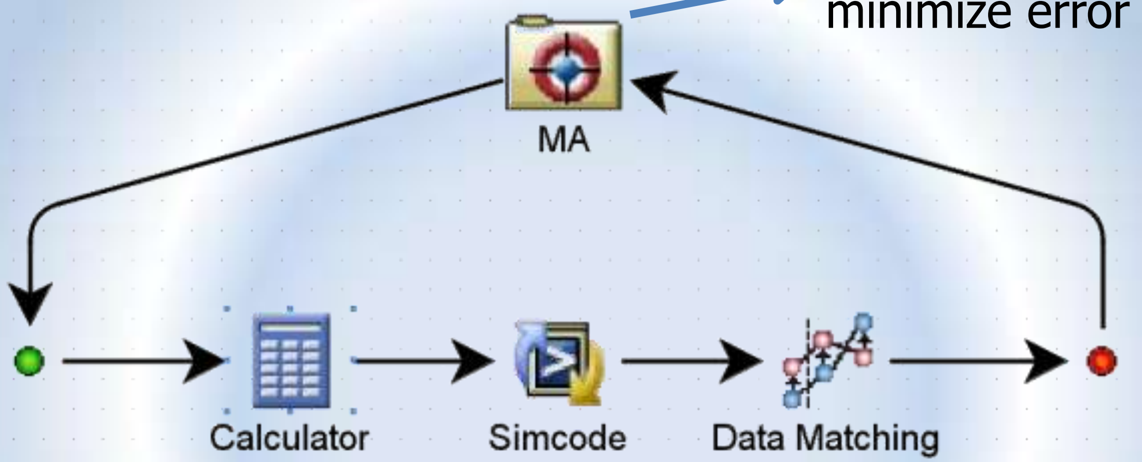
Project steps

Optimization algorithm to minimize error



Value of parameter A can vary orders of magnitude

log(A) used instead

Compare simulation with test results

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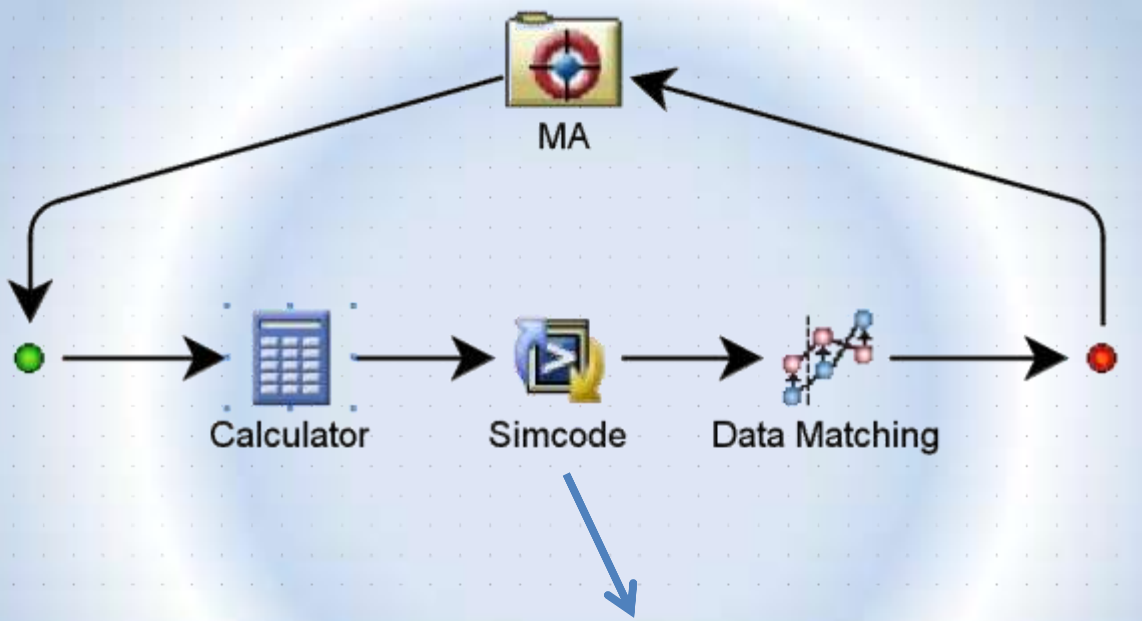
Project steps



4 different creep tests (different stress levels); so 4 different analyses?

Token usage and runtime optimized by merging the 4 analyses into 1…

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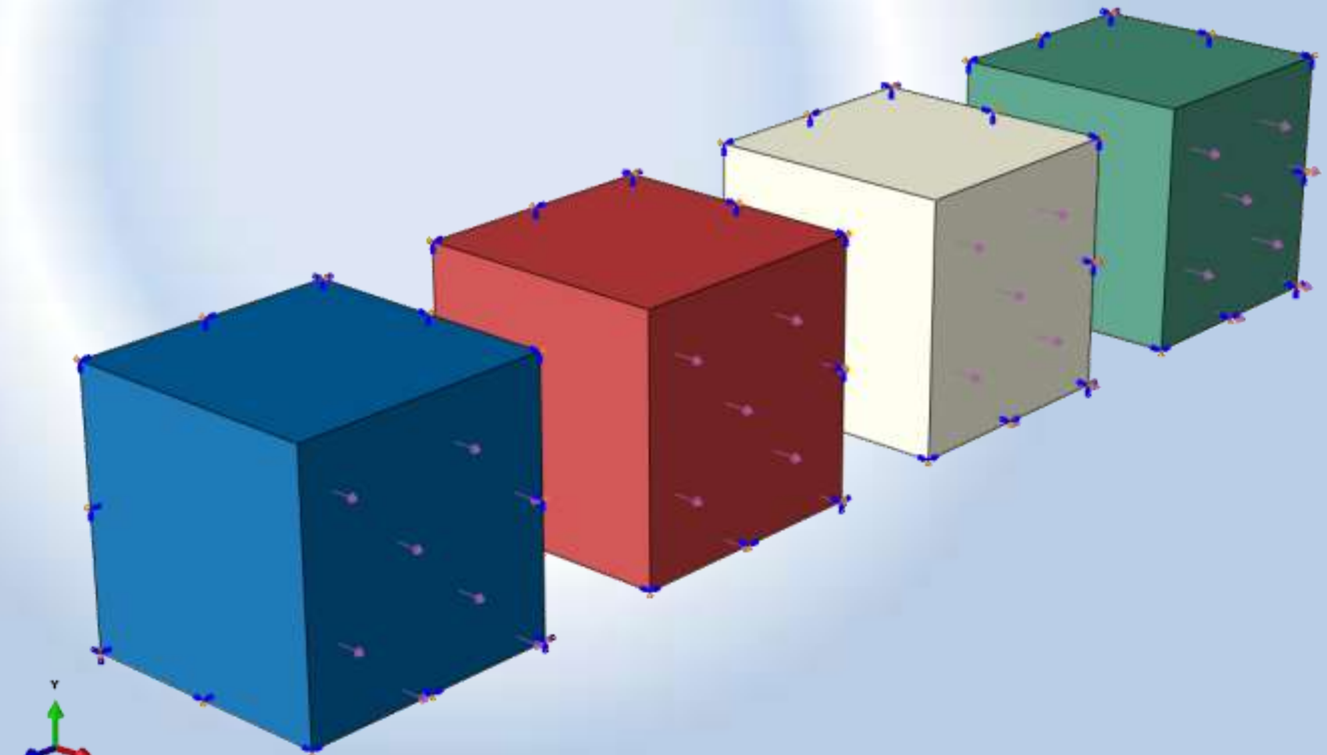
Project steps

Token usage and runtime optimized by merging the 4 analyses into 1

- Different load to every element
- Independent postprocessing of every element



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Project steps

- Simple 1-element model with the nonlinear viscoelastic material model
- Automate and optimize the simulation process with Isight
- Calibrate material model to minimize error between simulation and test

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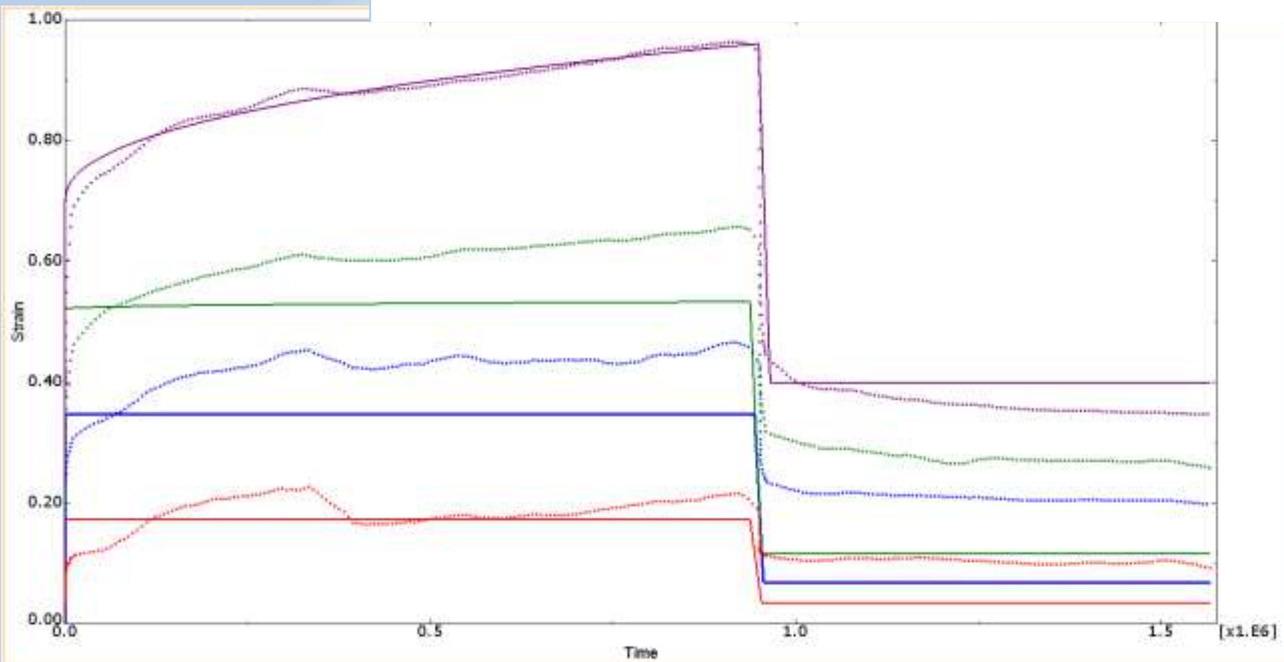
Initial result from PRF-model

```
** MATERIALS
**
*Material, name=prf-fit
*Hyperelastic, neo hooke, moduli=instantaneous
u, 0.01
*Viscoelastic, nonlinear, networkid=1, sratio=1, law=strain
** A, n, m
** A>0, n>0, -1<m<0
x,y,z
```



Include more networks...

but maybe not that nonlinear?

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Project steps

- Simple 1-element model with the nonlinear viscoelastic material model
- Automate and optimize the simulation process with Isight
- Calibrate material model to minimize error between simulation and test
- Simpler material model?

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Project steps

- Simpler material model?

```
** MATERIALS
**
*Material, name=prf-fit
*Hyperelastic, neo hooke, moduli=instantaneous
u, 0.01
*Viscoelastic, time=prony
x1, ,x2
y1, ,y2
z1, ,z2
```

- Automate simulation process with Isight
- Calibrate material model to minimize error between simulation and test

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Project steps

```
** MATERIALS
**
*Material, name=prf-fit
*Hyperelastic, neo hooke, moduli=instantaneous
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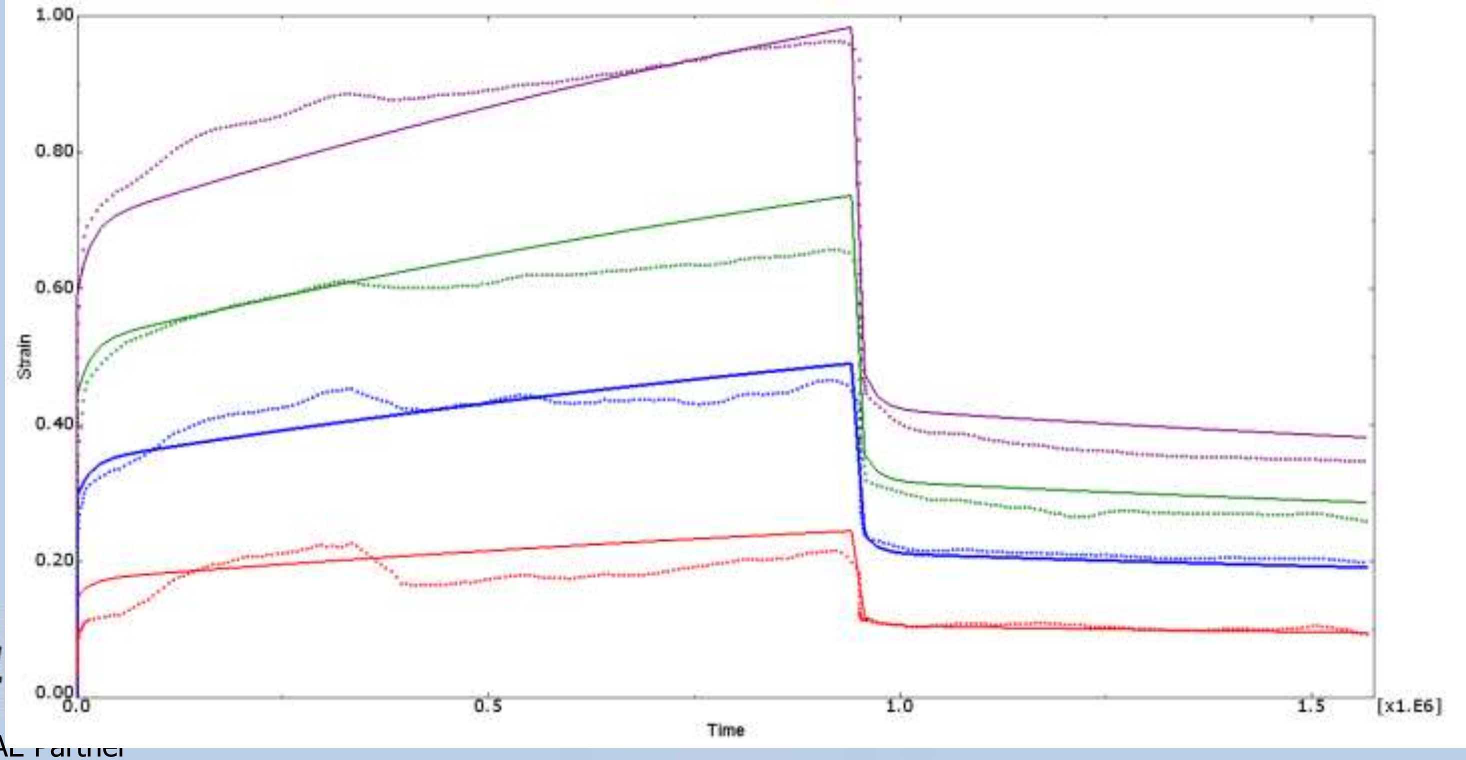

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Conclusion

- Efficient Isight methodology and Abaqus workflow developed
  - Robust calibration process
- Simple Abaqus material model fitted to testdata
  - Replaces the unstable UMAT
- Inergy is generalizing and deploying the calibration process to production sites (non-experts)
  - Automatic smoothing via Abaqus/CAE
  - Automatic calibration via Isight

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Isight Advanced Training Material

- http://4realsim.com/services/advanced-isight-workshop/

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Urea freezing simulations

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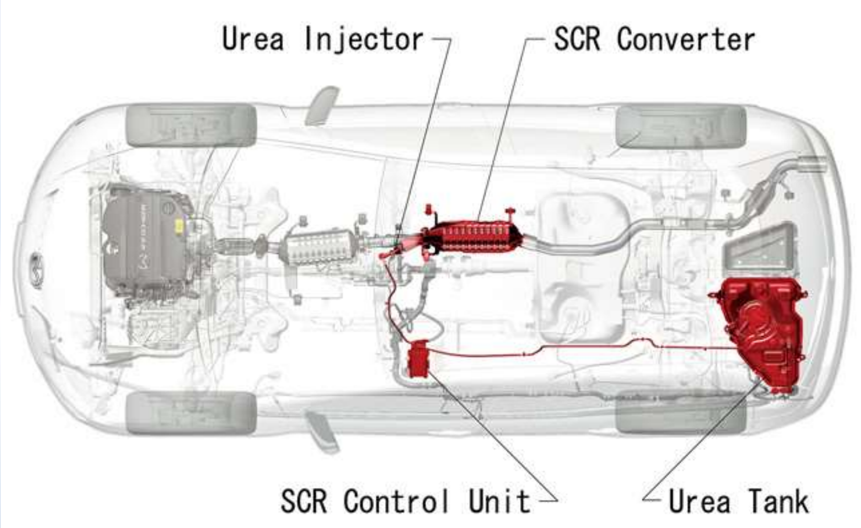
Introduction

- **S**elective **C**atalytic **R**eduction
  - Converts NO_x into N_2 and H_2O
  - Urea - water solution as reducing agent
  - Powerfull emission reduction technique in automotive industry

  - Thermal engineering is a challenge
    - Melting/freezing point in range of ambient temperatures of typical usage



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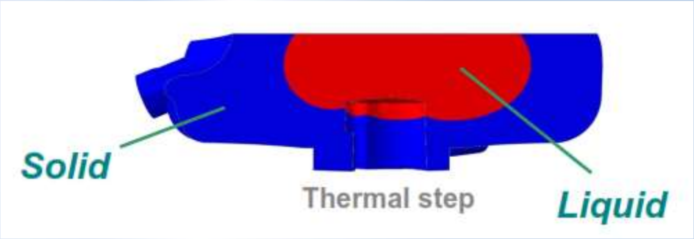
Introduction

- Freezing Test
  - Target
    - Verify if tank and its components pass freezing test (without observing failure or leakage)
  - Procedure
    - Tank filled with Adblue (100% of volume)
    - Climatic room conditioned at -40°C
  - Issues
    - Cracks, failure and leakage



- Simulation
  - Target
    - Compute shape evolution of the freezing front with time
    - Predict the last freezing area (“liquid bubble”)
  - Value
    - Detect which tanks can cause potential issues during freezing test
    - Test and validate design modifications of tank
    - Identify areas where to put insulation to move last liquid bubble

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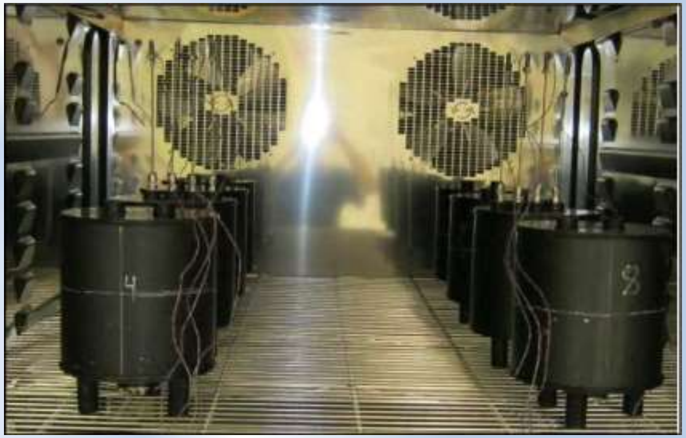
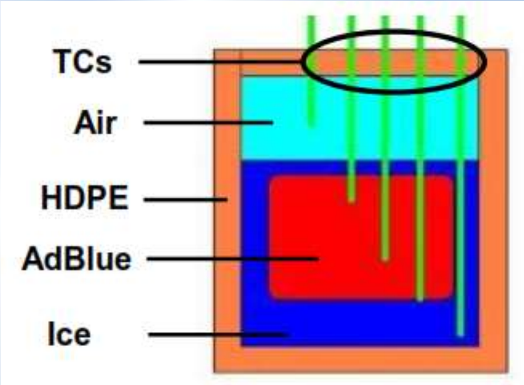
Step 1 HDPE cylinder thermal



- Cylinders
  - Volume 4,2 l (filled at 80%)
- Initial temperature of 22°C
- Cooling to -40°C (24 hours)
- Goal
  - Develop and validate thermal model on simple case of SCR tank



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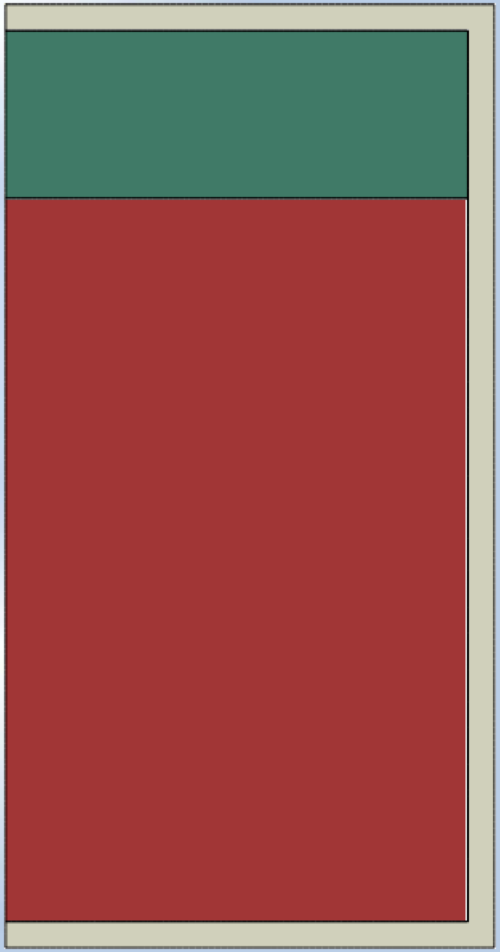
Thermal model of cylinder

- Axisymmetric thermal model
  - Initial temperature of 30°C
  - Cooling to -40°C
  - Film condition outside of tank



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Thermal model of cylinder

- Temperature dependent material properties
  - Difference in specific heat and thermal conductivity below and above melting point.
  - Effect of phase transition accounted for by ‘latent heat’
  - Natural convection accounted for by adjusting thermal conductivity of liquid urea and air
    - Fitting of simulation results onto test results

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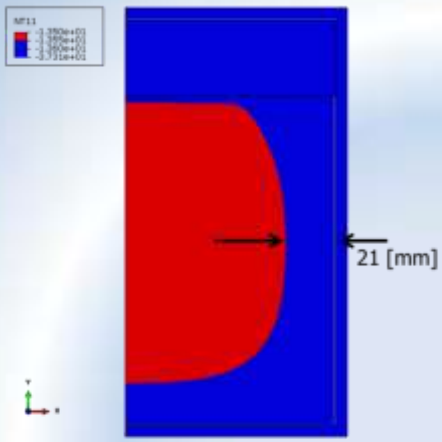
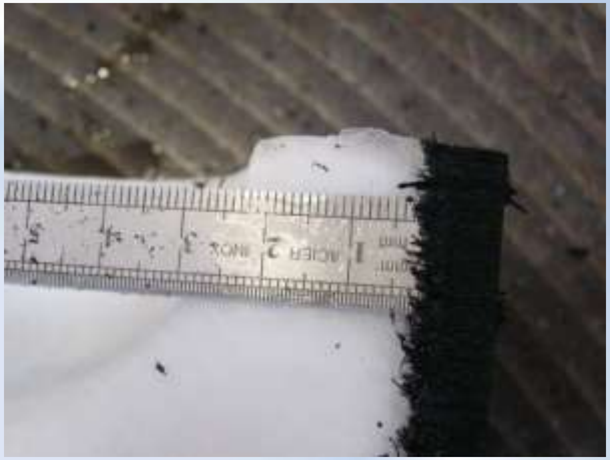
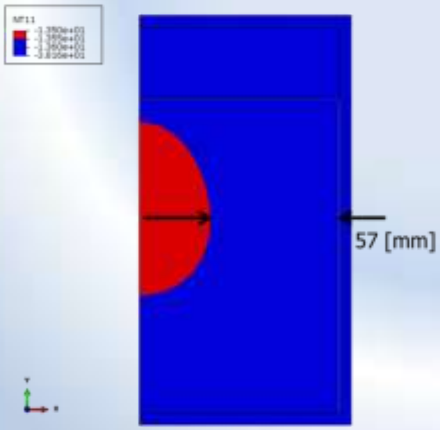
Thermal results





Pot 8 after 72320 [s], Simulation after 21920 [s]



Pot 1 after 85080 [s], Simulation after 34680 [s]

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Step 1 Conclusion

- A thermal freezing model has been developed
- Numerical parameters such as material properties and heat transfer coefficient have been calibrated
- Mechanism of freezing and the influence of each parameter is understood
- *Tuned simulation results in agreement with experiment*

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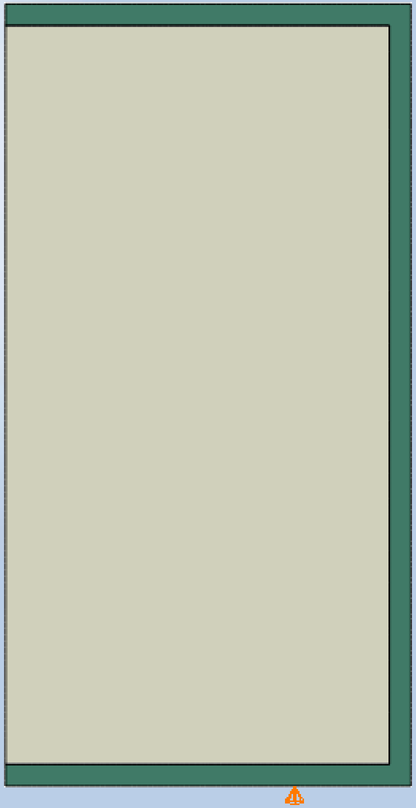
Step 2 HDPE cylinder structural

- Axisymmetric structural model
  - Armaflex ignored – not significant for mechanical response
  - Temperature mapped from thermal results – sequentially coupled
  - Contact between tank and urea, frictionless for liquid urea
  - Boundary condition at single bottom node



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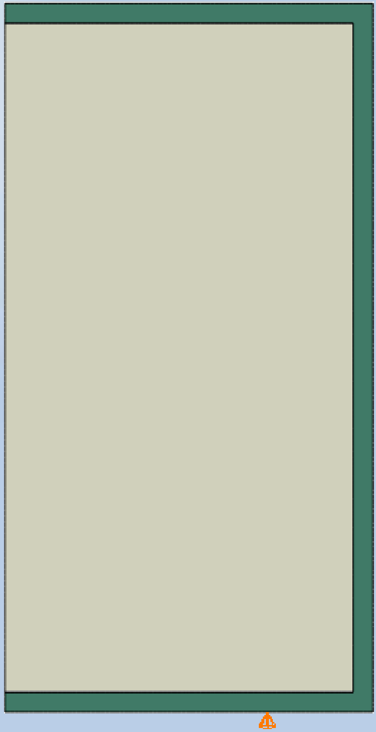
Step 2 HDPE cylinder structural

- Temperature dependent material properties
  - Urea modeled as elastic-plastic
    - Large yield stress for frozen urea (=elastic)
    - Perfectly plastic with low yield stress for liquid urea
  - Difference in TEC below and above melting point
    - Definition of TEC includes 5% volume increase due to freezing



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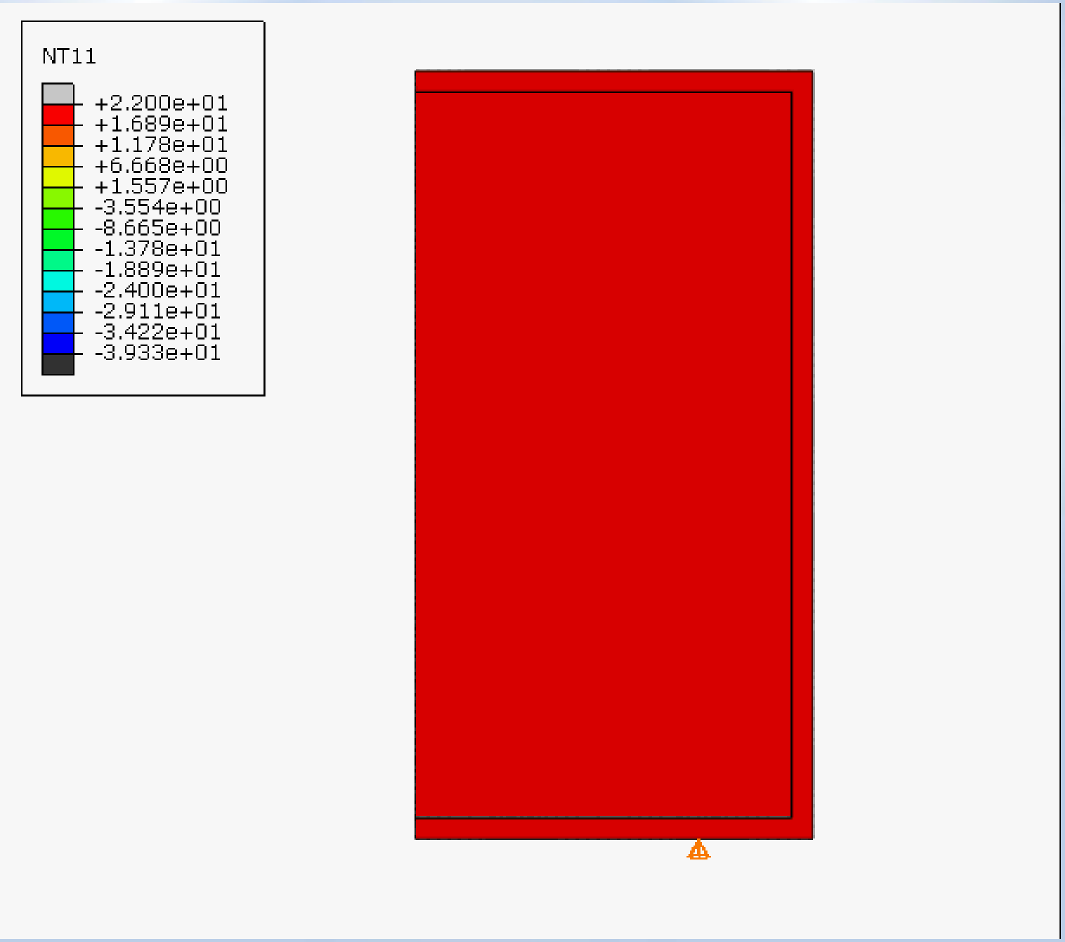
Mechanical results

- Animation of temperature and deformation



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Step 3 Real SCR tanks

- Pictures removed due to confidentiality

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Step 3 Real SCR tanks

- Pictures removed due to confidentiality

Conclusion

- Continuum heat transfer and structural analyses – easy to set-up, quick result
- Robust computation demonstrated on actual SCR tank
- Quite accurate results

- This simulation methodology is deployed at the production sites and has been used on various tank models