Material Characterization and Numerical Simulation of Complex Materials and Structures

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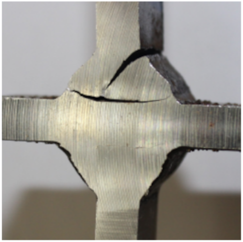
MOD Research Group

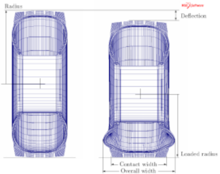
Mr Johann Bredell **Prof Martin Venter** **Prof Gerhard Venter**



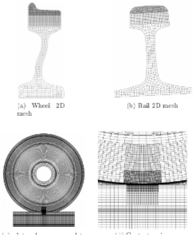
- Materials, Optimisation and Design Research Group
  - Complex (structural) numerical simulations
  - Optimisation and machine learning
  - Programming and automation
  - Experimental work/validation

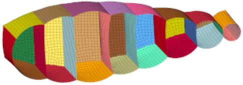
Topics




Radius
Deflection
Loaded radius
Contact width
Overall width

Topics





In-Depth Discussion: Material Characterization

- Project motivated from a biological perspective
  - Small samples that are difficult to get hold of
  - Difficult to perform traditional material tests due to sample size
  - Not well-characterized material
- These materials are well-represented by soft silicone rubbers
- The techniques developed here apply to any biological material and/or rubber-like material that the Mooney-Rivlin material model describes
- The goal of this work is to obtain material properties for use in FE analysis for design purposes

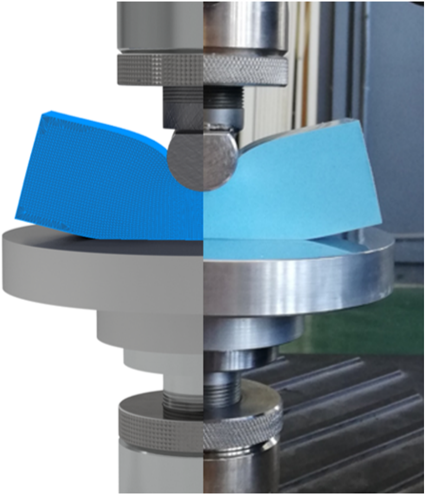
Characterization of Soft Rubber

- Work done by Dr JD van Tonder
- How to characterize the Mooney-Rivlin 3 parameter material model for Silicon rubber?
- Traditionally done using multiple tensile and compressive tests
- Our goal is to perform this using a single, complex test case using:
  - Inverse FE model updating (FEMU)
  - Full-field displacement data from Digital Image Correlation (DIC)

There is a Problem

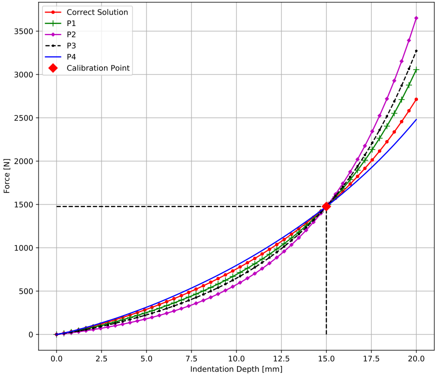
The results obtained from the inverse approach are not unique

Inverse FE Model Updating



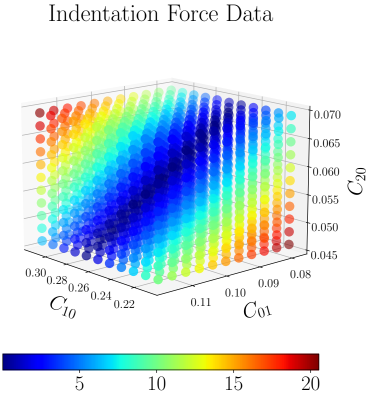
Non-Uniqueness

- Multiple sets of material parameters provide the correct load-displacement data at the test point
- Behavior away from the test point is not the same



Hyperplanes - Discovery

- We started to investigate the problem by running a large number of simulations with different material properties
- From these results, it was clear that certain patterns emerge



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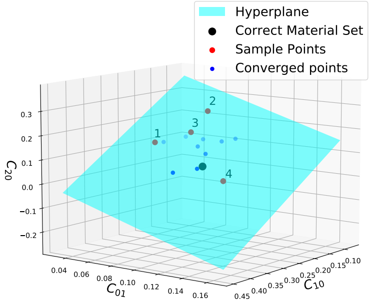
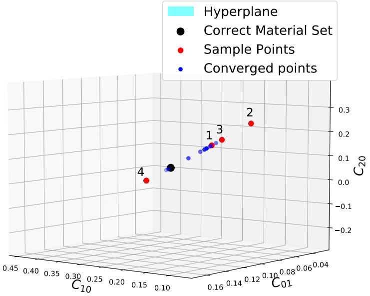
Hyperplanes - End Result

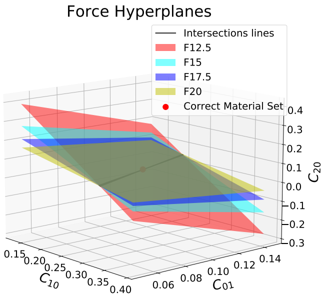
- Based on these numerical experiments, we obtained the following

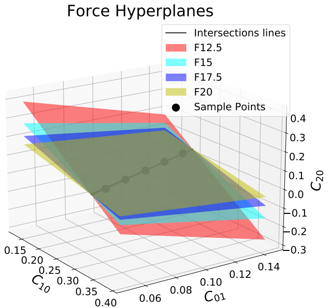




Hyperplanes - There is More

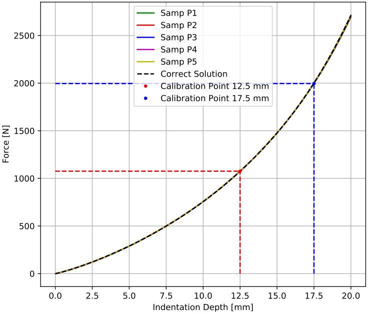
- It turns out that for different force/displacement levels, the hyperplanes rotate about a line that passes through the correct value
- The force hyperplanes behave better than the displacement hyperplanes, so we will concentrate on those here





Non-Uniqueness Solved?

- Instead of having solutions on a plane, we now have solutions on a line
- This improves but does not solve the non-uniqueness problem yet



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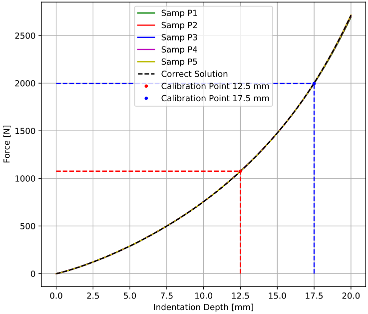
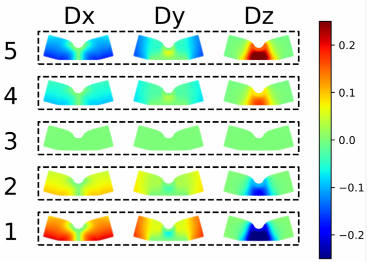
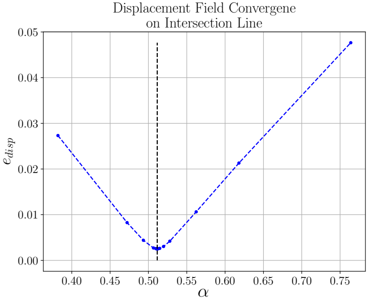


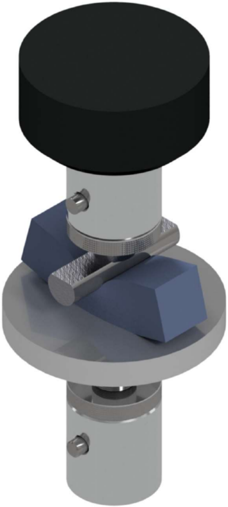


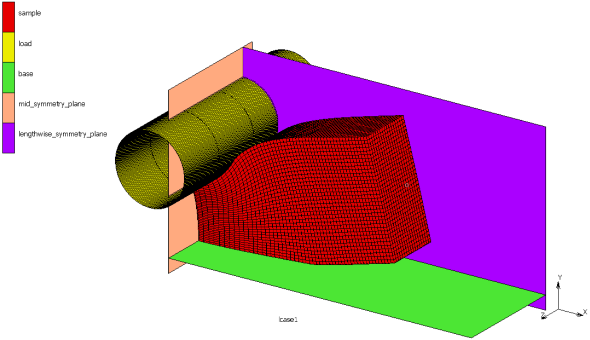
Also Consider the Displacement Field

- To resolve the non-uniqueness problem, we can also consider the DIC displacement
- Perform a displacement field match for solutions that lay along the hyperplane rotation line



Application





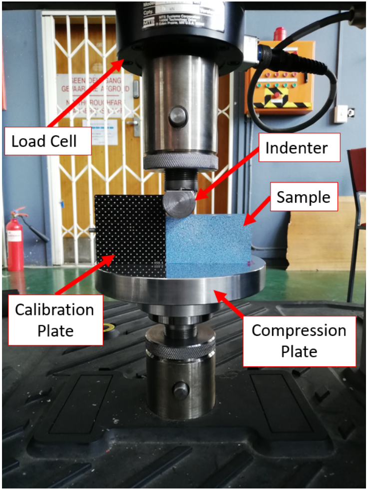
Results

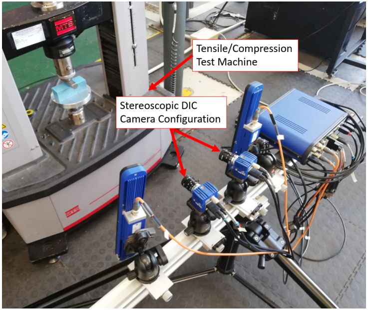
- We concentrate on the numerically simulated experiment
  - Exact results known
  - No experimental error/noise
- Can reliably match the known parameters within 1 %
- Results are independent of indentation level
- Results are dependent on mesh convergence

Physical Experiments

Results were replicated in physical experiments as well

Physical Experiments





Concluding Remarks

- We are characterizing soft silicon rubber materials using a single, complex test case
- For the test, we measure the applied load and full field displacement values using DIC
- Hyperplanes are introduced as a way of solving the non-uniqueness problem associated with the inverse method
- The results have been extensively validated with numerical experiments and limited physical experiments
- To date, the approach has only been applied to the three-parameter Mooney-Rivlin material model

Questions

Inverse FE Model Updating