COMSOL CONFERENCE 2015 BOSTON

the Energy to Lead

Assessment of Squeeze-off Location for Small Diameter Polyethylene (PE) Pipe and Tubing

Presented by Oren Lever

COMSOL Conference 2015

October 8, 2015

OTD Operations Technology Development

Veryst Engineering

gti

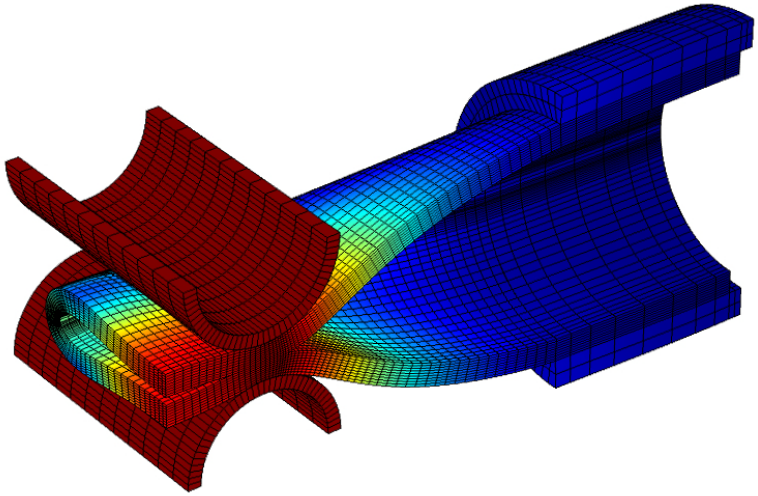
Objective

- The scope of the project is to revise *Section 7.3 "Tool Location"* of ASTM F1041 by removing the minimum requirement of 12 inches for location of the squeeze-off tool next to a butt fusion or mechanical fitting joint. This minimum distance of 12 inches has been an issue for some gas operators, especially for installation or repair of smaller pipe sizes. GTI is currently undertaking a project to scientifically investigate the applicability of minimum squeeze-off distances from fittings and other appurtenances in the case of small diameter (2″ or less) PE pipe and tubing.

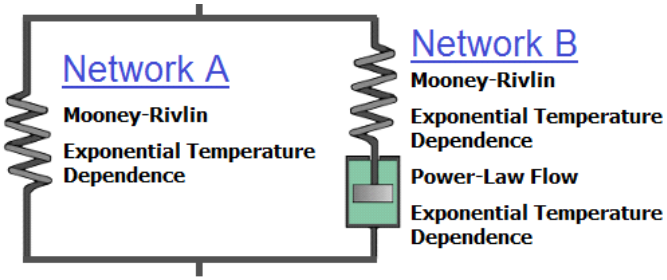
Photos taken from: http://www.lesafety.kr/Board/read.php?board=LE0518_B1&aid=14

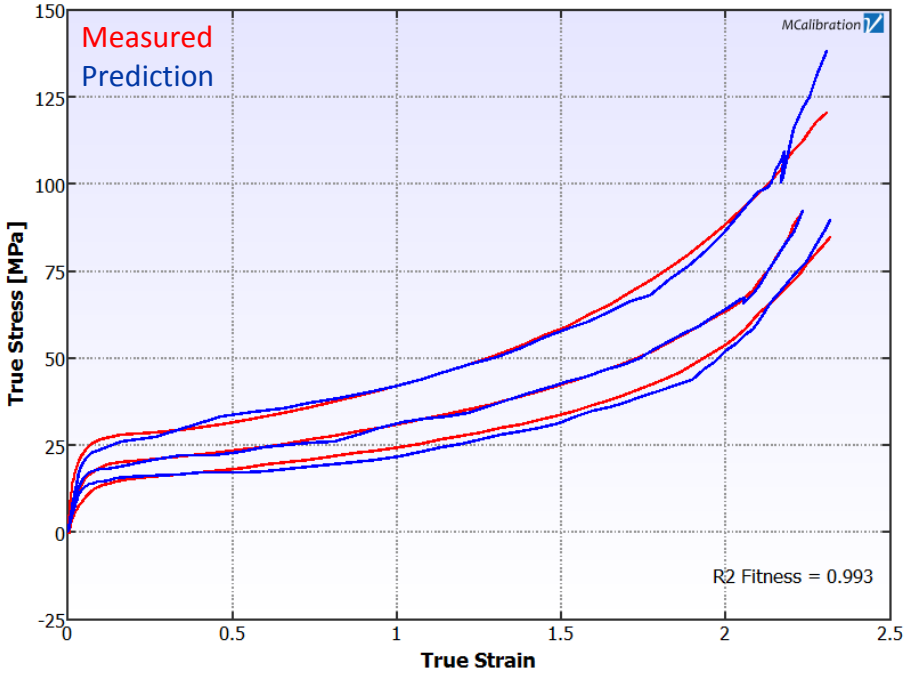
Finite Element Analysis

- Using COMSOL Multiphysics with the Nonlinear Structural Materials Module, squeeze-off simulation was performed on a number of combinations of pipe size and distance from a coupling.
- To enable the simulation of squeeze-off, a constitutive model for MDPE was developed by Veryst Engineering and implemented via the Ordinary Differential Equations (ODE) functionality in COMSOL Multiphysics.
- The constitutive model was calibrated using a comprehensive set of test data from GTI.



Material Testing and Model Calibration

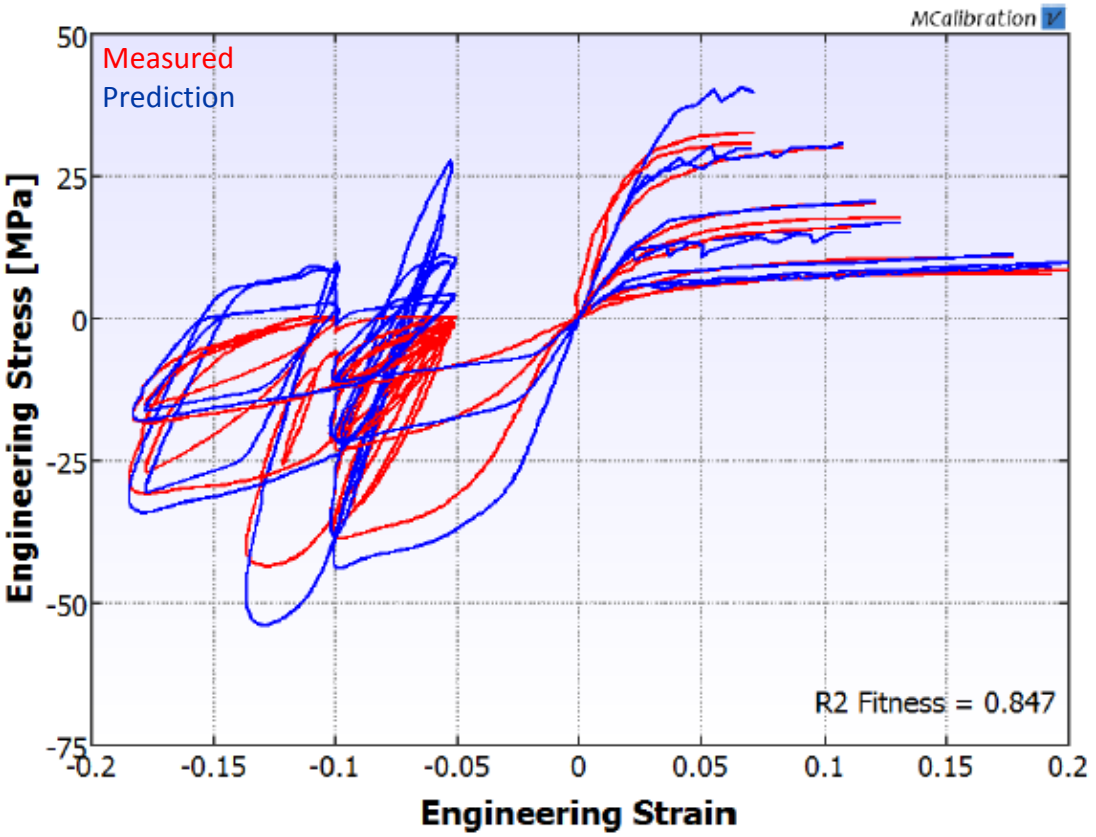




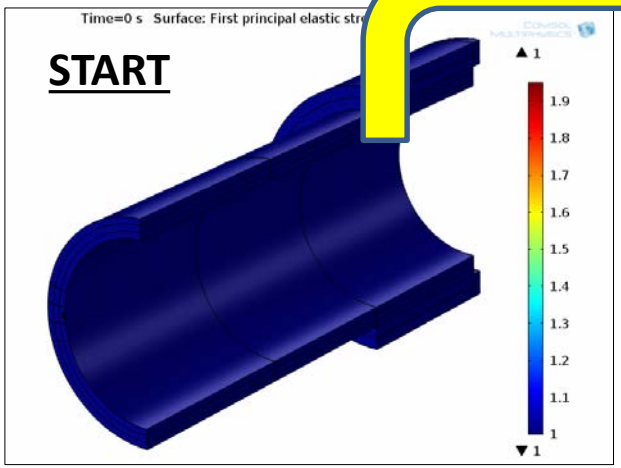
> The above network model resulted in very good fits in tension, at a range of temperatures

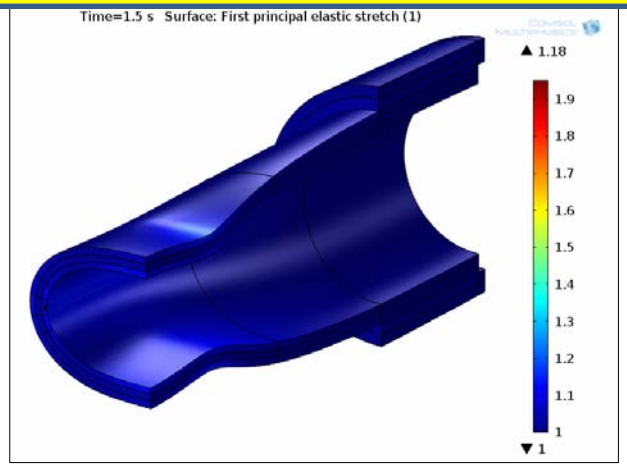
Material Testing and Model Calibration – continued

> Calibration also resulted in good fits in tension and compression, and at a range of temperatures

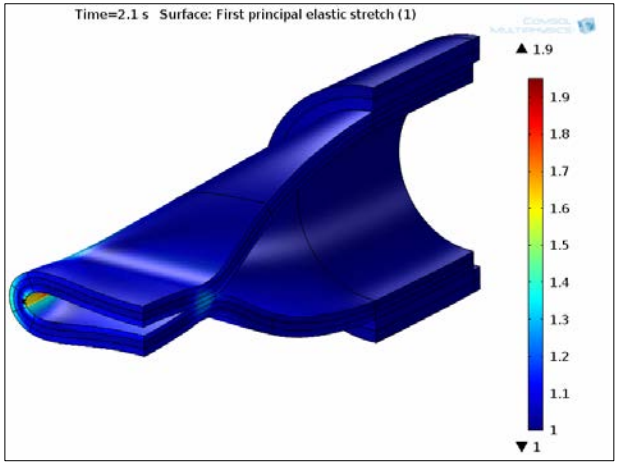


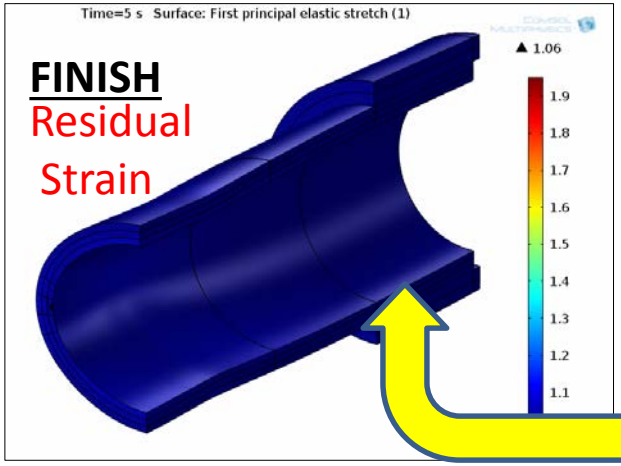
Squeeze-Off Sequence in COMSOL

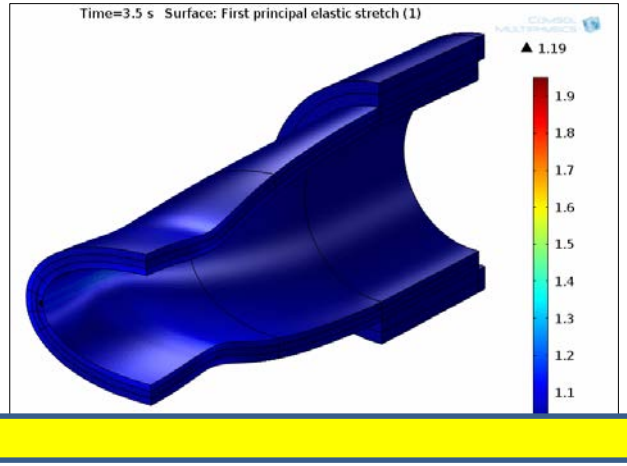




Compression

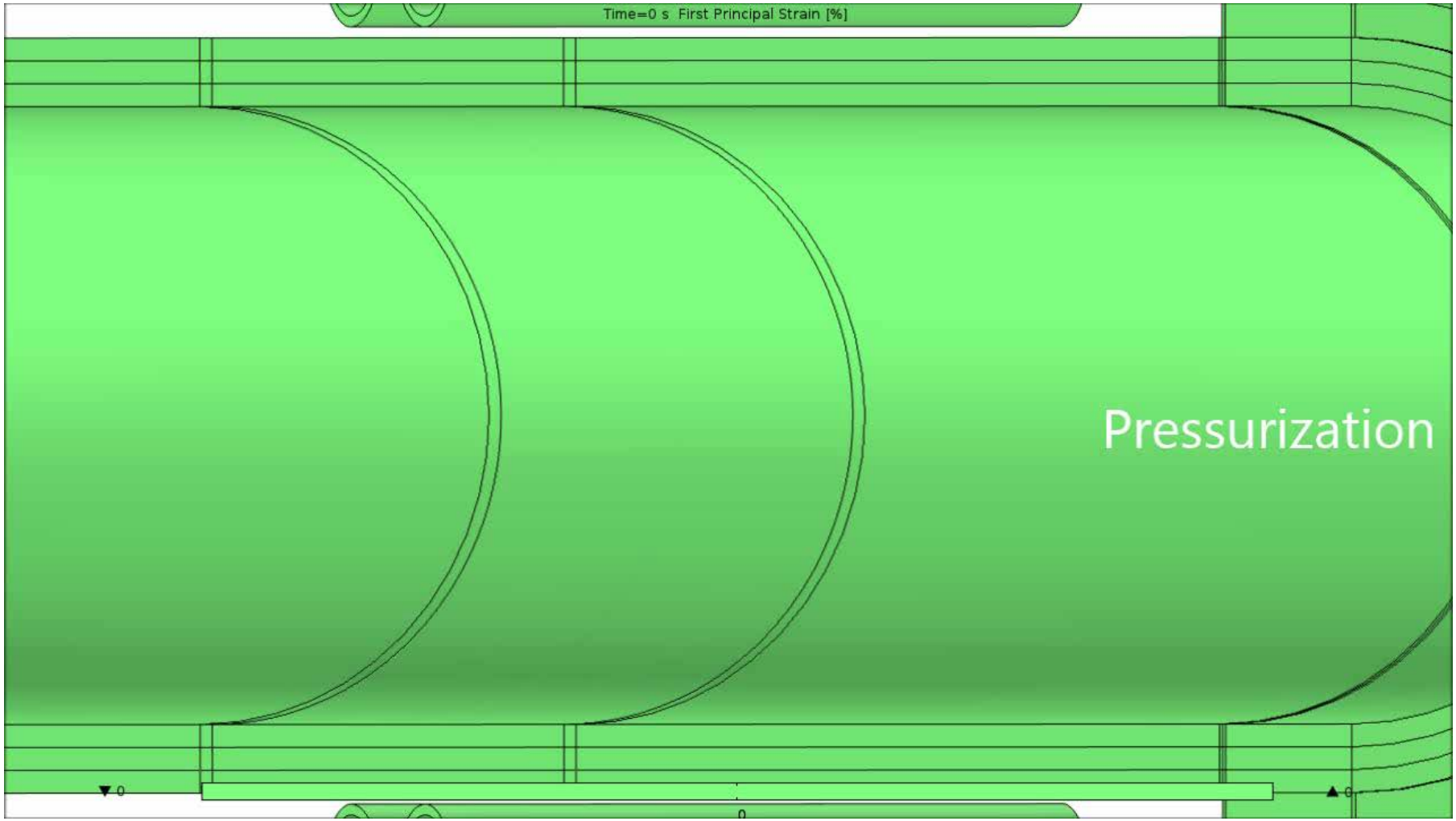




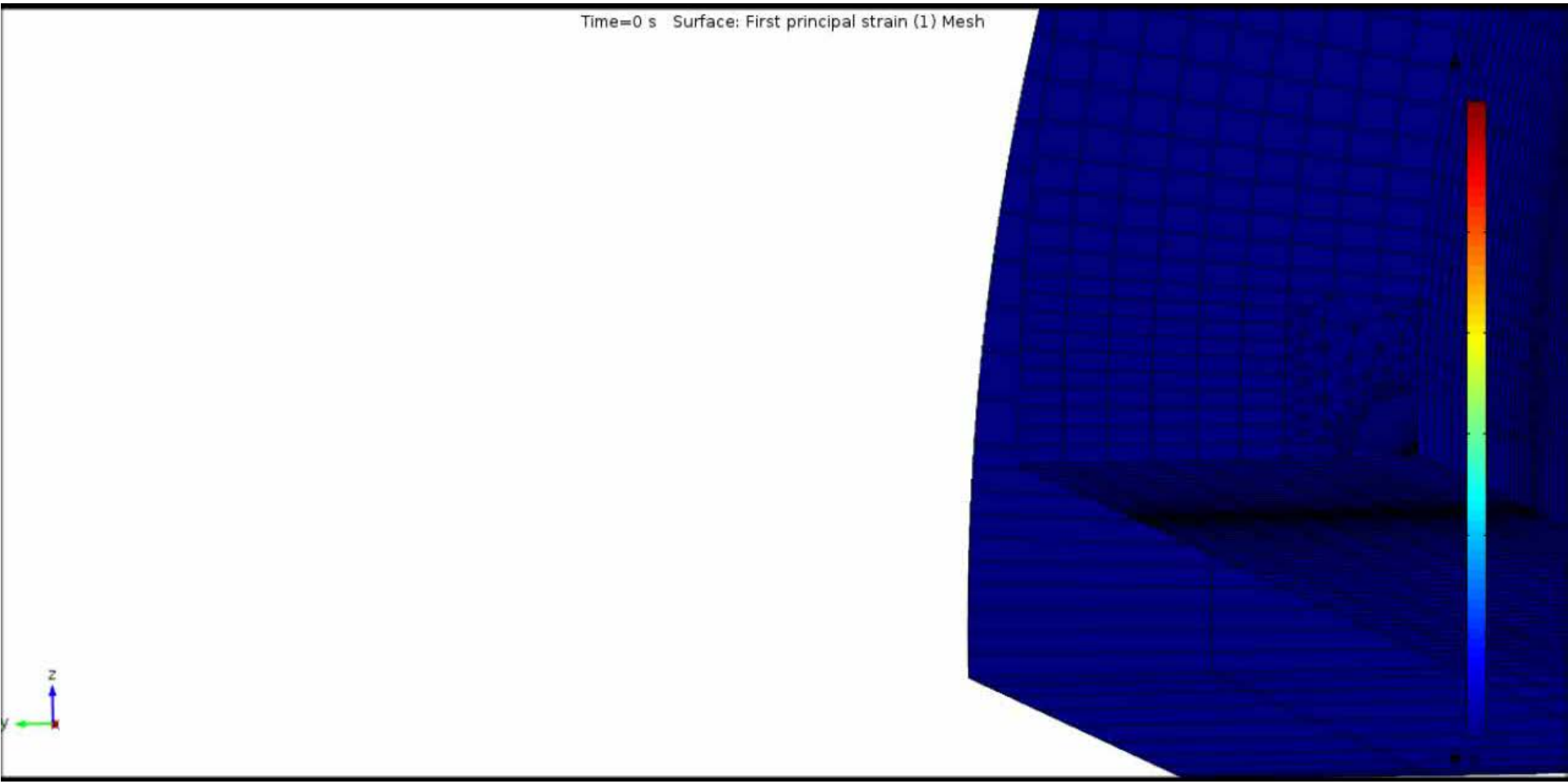


Relaxation

Squeeze-Off In Motion



Squeeze-Off Fold Detail

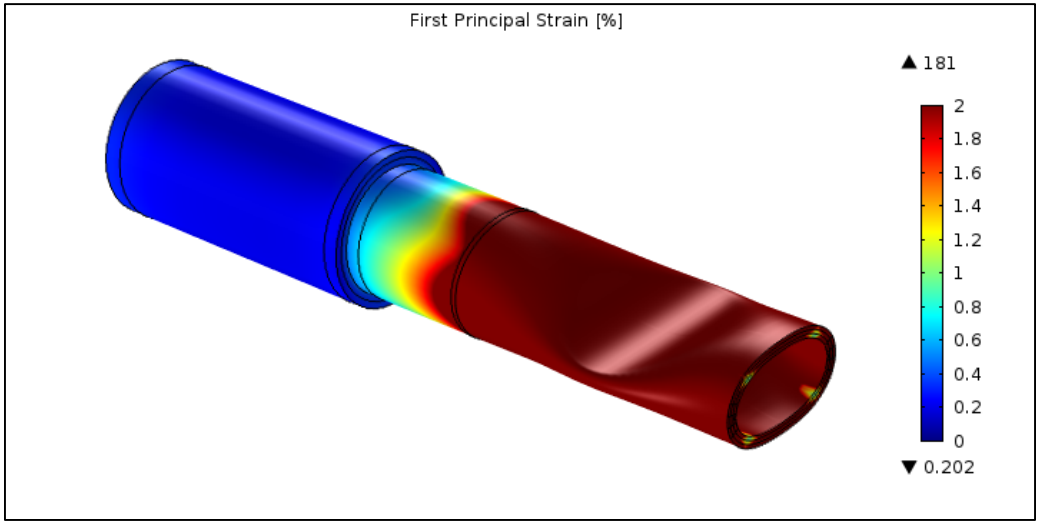


Finite Element Analysis – Results

Maximum First Principal Strain at vicinity of coupling edge, per geometric configuration

- The resulting strains are lower than those encountered in normal pipe bend radius per industry guidelines. See next slide.

Pipe Configuration	**1/2" IPS 11**	**1/2" IPS 11**	**1/2" IPS 11**	**2" IPS 11**	**2" IPS 11**
Offset from Coupling	12-inch	3xOD	2.5xOD	12-inch	3xOD
Offset Distance [in]	12.000	2.520	2.100	12.000	7.125
FEA Pipe Strain [%]	0.38	0.92	1.06	1.19	1.26
FEA Coupling Strain [%]	0.4	1.26	1.47	0.61	0.66



Accepted Pipe Strains

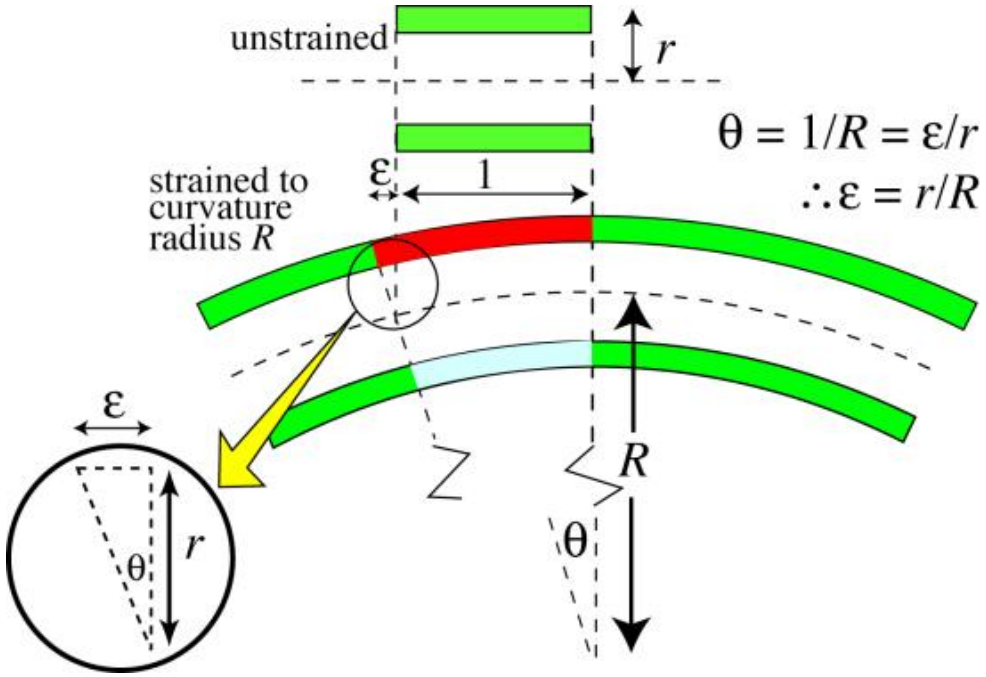


Image taken from: http://www.doitpoms.ac.uk/tlplib/beam_bending/printall.php

The maximum strain in a bent pipe occurs at the outer fiber of the pipe, away from the origin of the bend radius.

$$\varepsilon_{\max}[\%] = \frac{D_{outer}/2}{R_{bend}} * 100$$

$$= \frac{D_{outer}/2}{D_{outer} * f_{bend}} * 100$$

$$\varepsilon_{\max}[\%] = \frac{100}{2 * f_{bend}}$$

OD Multipliers for Minimum Pipe Bend Radius (From PPI Chapter 7, pg. 292, Table 4) and Resulting Maximum Nominal Bend Strain

DR	7	7.3	9	11	13.5	17	21	26	32.5	41	Fitting
f_{bend}	20	20	20	25	25	27	27	34	42	52	100
Max Strain [%]	2.50	2.50	2.50	2.00	2.00	1.85	1.85	1.47	1.19	0.96	0.50

Empirical Testing

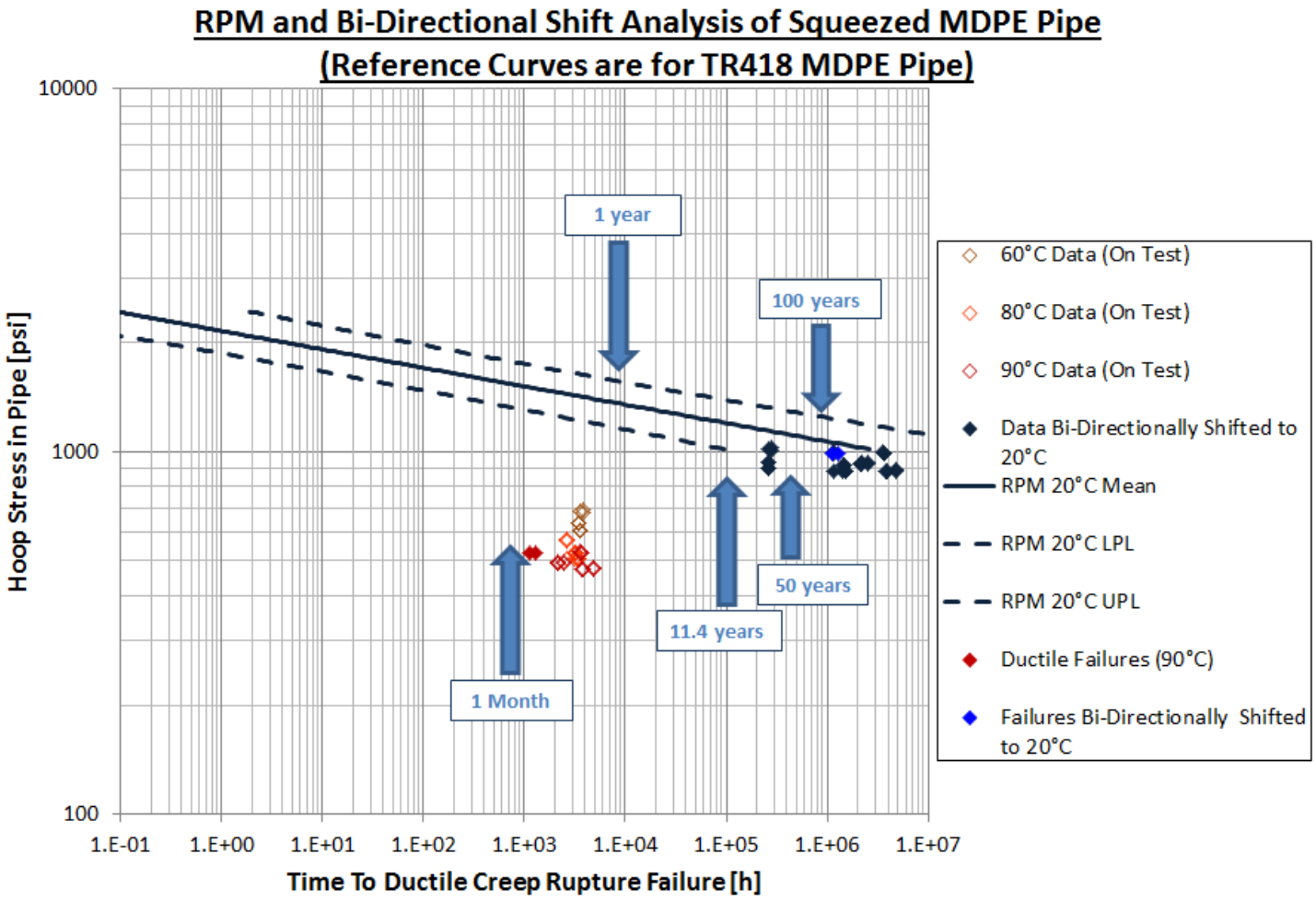
- Squeeze-off performed in accordance with ASTM D2513-14e1 and ASTM F1563
  - At 2″, 4″ & 12″ away from coupling
  - Held in constraint for 4 hours
  - Specimens capped with free-end type end closures, filled with deionized water, and tested in accordance with ASTM D1598-02(2009)
  - RPM test program is performed in accordance with PPI TN-16
    - 140°F, 176°F, 194°F (60°C, 80°C, 90°C)
    - Three (3) stress levels
    - Three (3) specimens tested at each stress level

Pipe Samples & Fittings

Overall view of entire sample assembly

Classic ductile rupture

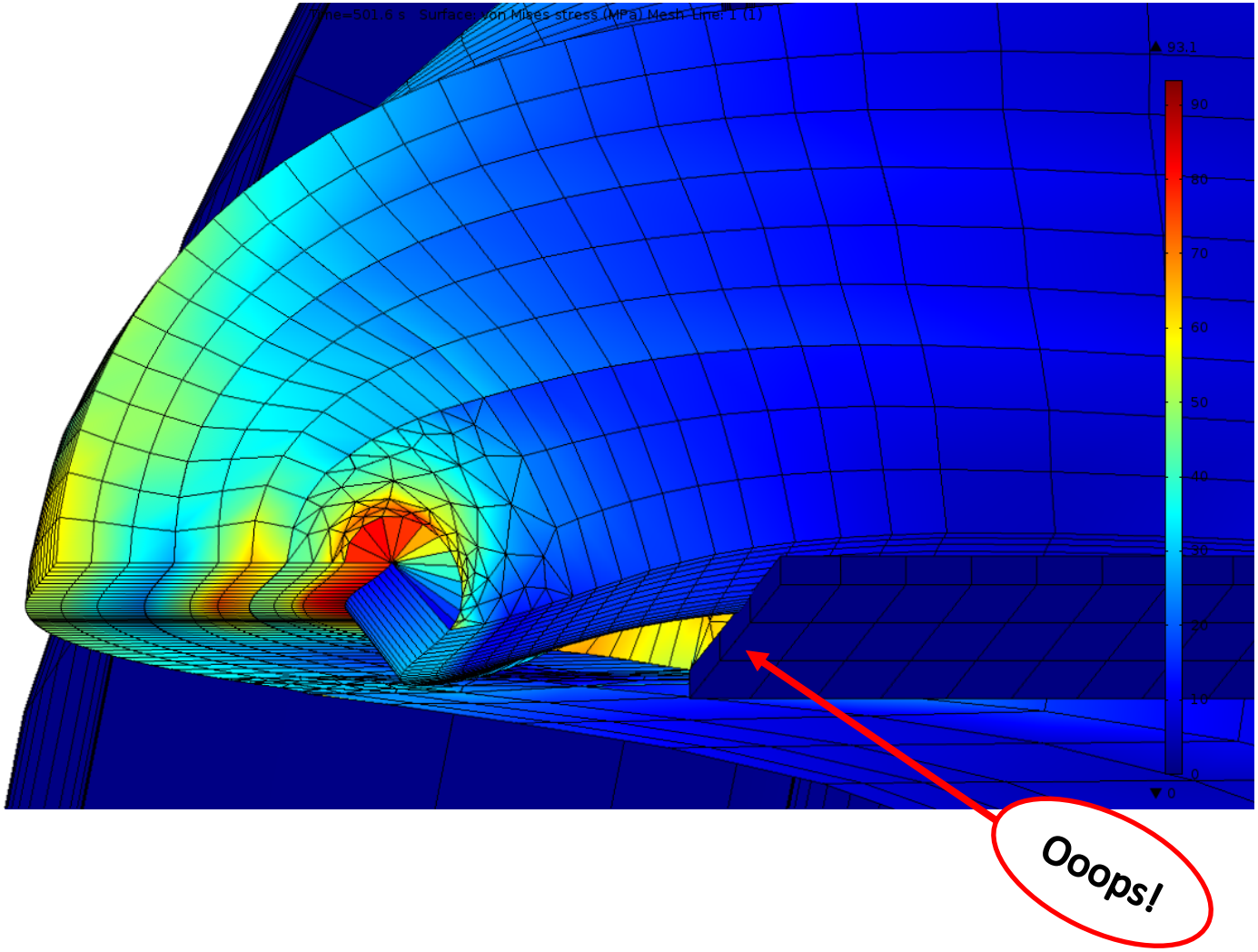
RPM & Bi-Directional Shift Analysis



Conclusions

- COMSOL Multiphysics was extremely helpful in gaining insight into the squeeze-off process.
- Simulations results indicated that the minimum squeeze-off distance from a fitting could be reduced from 12 inches to 3xOD for small diameter pipes.
- Empirical testing thus far has shown no premature failures due to squeeze-off distances of less than 12 inches.

Questions?


Time=501.6 s Surface: von Mises stress (MPa) Mesh Line: 1 (1)
▲ 93.1
90
80
70
60
50
40
30
20
10
0
▼ 0
Ooops!