A Mechanism for Validation of Hyperelastic Materials in ANSYS

Megan Lobdell, Brian Croop
DatapointLabs Technical Center for Materials,
Ithaca, USA

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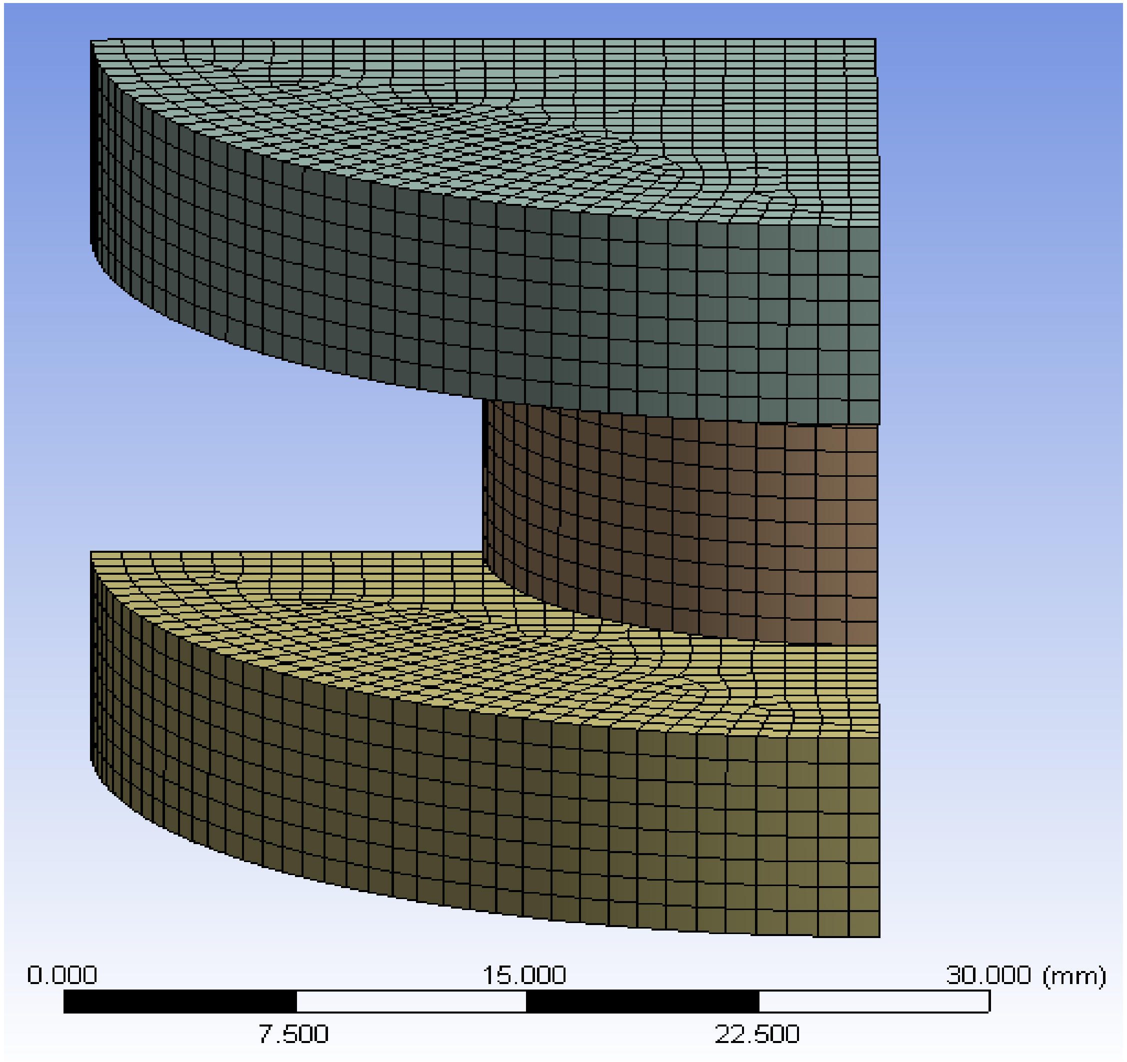

0.000
15.000
30.000 (mm)
7.500
22.500

DatapointLabs

EST 1995

ISO 17025 Quality

technical center for materials

matereality

software for materials

TestPaks

testing for simulation

picsci

electronic lab notebooks

knowmats

materials in simulation

Material Testing Expertise

- Product development / R&D support
  - CAE-centric
  - Commitment to simulation accuracy
- All kinds of materials
  - Over 1,800 materials tested each year
- All kinds of material behavior
  - Over 200 physical properties:
    - Mechanical properties
    - Thermal properties
    - Flow properties
- Globally available at
  www.datapointlabs.com
  visit | browse | buy | download

Plastic
Rubber
Film
Metal
Foam
Composite
Cement
Ceramic
Paper
Wire
Fiber

Tensile
Compressive
Flexural
Stress-strain
Poisson’s ratio
High strain rate
Bulk modulus
Fatigue
Viscoelasticity
Stress relaxation
Creep
Friction
Hyperelasticity
Thermal expansion
Thermal conductivity
Specific heat
PVT
Rheology

Objective

- Create a process to validate solver+ simulation inputs before real-life application
- Benefits
  - increase confidence
  - reduce risk
  - save time

CAETestBench Validation Mechanism

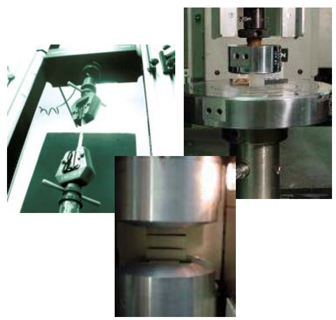
- Use a standardized geometry
  - May not be real-life part
- Test must be ‘perfect’
  - Boundary conditions can be correctly simulated
  - Load case can be correctly simulated
- Comparison
  - Obtain test output that is also available in simulation
  - For example, DIC strain pattern, force v. time…

Overview of this Validation

- Measure hyperelastic properties
- Create material model
- Devise “standardized” compression test
  - Both faces slipping (closed loop case)
  - Top face fixed (open loop)
  - Top and bottom faces fixed (open loop)
- Simulate and compare to experiment
- Quantify simulation accuracy

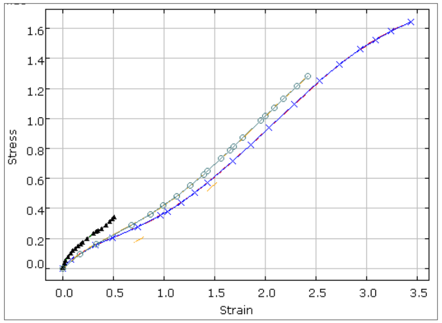
Expert Material Testing

rubber

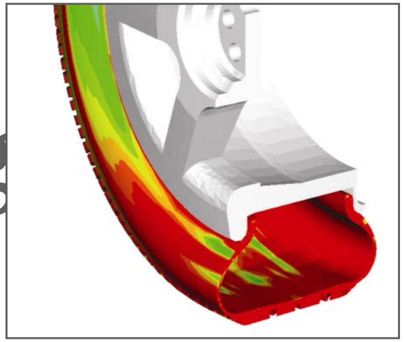


test

+



conversion



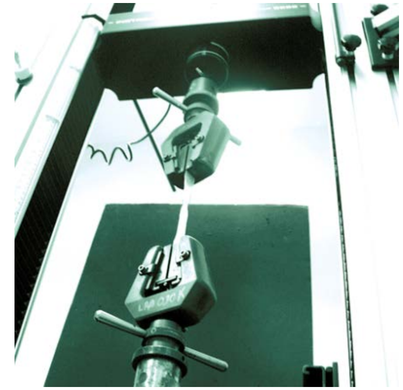
Your CAE

- Rubber testing and CAE material parameter conversion
  - ANSYS – hyperelastic, viscoelastic, Ogden foam
  - LS-DYNA – rate-dependent data MAT77, MAT181, MAT183

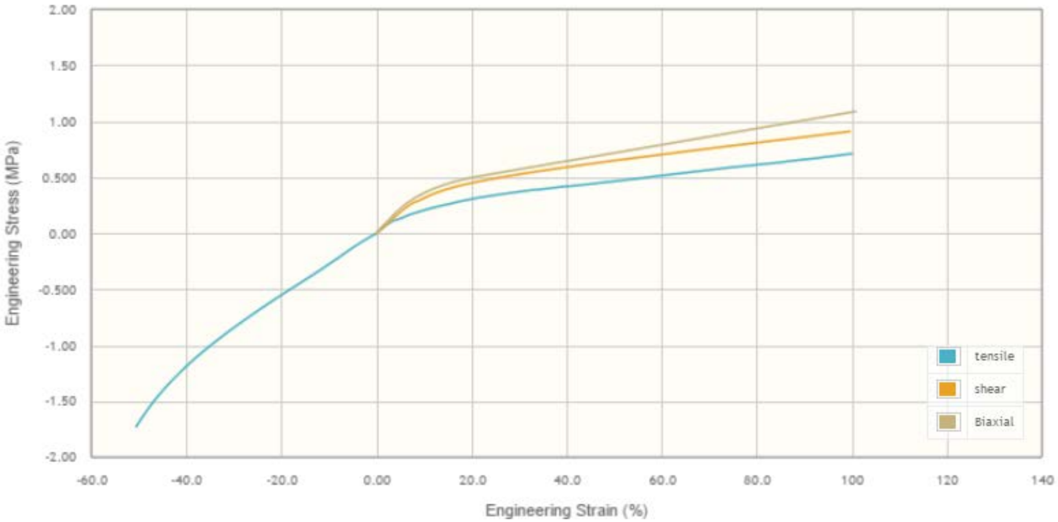
EST 1995
ISO 17025 Quality

Hyperelastic Tests

- Tensile
- Compressive
- Planar
- Volumetric
- Range
  - first pull



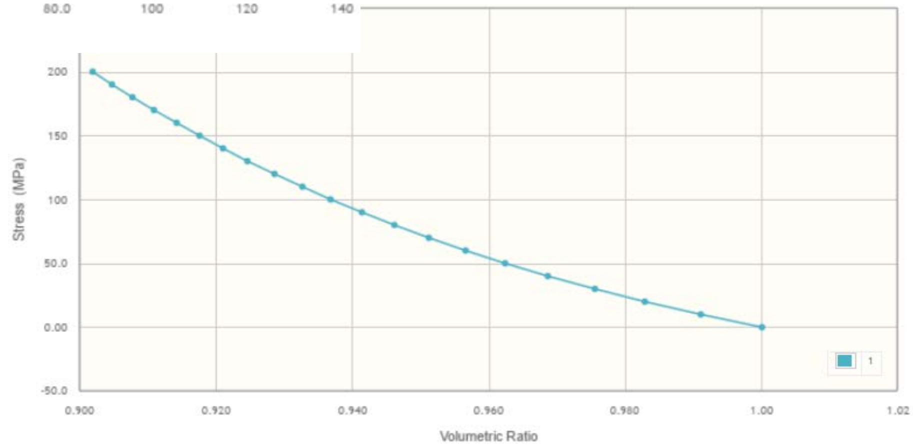
Material Properties



Deviatoric data

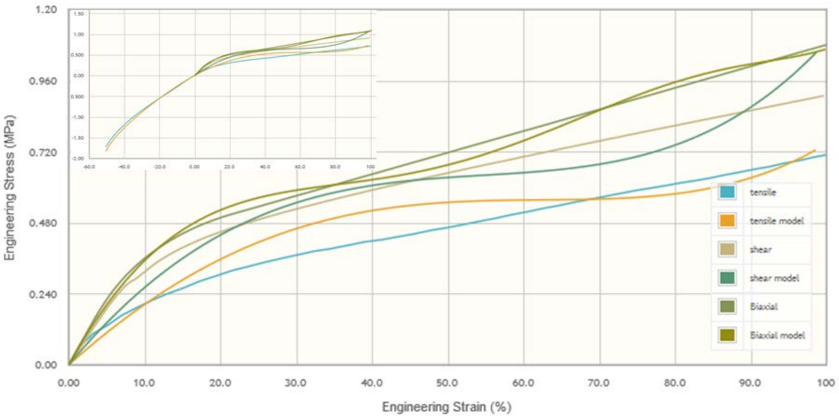
- Uniaxial
- Biaxial
- Shear

Volumetric data



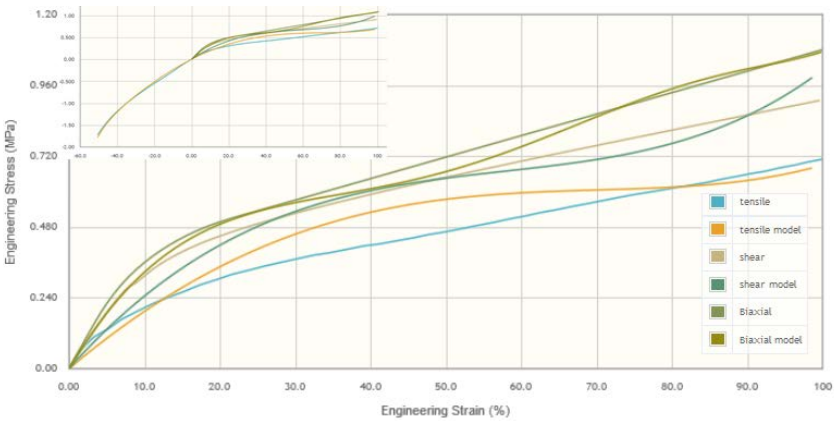
Mooney-Rivlin 9 Parameter

Matereality



C10	3.47E-01	MPa
C01	3.52E-02	MPa
C20	-1.36E-01	MPa
C11	2.88E-02	MPa
C02	-7.90E-03	MPa
C30	2.33E-02	MPa
C21	1.44E-02	MPa
C12	-1.15E-02	MPa
C03	1.91E-03	MPa
D1	1.34E-03	1/MPa

Workbench

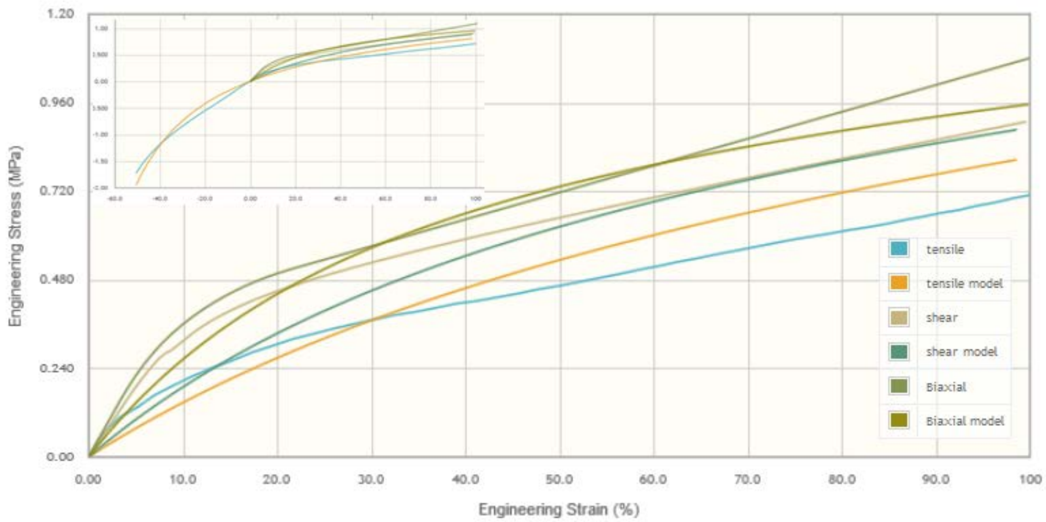


C10	3.64E-01	MPa
C01	-5.81E-03	MPa
C20	-1.19E-01	MPa
C11	4.54E-02	MPa
C02	-1.11E-02	MPa
C30	1.38E-02	MPa
C21	1.35E-02	MPa
C12	-9.47E-03	MPa
C03	1.56E-03	MPa
C10	3.64E-01	MPa

Ogden 3 Term

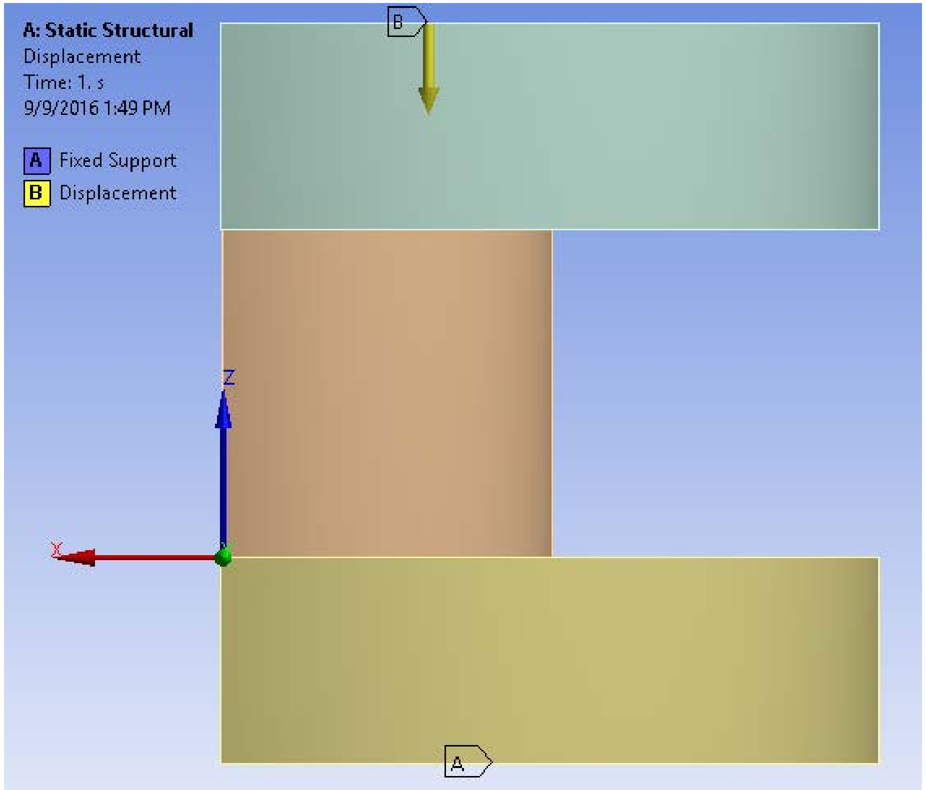
Matereality

MU1	3.715023	MPa
MU2	-1.58648	MPa
MU3	-1.58647	MPa
A1	1.141617	
A2	0.994652	
A3	0.99404	
D1	0.001763	1/MPa
D2	3.1128e-5	1/MPa
D3	-1.5446e-6	1/MPa



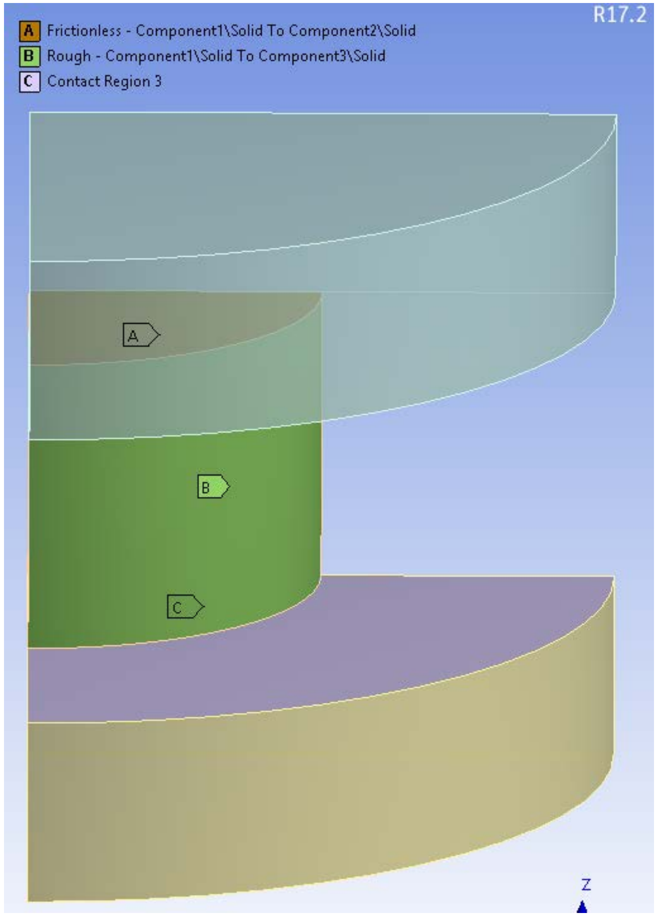
Simulation B.C.s

- Top is displaced
- Bottom platen fixed
- Contact varies between sliding and fixed
- Quarter model



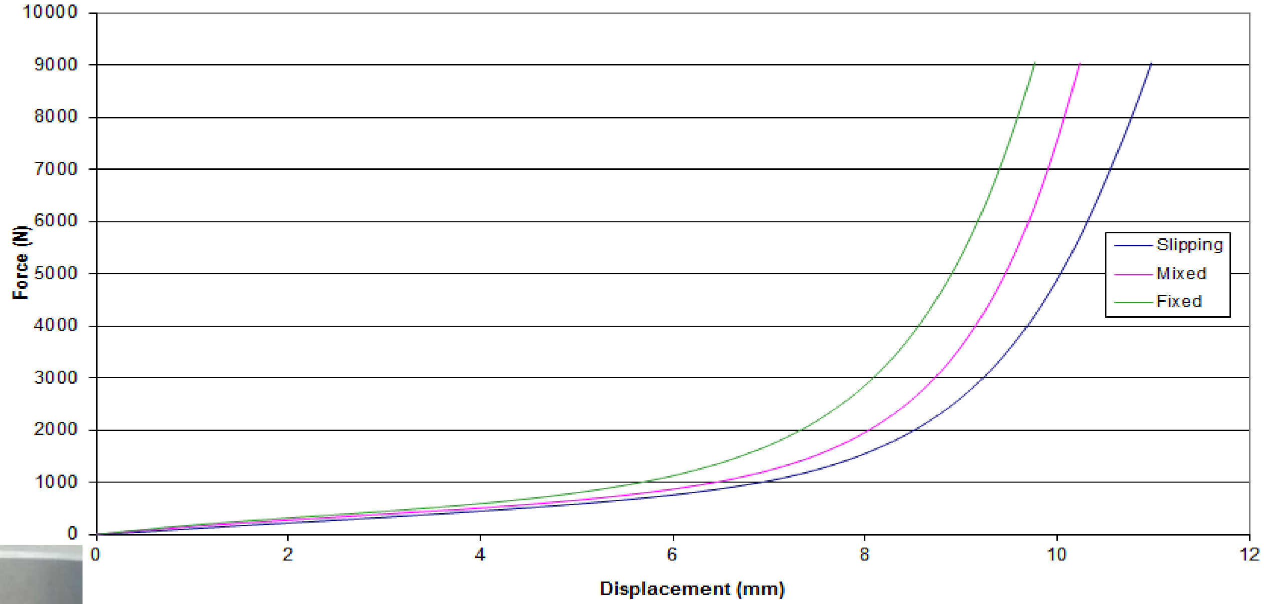
Contact Conditions

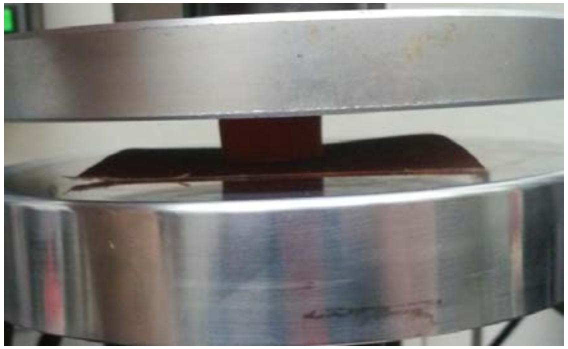
<table>
<tr><td colspan="3">Quarter model, symmetry on the x and y faces</td></tr>
<tr><td colspan="3">Fixed bottom platen</td></tr>
<tr><td colspan="3">Displacement to 6.35mm on the top platen</td></tr>
<tr><td colspan="3">Bonded contacts accompany a rough contact for the circumfrential side</td></tr>
<tr><td>Contact</td><td>Location</td><td>Type</td></tr>
<tr><td>Slipping</td><td>Top</td><td>Frictionless</td></tr>
<tr><td></td><td>Bottom</td><td>Frictionless</td></tr>
<tr><td>Mixed</td><td>Top</td><td>Frictionless</td></tr>
<tr><td></td><td>Bottom</td><td>Bonded</td></tr>
<tr><td>Fixed</td><td>Top</td><td>Bonded</td></tr>
<tr><td></td><td>Bottom</td><td>Bonded</td></tr>
</table>



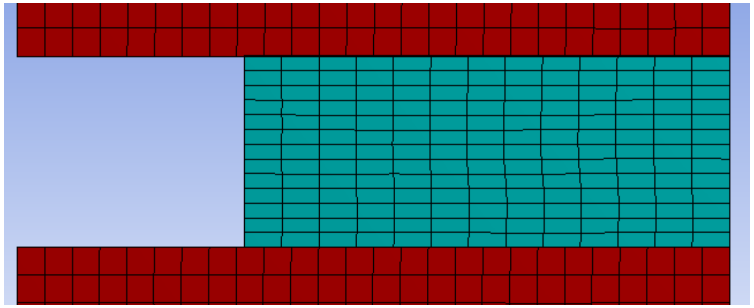
Validation Experiments

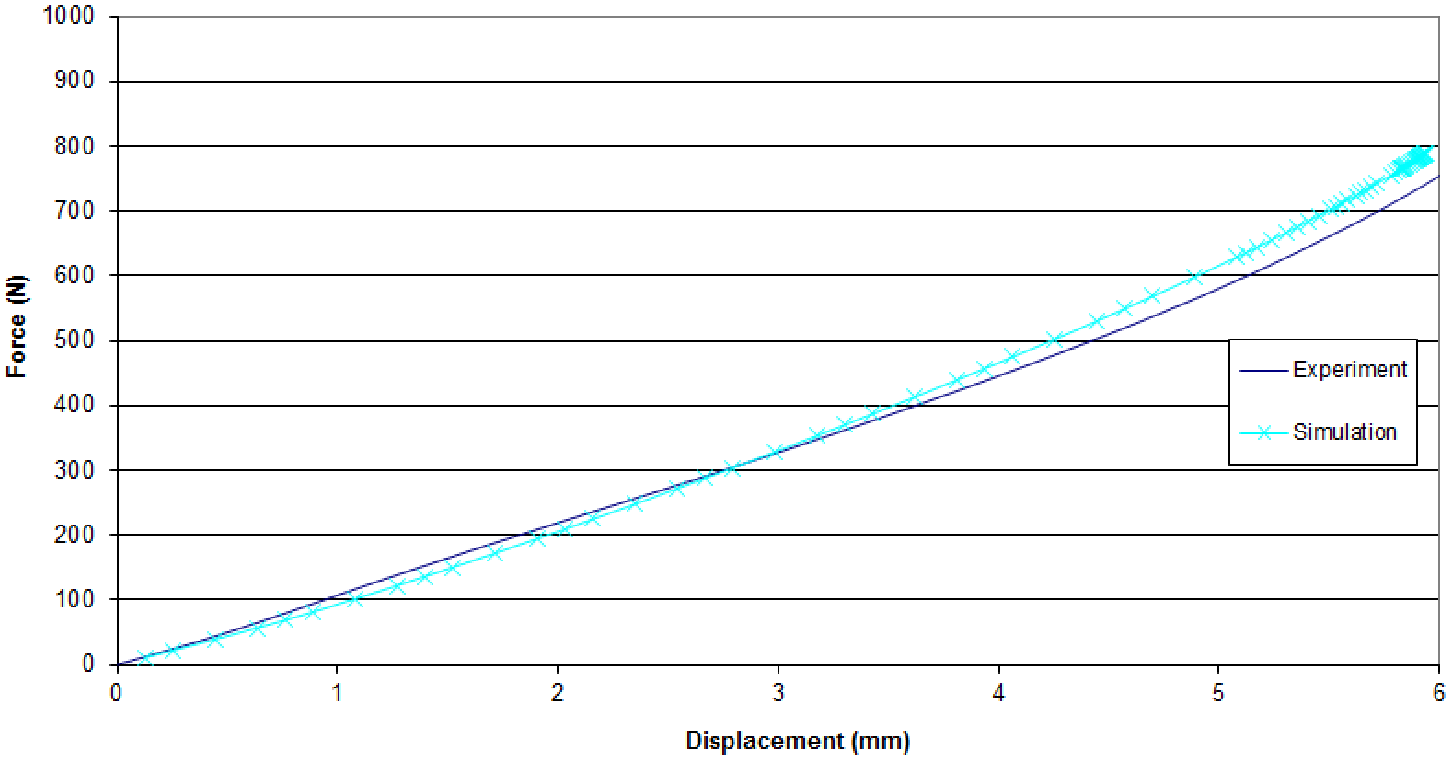
- Slip
- Mixed
- Fixed





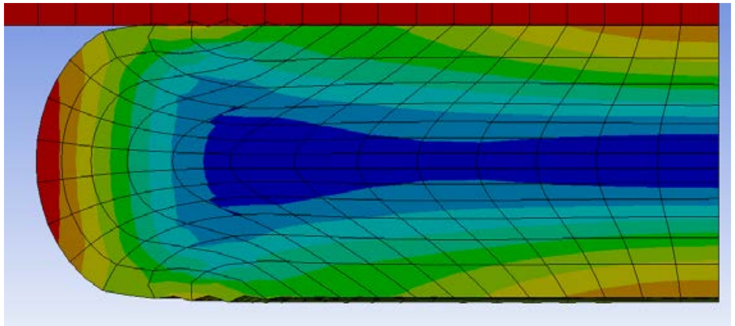
Slip

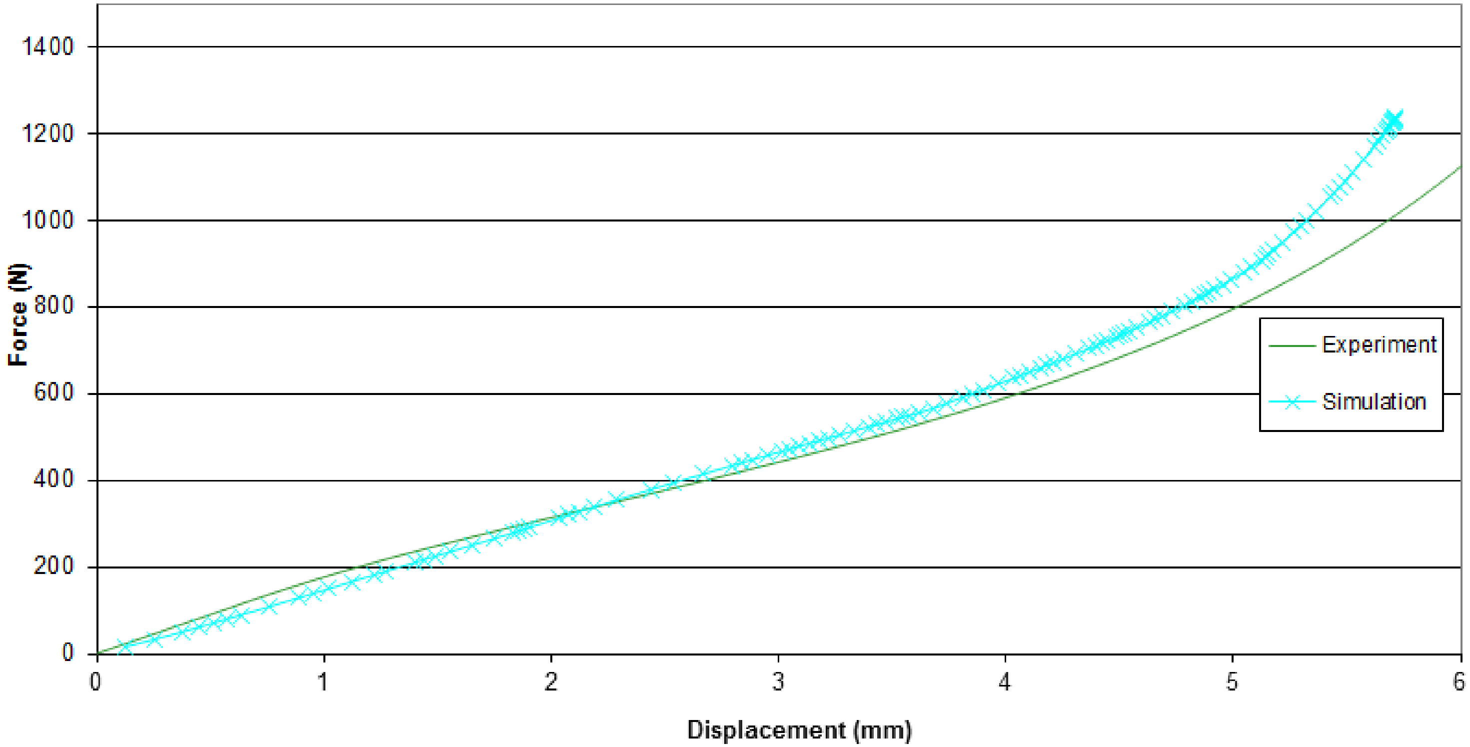




1000
900
800
700
600
500
400
300
200
100
0
Force (N)
0
1
2
3
4
5
6
Displacement (mm)
Experiment
Simulation

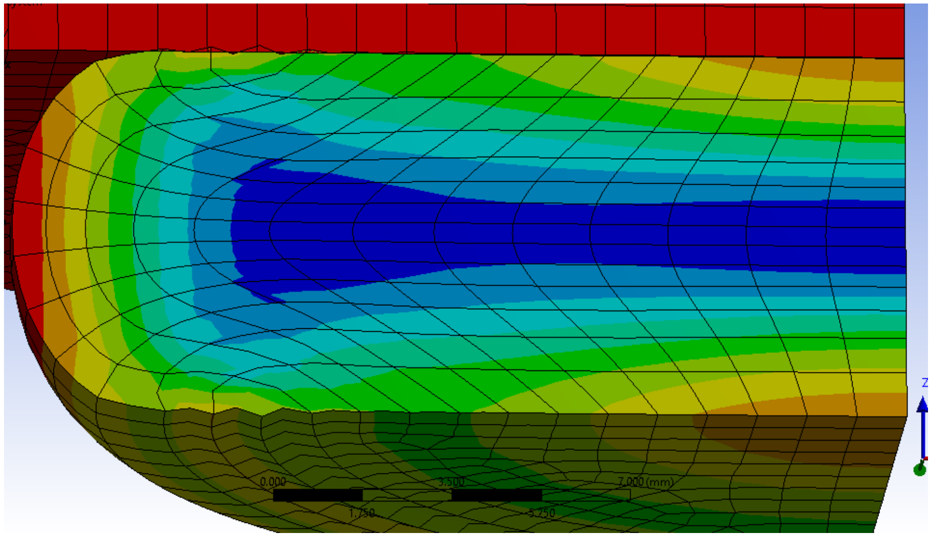
Fixed



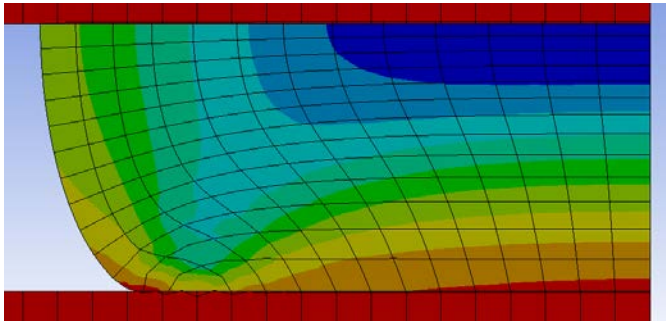

1400
1200
1000
800
600
400
200
0
Force (N)
0
1
2
3
4
5
6
Displacement (mm)
Experiment
Simulation

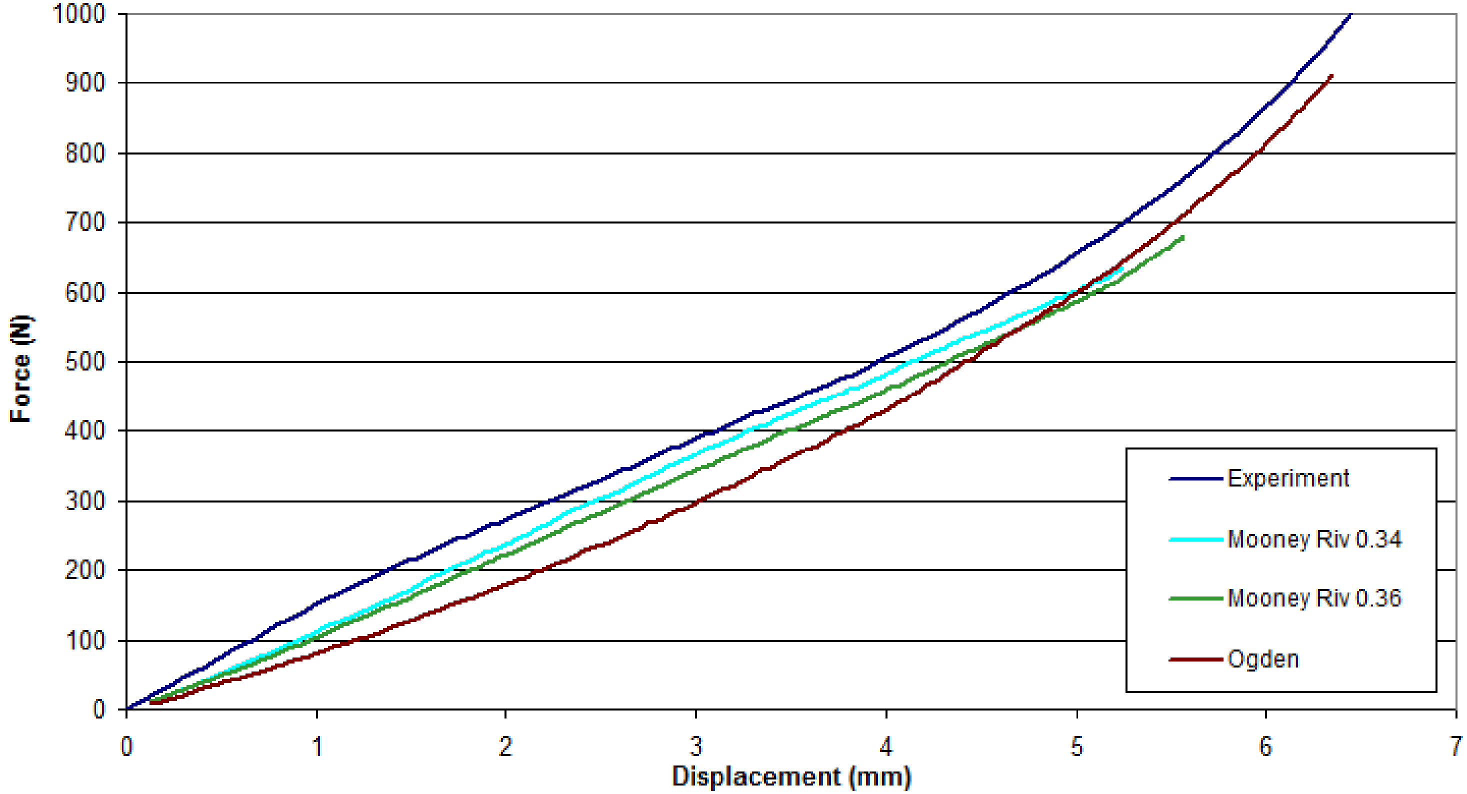
Contact Issues

- Fixed boundary has roll over which is addressed with the rough contact
- The corner element and nearby mesh are distorted

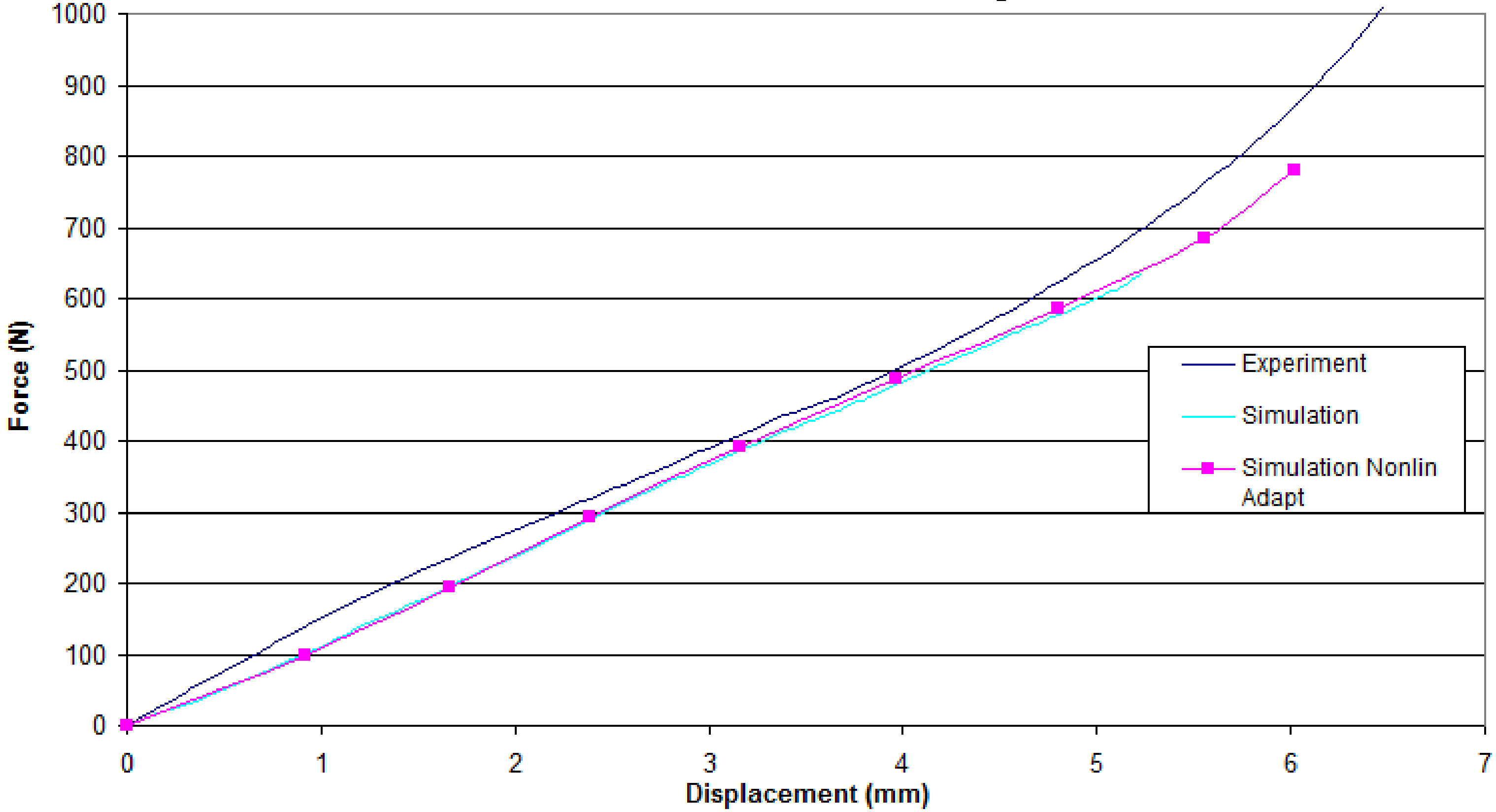


Mixed




1000
900
800
700
600
500
400
300
200
100
0
Force (N)
0
1
2
3
4
5
6
7
Displacement (mm)
Experiment
Mooney Riv 0.34
Mooney Riv 0.36
Ogden

Mix - Nonlinear Adaptive Mesh



Results

- Accurate for moderate strains (40%)
- Closed-loop validation unsurprisingly shows least deviation
- The most complex set of boundary conditions (mixed) has the least accuracy
- Different data fitting programs yields variability on parameters, with only slight impact on the simulation

Conclusions

- Validation of simulation quantifies the difference between virtual world and reality
- Should be performed each time a material is being tested for use in simulation
- Data, model, and simulation can be checked using test cases that contain real-life behaviors, giving confidence to the analyst