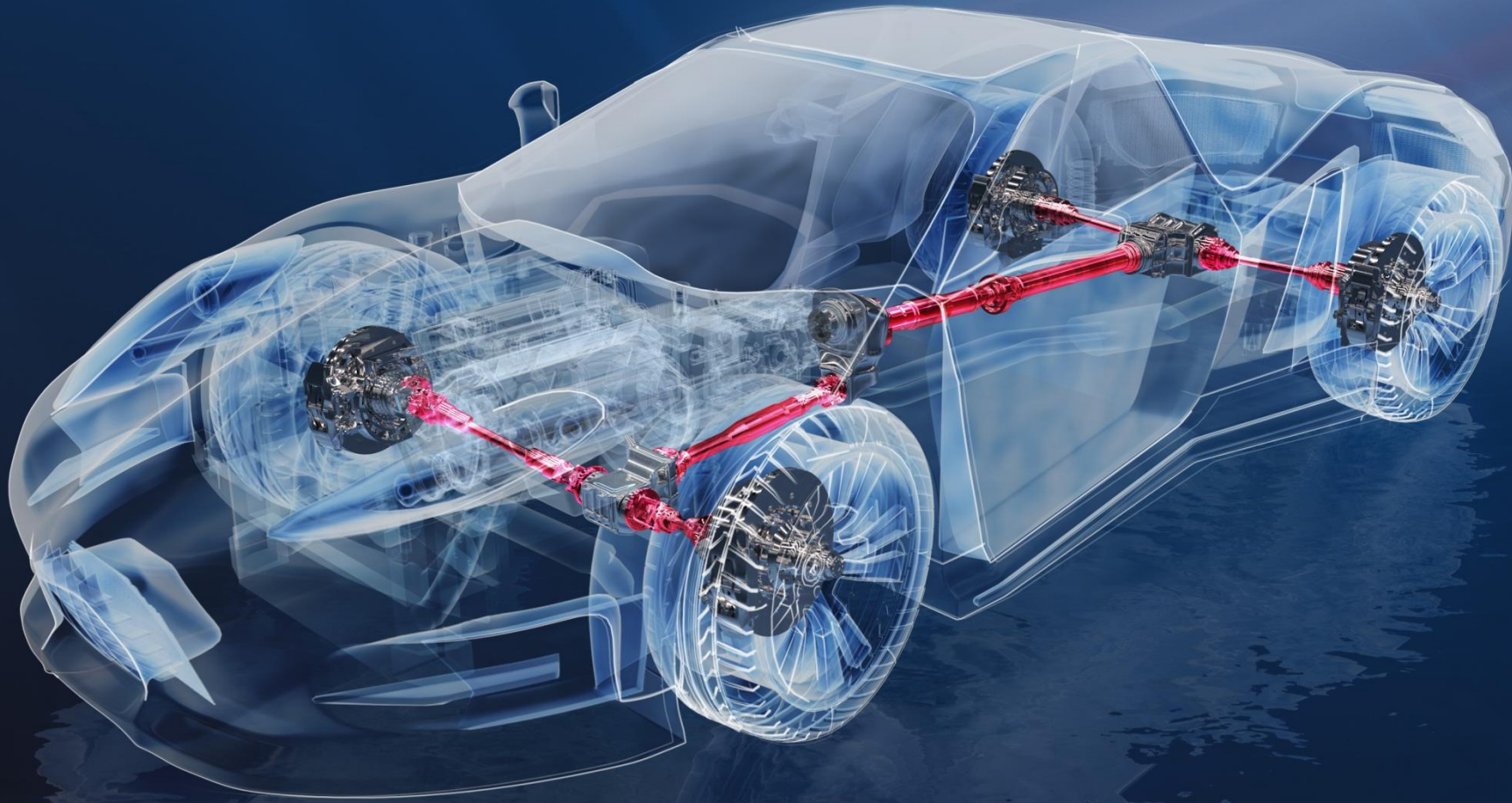


Parameter identification for an hyperelastic material model of an elastomer rubber boot





Motivation



Parameter identification and curve fitting with optiSLang



2D – axis symmetric analysis of an elastomer rubber boot



Summary



Motivation



Parameter identification and curve fitting with optiSLang

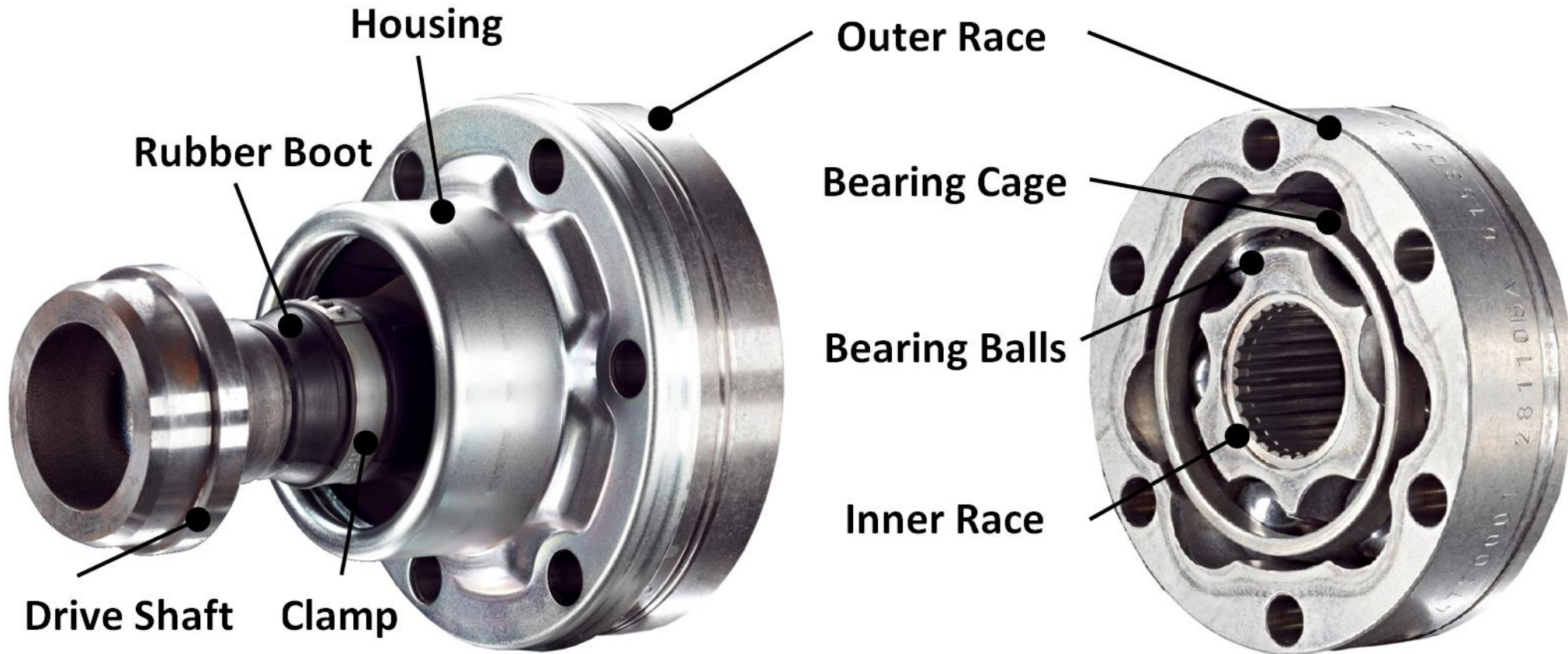


2D – axis symmetric analysis of an elastomer rubber boot

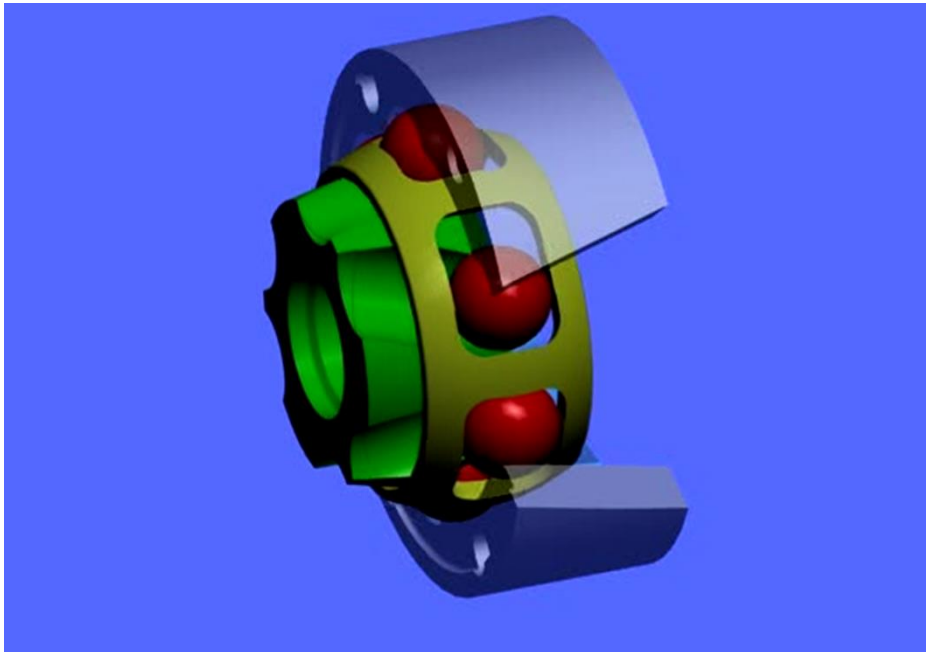


Summary

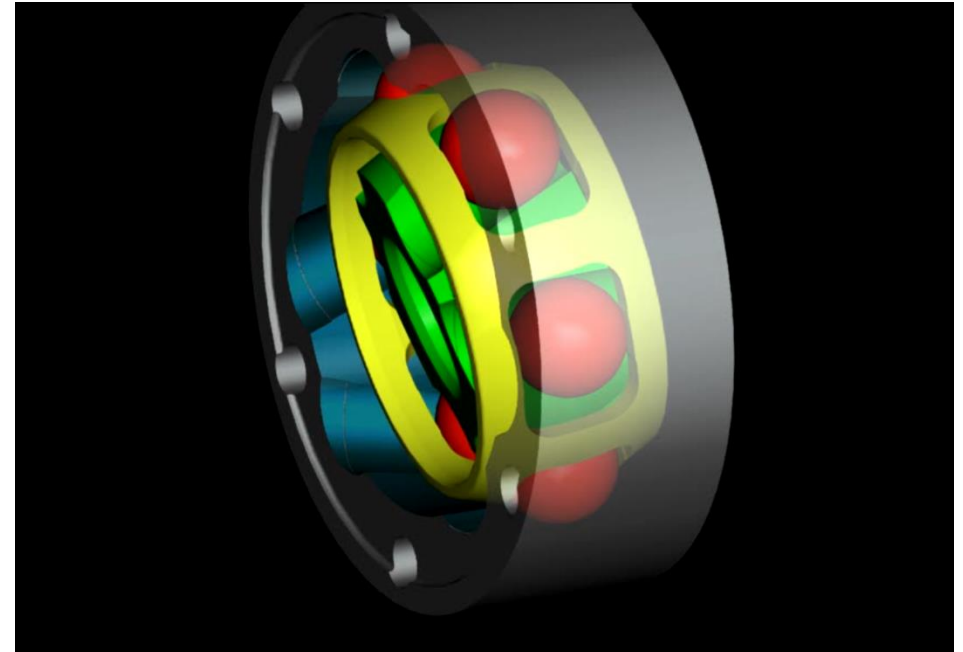
Constant velocity (CV) joint



Length compensation:



Flexion:





Damage symptoms



- Unintended “S”-shaped deformation by negative length compensation.
- Breakage caused by damage areas on rubber boot surface.



- Lost contact caused by fluid pressure penetration at housing site.



Motivation



Parameter identification and curve fitting with optiSLang



2D – axis symmetric analysis of an elastomer rubber boot

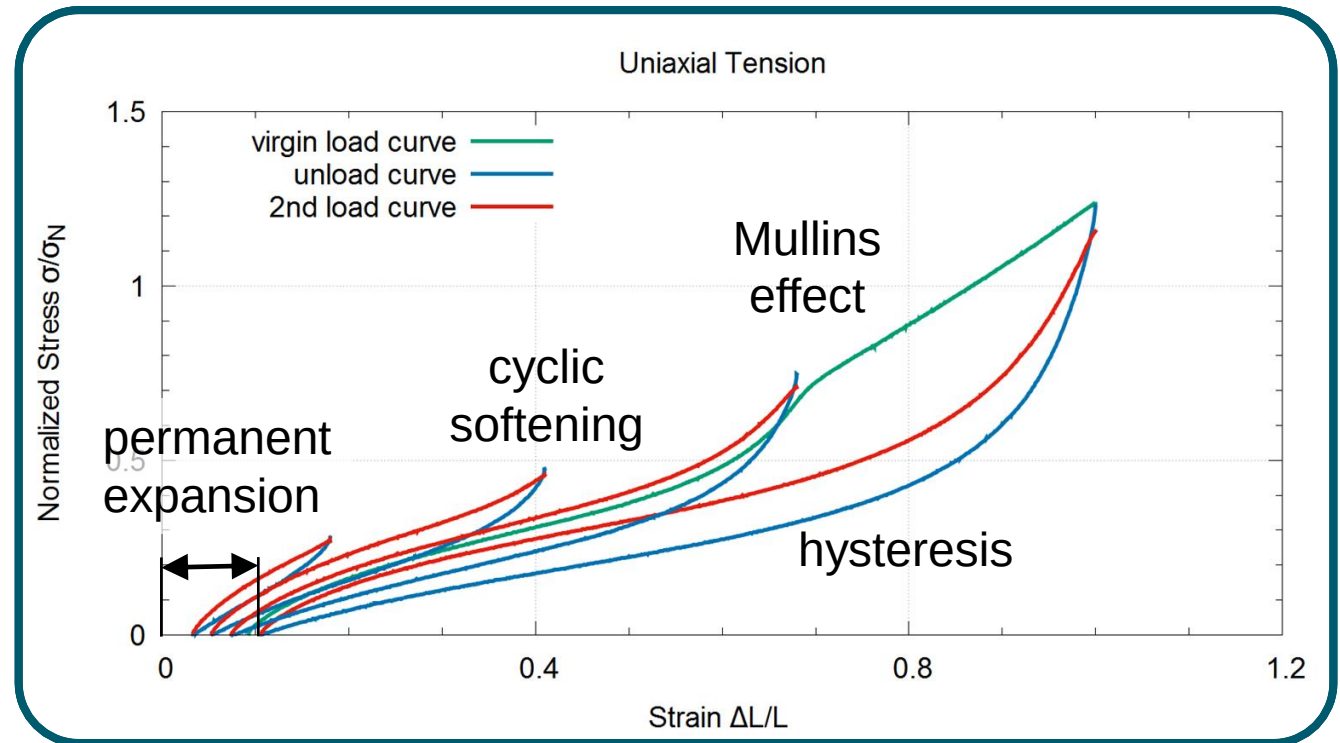


Summary

Hyperelasticity - characteristics of rubber material



large deformation_[1]



non-linear stress-strain behaviour

[1] <http://www.instron.de/de-de/testing-solutions/by-material/biomedical/tension/bs-en-455-2>

Modeling of hyperelasticity

- strain energy potential W

$$W = W(I_1, I_2, I_3)$$

- invariants of strain tensor

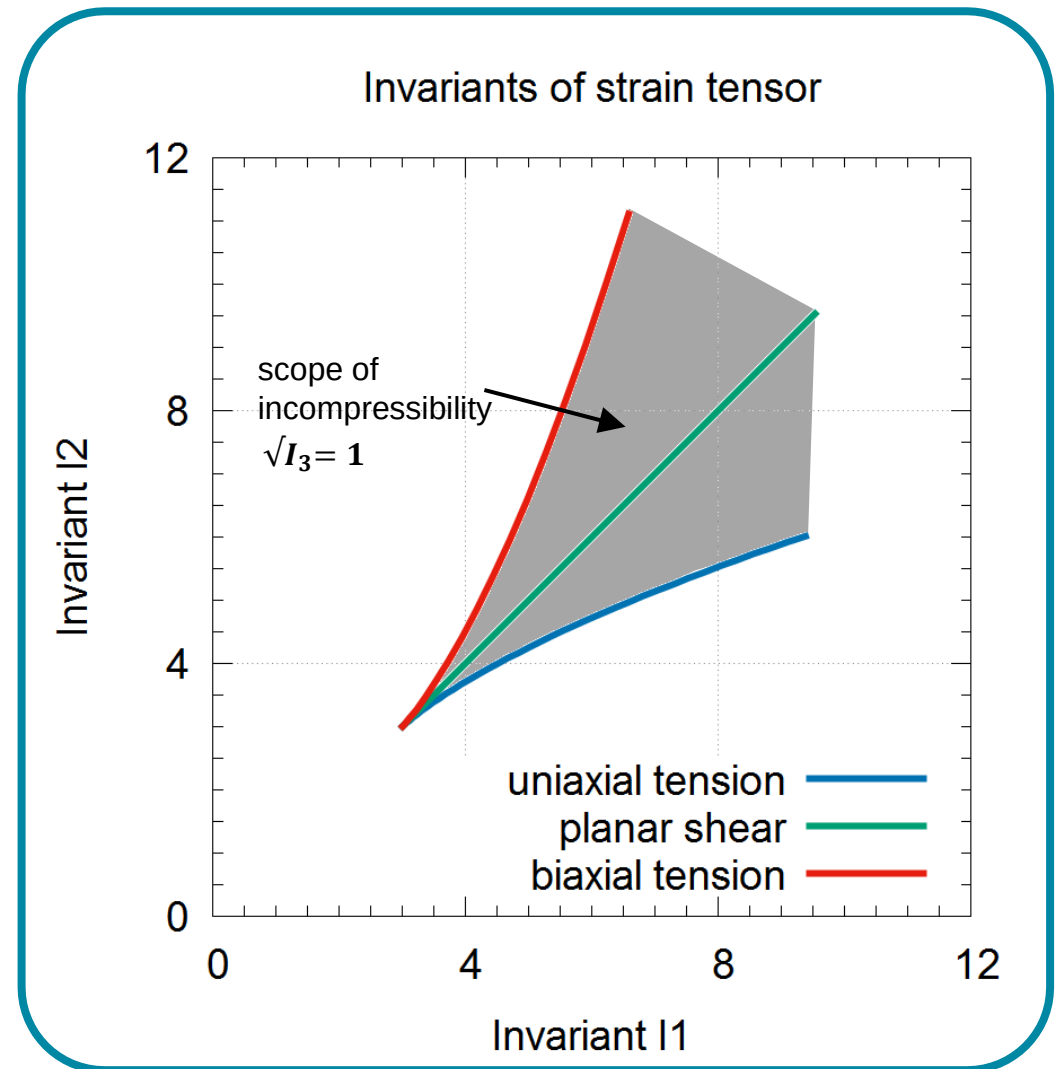
$$I_1 = \lambda_1^2 + \lambda_2^2 + \lambda_3^2$$

$$I_2 = \lambda_1^2 \lambda_2^2 + \lambda_2^2 \lambda_3^2 + \lambda_3^2 \lambda_1^2$$

$$I_3 = \lambda_1^2 \lambda_2^2 \lambda_3^2$$

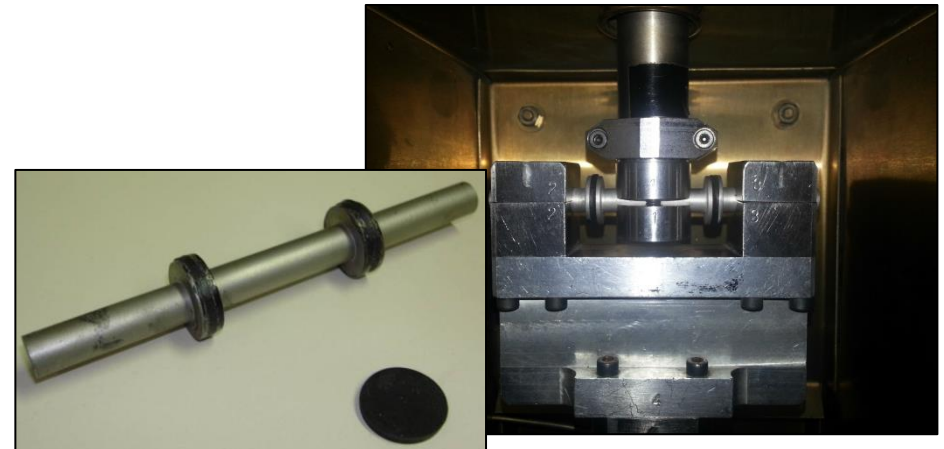
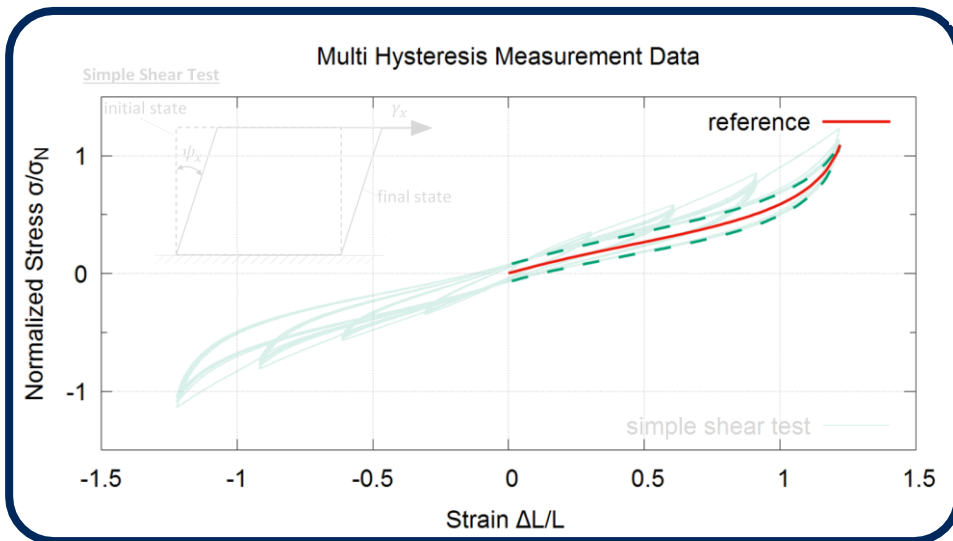
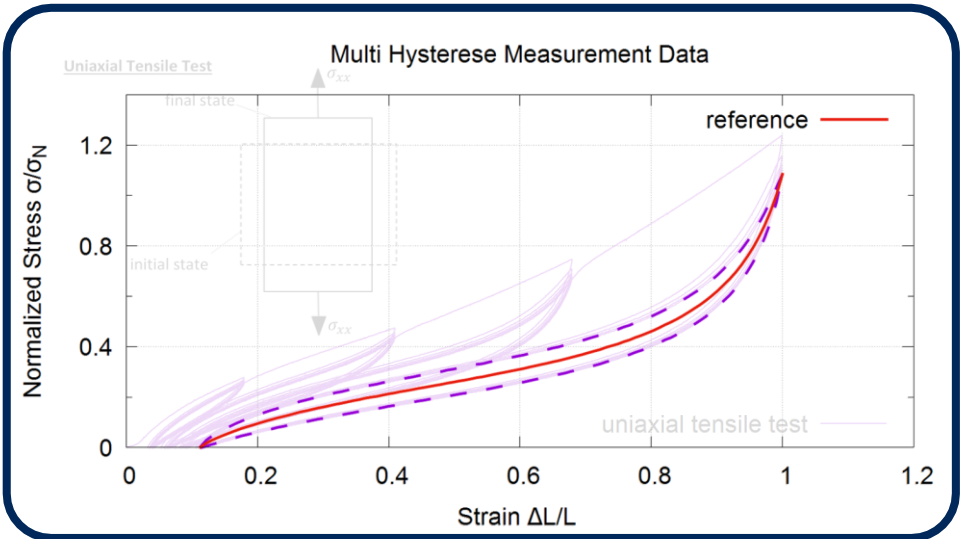
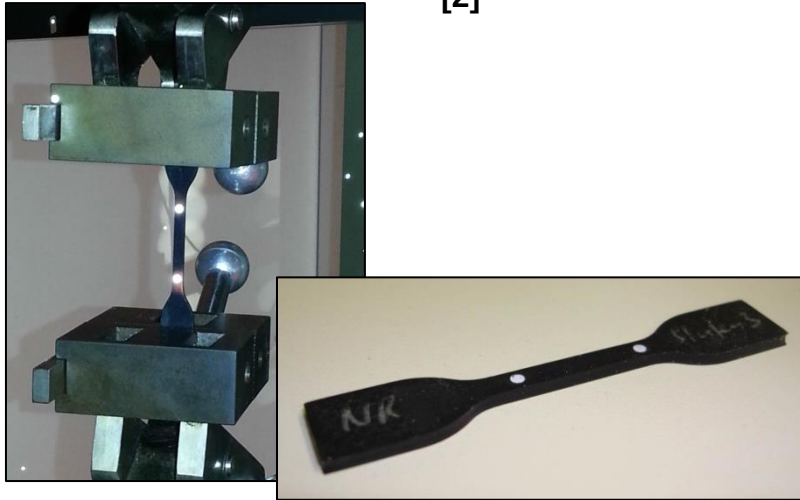
- polynomial approach:
Ogden (6 parameter)

$$W = \sum_{i=1}^N \frac{\mu_i}{\alpha_i} (\lambda_1^{\alpha_i} + \lambda_2^{\alpha_i} + \lambda_3^{\alpha_i} - 3)$$



Modeling of hyperelasticity

- measurement data [2]



[2]: DIK – Deutsches Institut für Kautschuktechnologie e. V. 2015

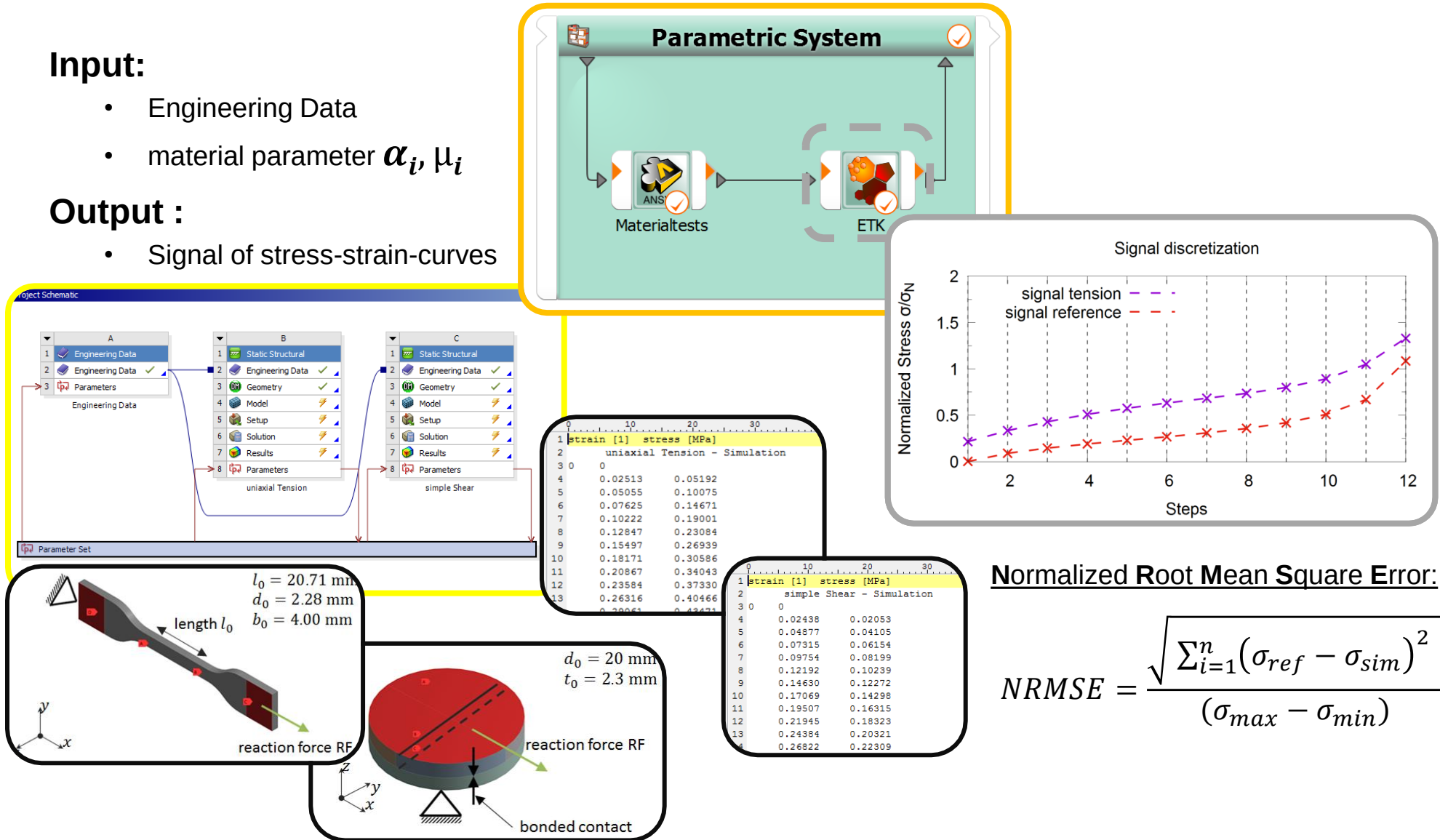
Project schematic

Input:

- Engineering Data
- material parameter α_i, μ_i

Output :

- Signal of stress-strain-curves



Normalized Root Mean Square Error:

$$NRMSE = \frac{\sqrt{\sum_{i=1}^n (\sigma_{ref} - \sigma_{sim})^2}}{(\sigma_{max} - \sigma_{min})}$$

Sensitivity analysis and direct optimization result

Parameter:

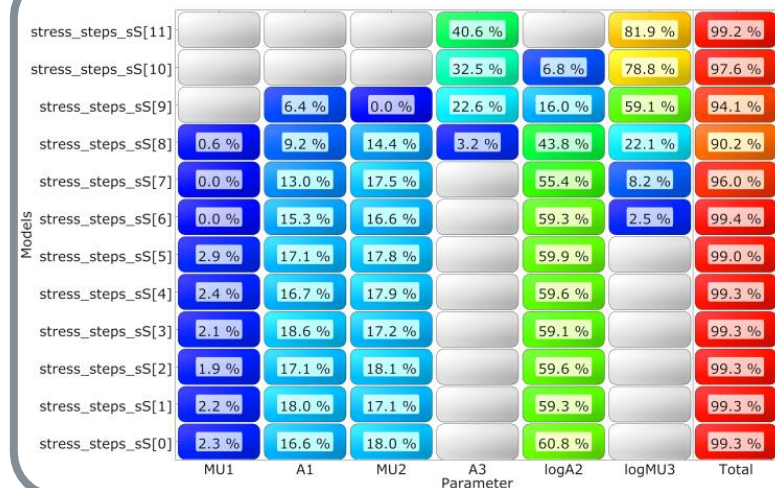
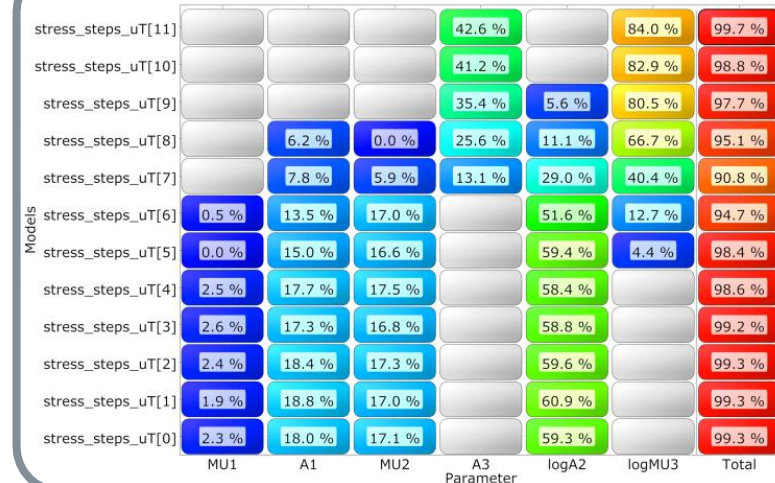
$$W = \sum_{i=1}^3 \frac{\mu_i}{\alpha_i} (\lambda_1^{\alpha_i} + \lambda_2^{\alpha_i} + \lambda_3^{\alpha_i} - 3)$$

$$\alpha_i = 10^{\log \alpha_i}$$

$$\mu_i = 10^{\log \mu_i}$$

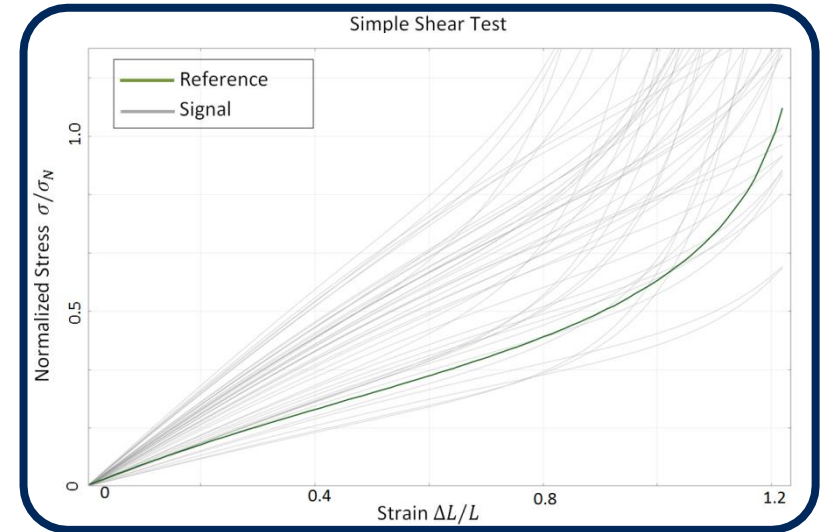
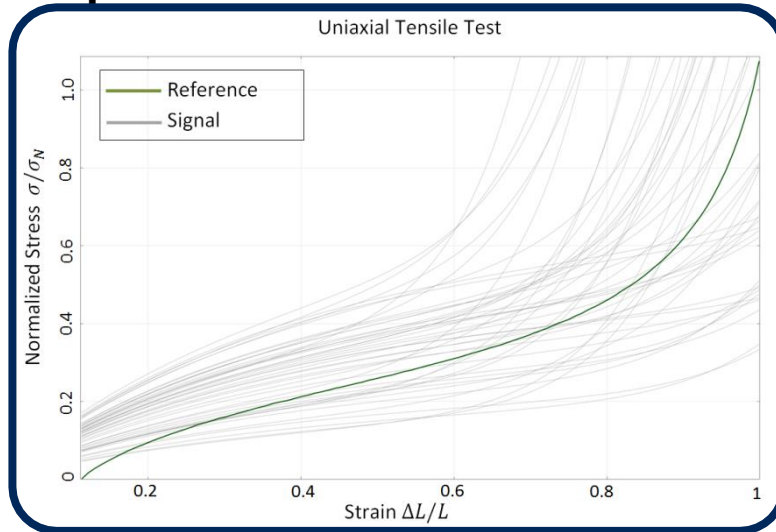
i	α_i	μ_i	$\log \alpha_i$	$\log \mu_i$
1	2 ... 4.5	0 ... 0.3	1	1
2	1	50 ... 100	-2 ... -1.5	1
3	16.5 ... 20.5	1	1	-6 ... -4

CoP-matrices:

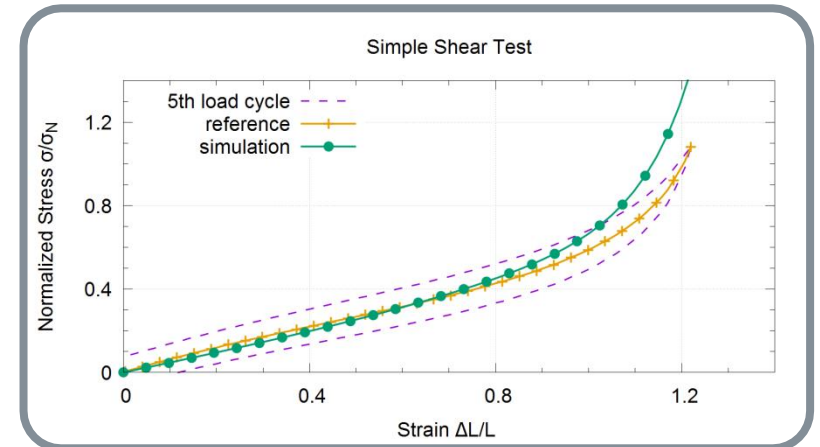
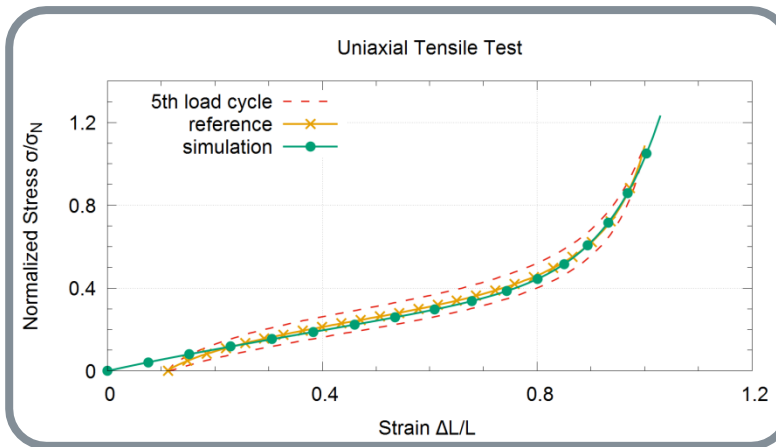


Sensitivity analysis and direct optimization result

Signal plots:



Optimization result:





Motivation



Parameter Identification and Curve Fitting with optiSLang

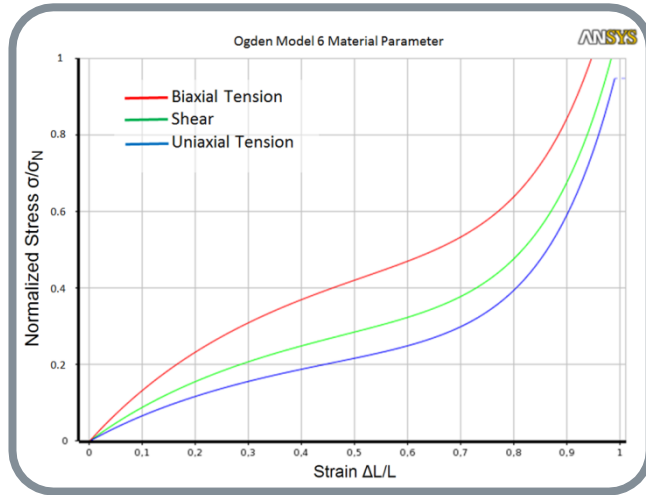


2D – axis symmetric analysis of an elastomer rubber boot

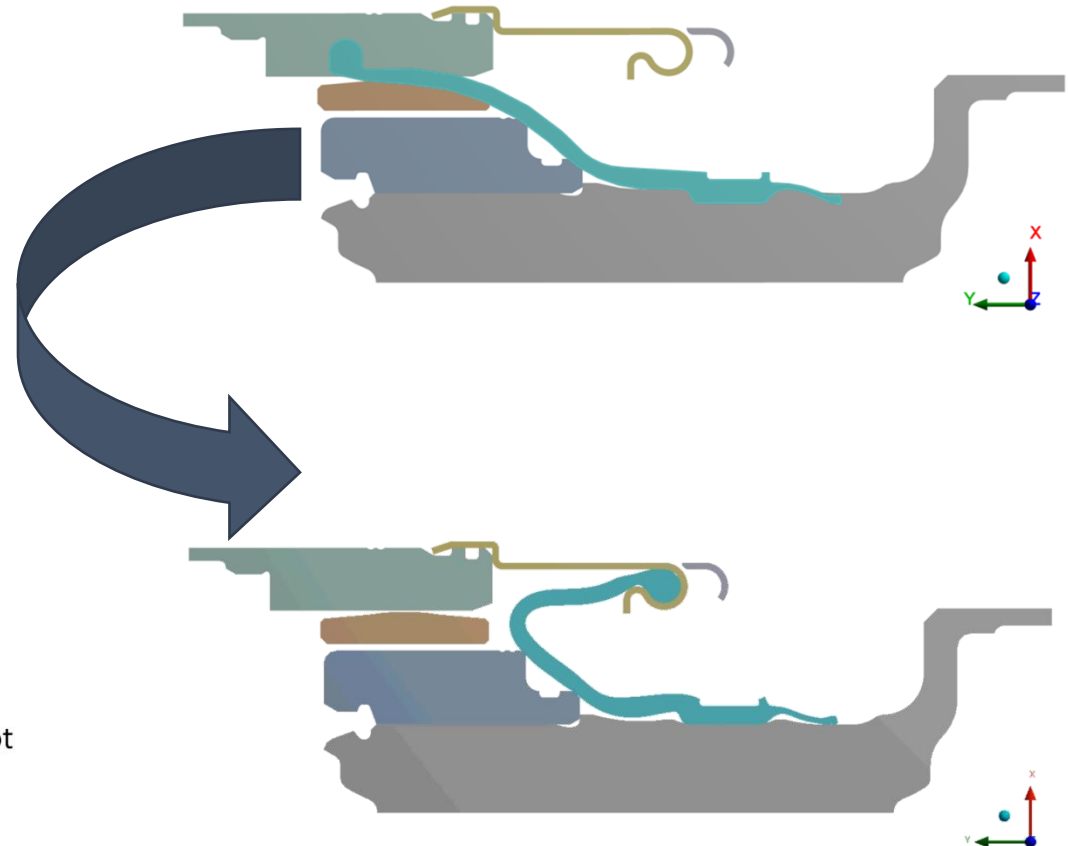


Summary

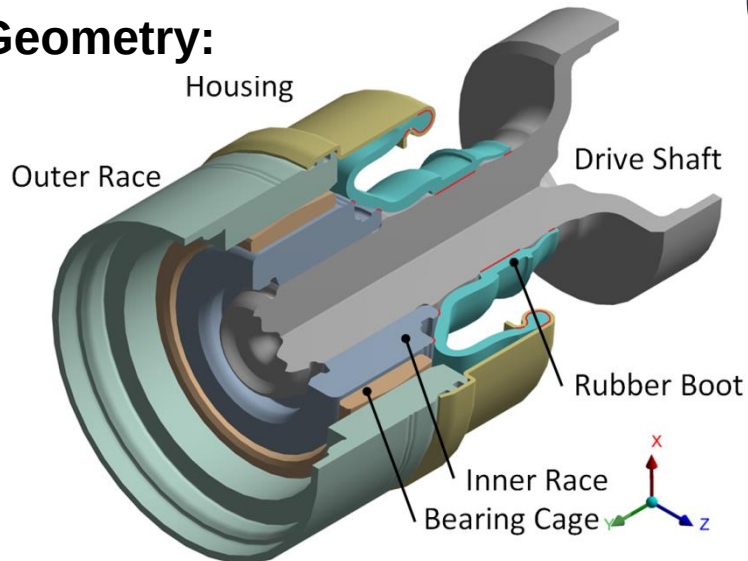
Hyperelastic material model:



Rubber boot positioning:

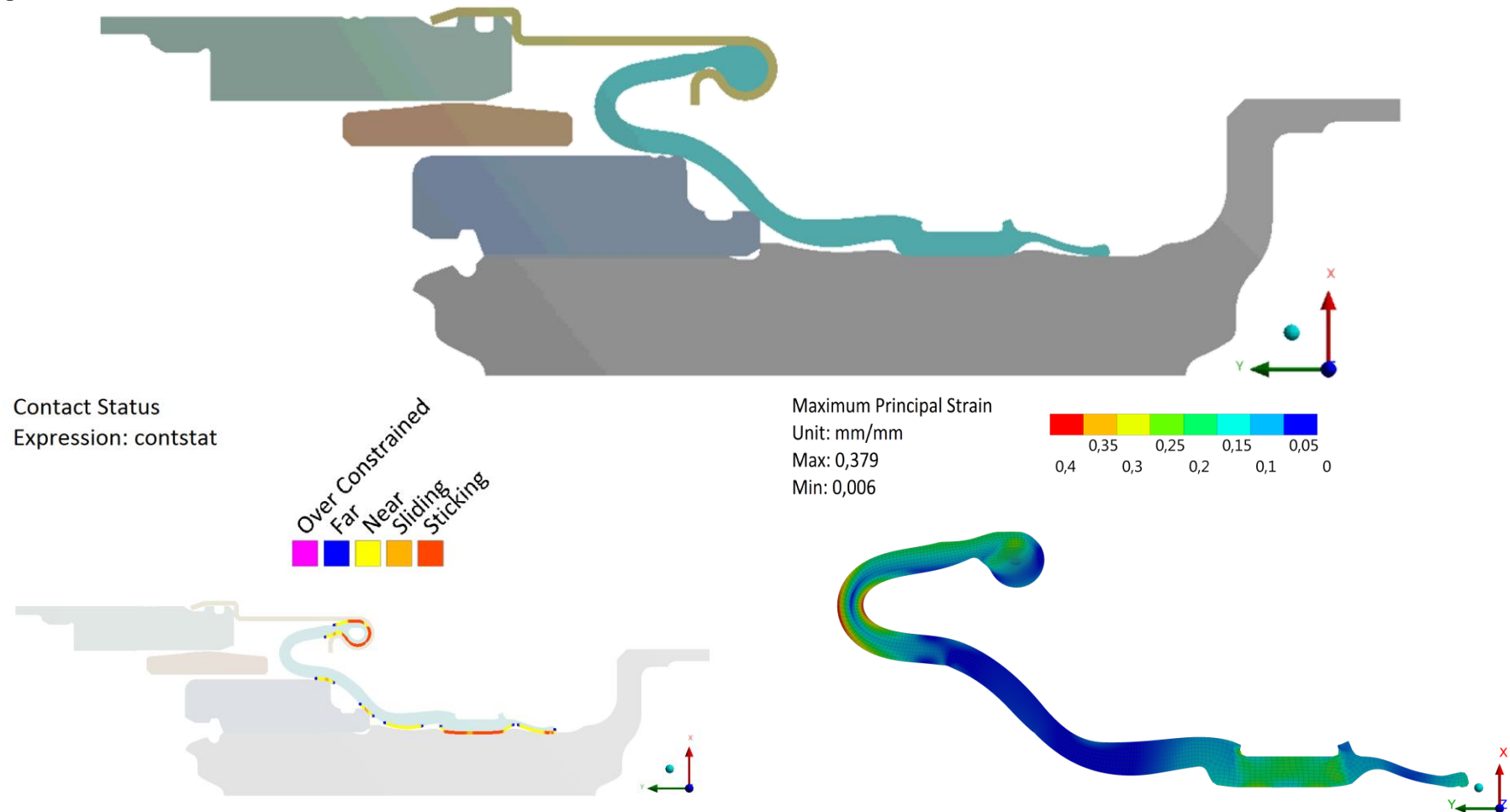


Geometry:



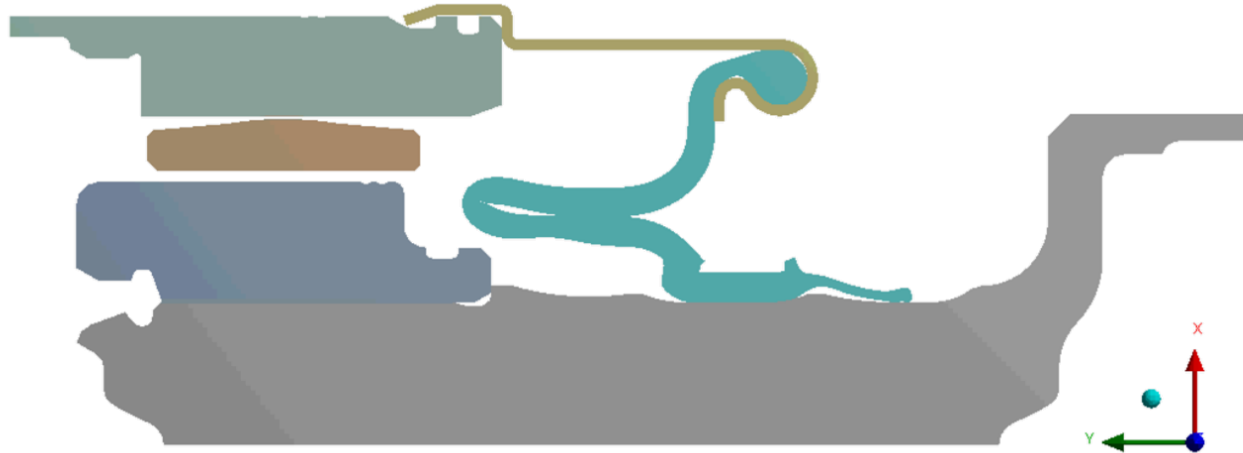
Length compensation and fluid pressure load

Positive length compensation
 $dy = +15 \text{ mm}$:

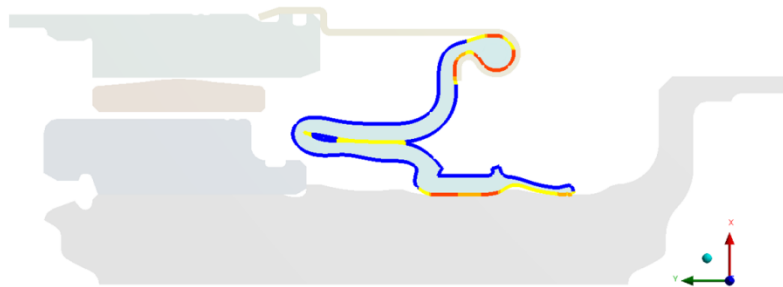


Length compensation and fluid pressure load

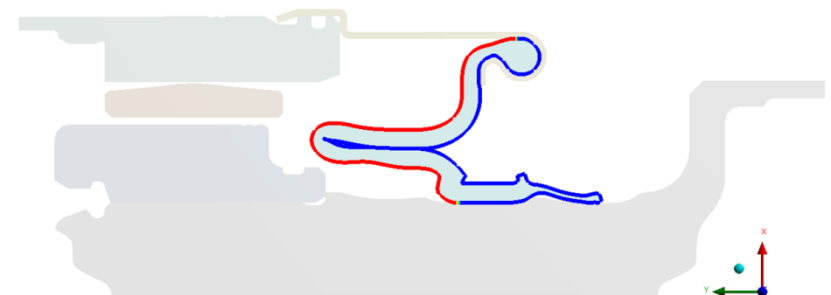
Negative length compensation
 $dy = -15 \text{ mm}$:



Contact Status
Expression: contstat



Fluid Pressure [1]
Expression: confspr





Motivation



Parameter identification and curve fitting with optiSLang



2D – axis symmetric analysis of an elastomer rubber boot



Summary

- **Use optiSLang to fit a 6 parameter Ogden model on experimental data of uniaxial tensile test and simple shear test.**
- **Determined parameter set correlates well with experimental material data for strain range from 0 to 1.**
- **Deformation and seal function of rubber boot could have been predicted reliable by 2 dimensional axis symmetric fluid penetration analysis.**
- **Experiences will be used to develop a 3 dimensional FE model to investigate effects during flexion.**

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