CHALMERS UNIVERSITY OF TECHNOLOGY

Improved modelling of tread brakes wheels

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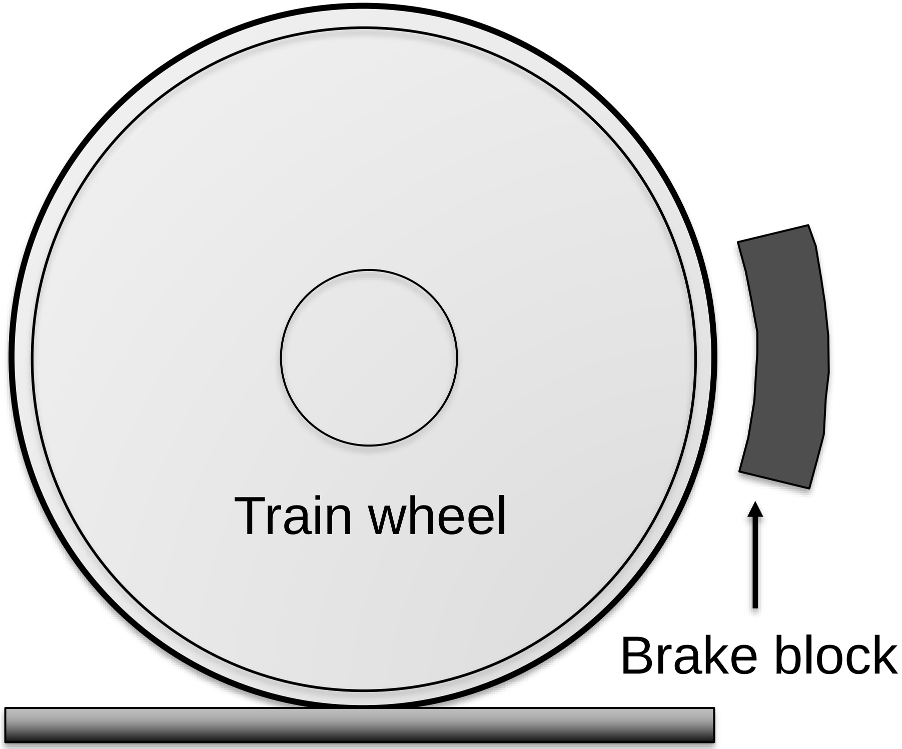
Introduction

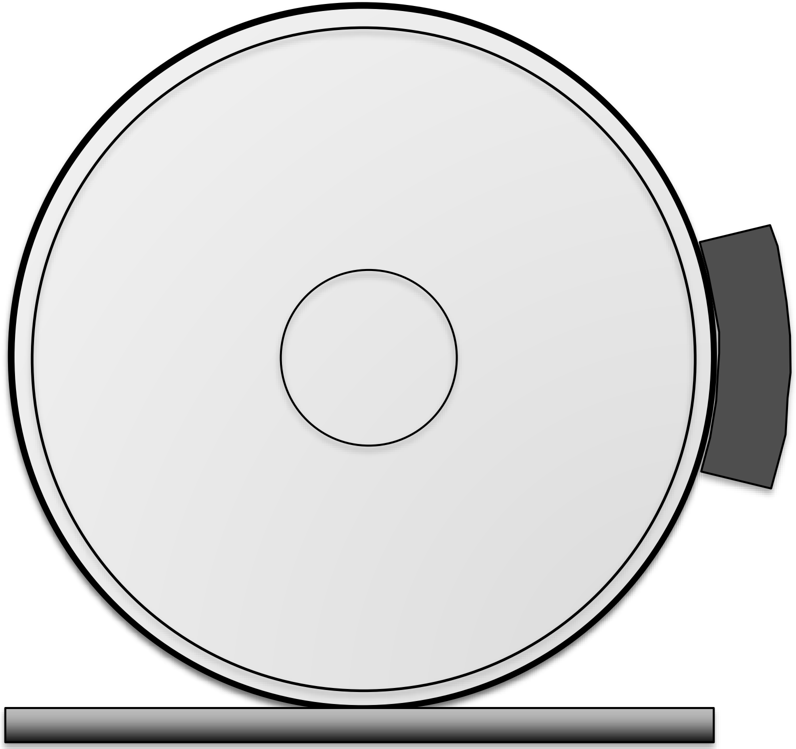
- Tread braking is a form of braking when friction brakes are applied directly onto the wheel tread
  - Inexpensive
  - Low-maintenance
  - Simple



Introduction

Friction heating of rim as a result of the braking

- Potentially very high temperatures *in the areas affected by large loads*
- Increased braking power and/or duration exacerbates issue



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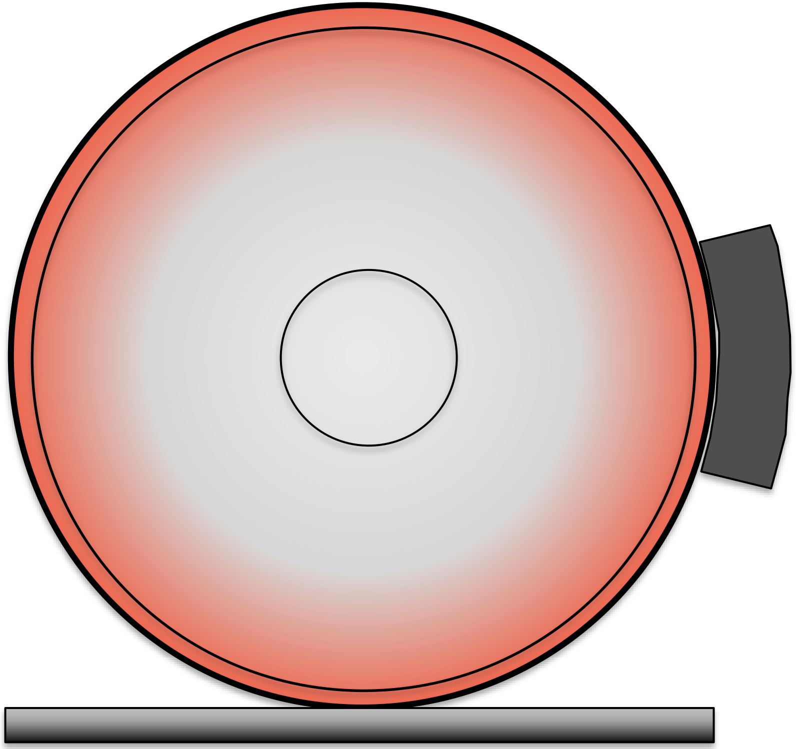


Why is this important?

At high temperature (>400 °C), the R7 steel shows

- Significant strength loss
- Microstructural changes

Compressive residual stress induced at high temperature turns tensile when cooled – crack formation can begin

Little prior research in on this problem with regards to railway steel, very much on the frontier

Approach

Experimental testing of samples to determine behaviour

⇕

Fitting of numerical model to experimental results

⇕

Full-scale experimental testing for verification

⇕

Continued improvements of model w.r.t.

Anisothermal experiments

Material model calibrated from isothermal experiments are not accurate enough

- Isolated calibrations do not lead to smooth curve (parameters change a lot)
- Material changes may have already occurred during pre-heating)

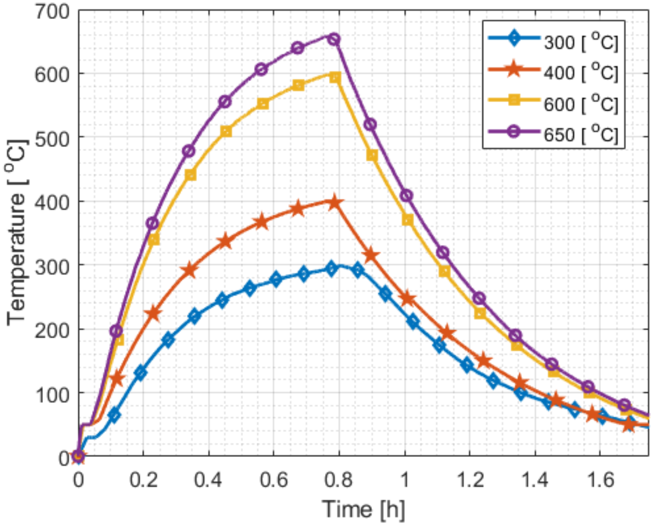
Anisothermal experiments required to characterize material!

Anisothermal experiments

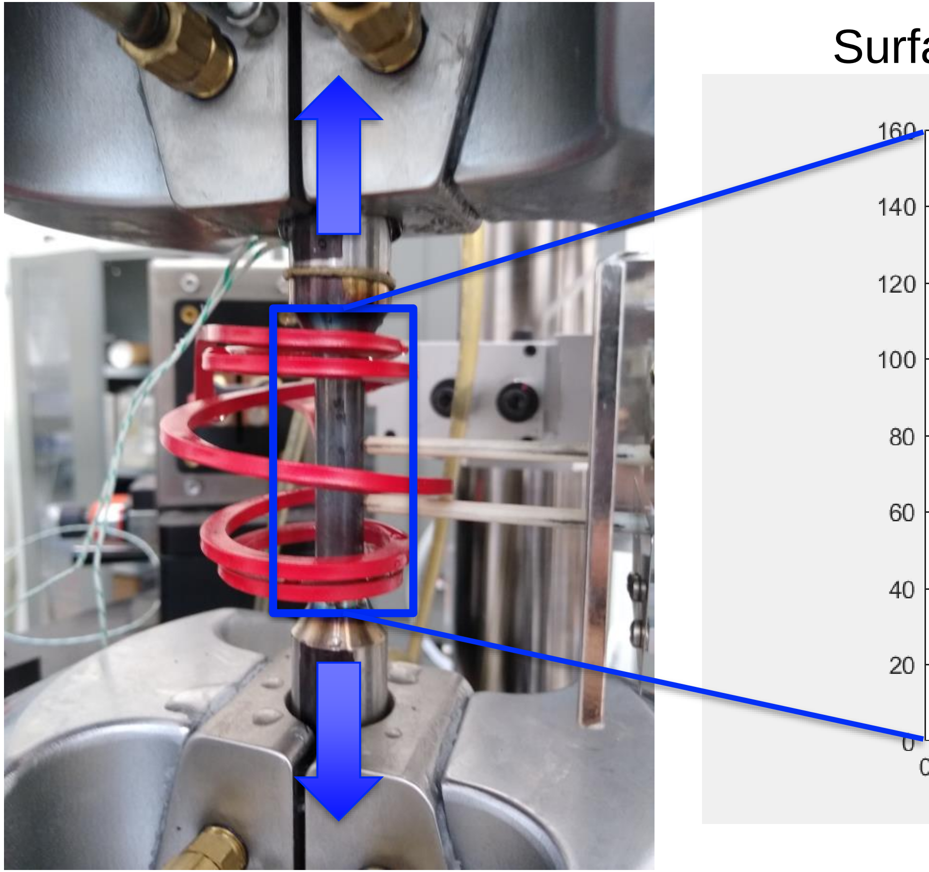
Experiments conducted by **Erika Steyn** at Chalmers

Subject wheel rim steel specimen to load similar to real drag braking situation

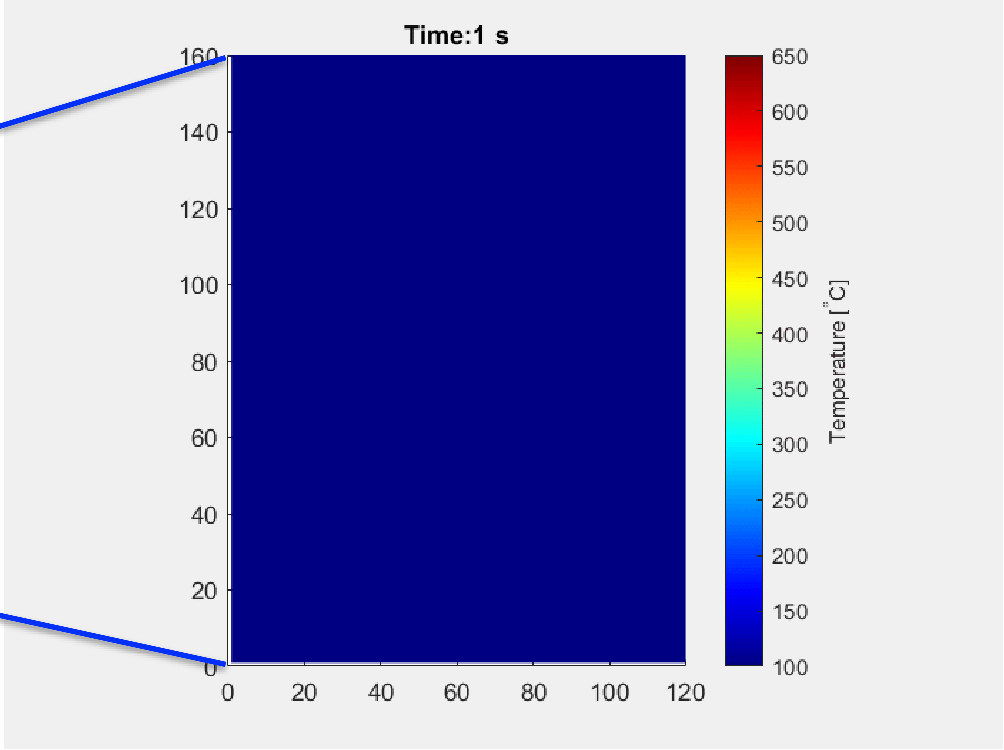
- Heat up to maximum temperature
- Restrict expansion to induce stress

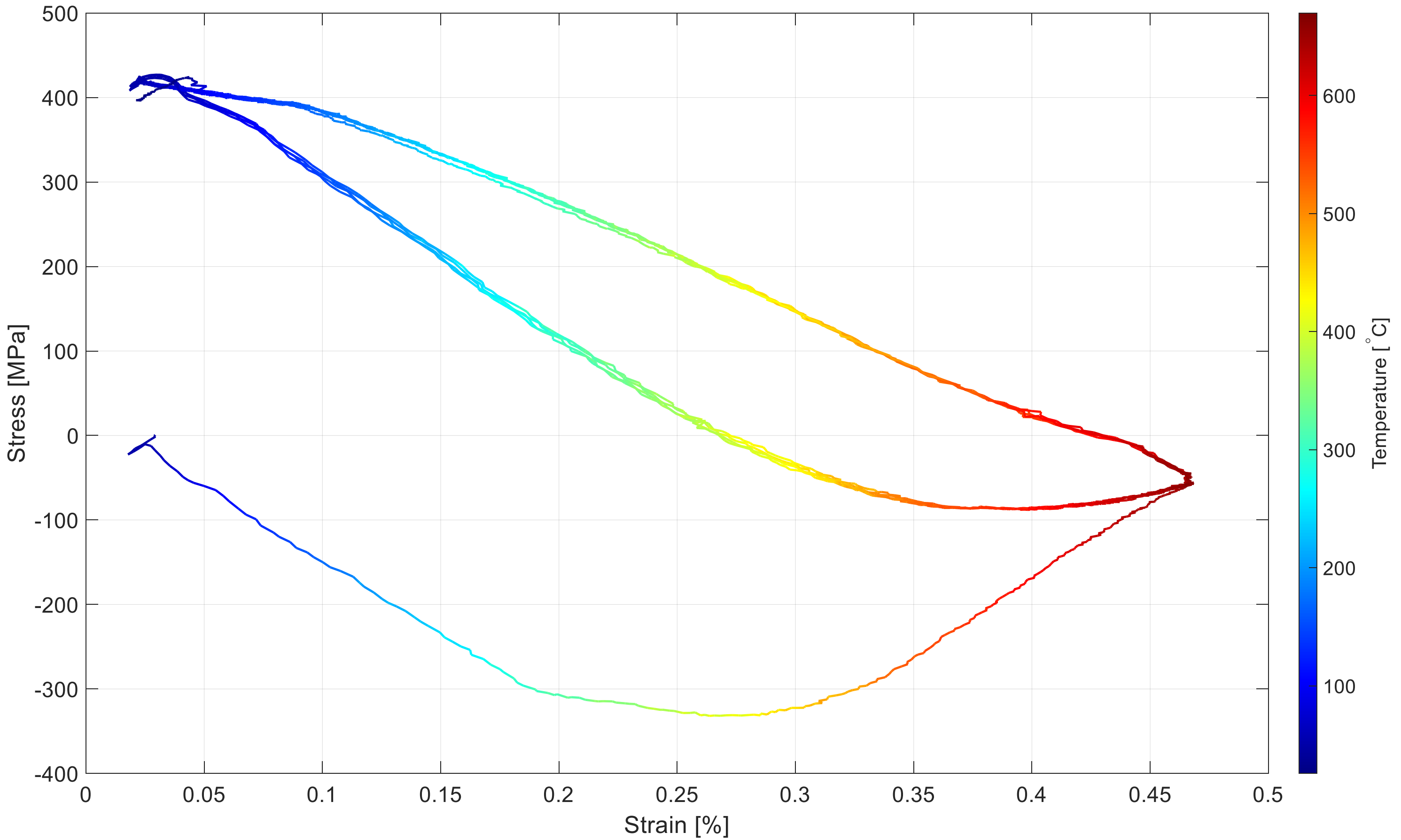


Anisothermal experiments



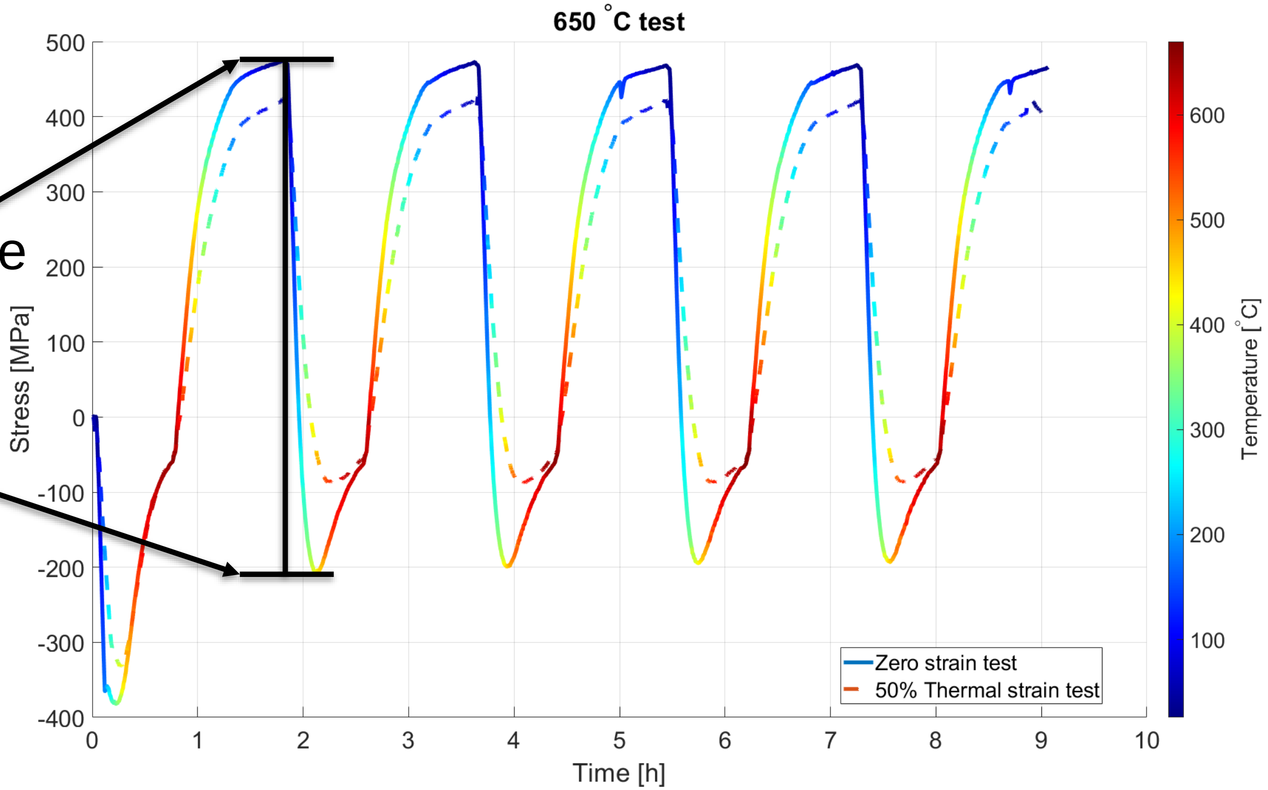
Surface temperature of sample (°C)




Stress [MPa]
500
400
300
200
100
0
-100
-200
-300
-400
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Strain [%]
Temperature [°C]
600
500
400
300
200
100

Anisothermal experiments

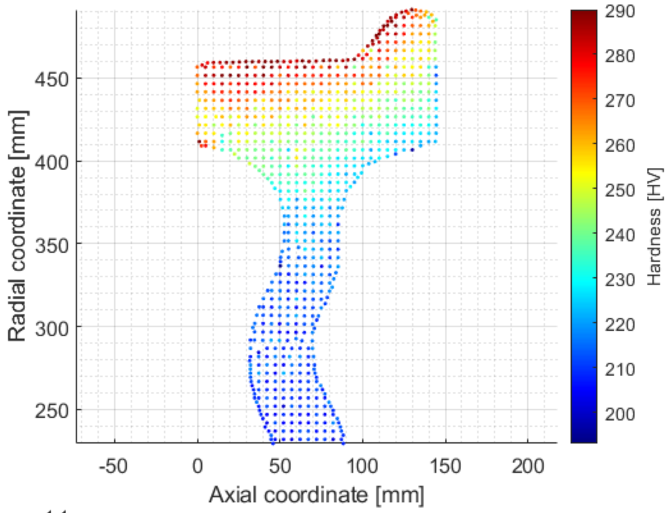
Stress amplitude reduced by roughly 20% after first cycle

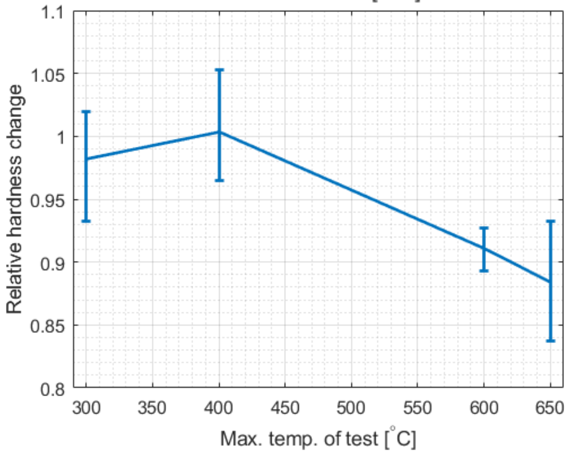


Hardness testing

The hardness of the wheel steel is dependent on extraction location

Hardness is reduced by 10 – 20% depending on max temperature of cycle

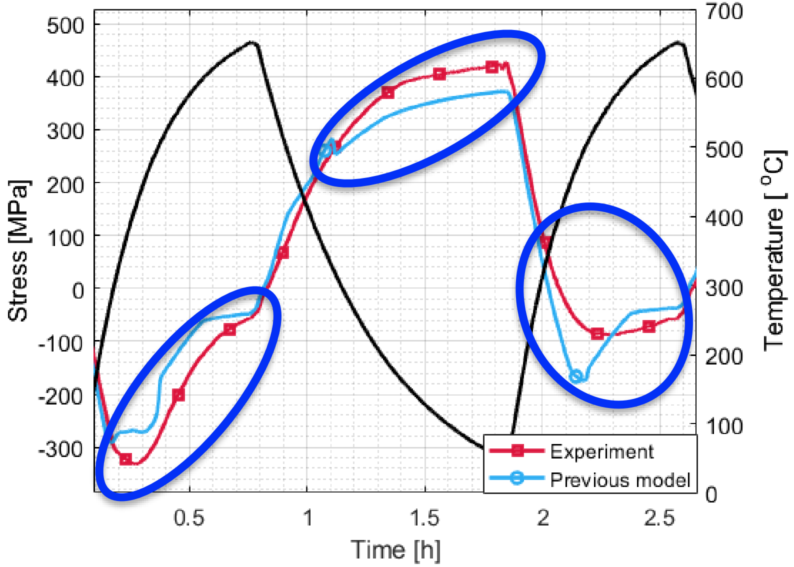




Numerical modeling

Initial material model (Esmaeili 2021) based on Chaboche viscoplastic model (Chaboche 1989) but adapted for faster ratcheting.

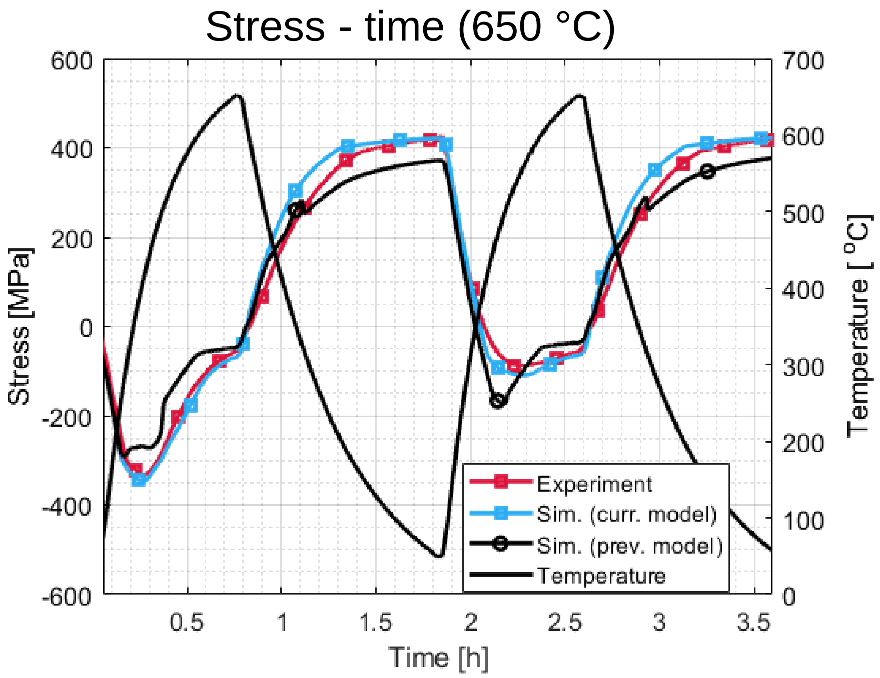
Model shows issues when applied to anisothermal cycles, in particular residual stress and smoothness.

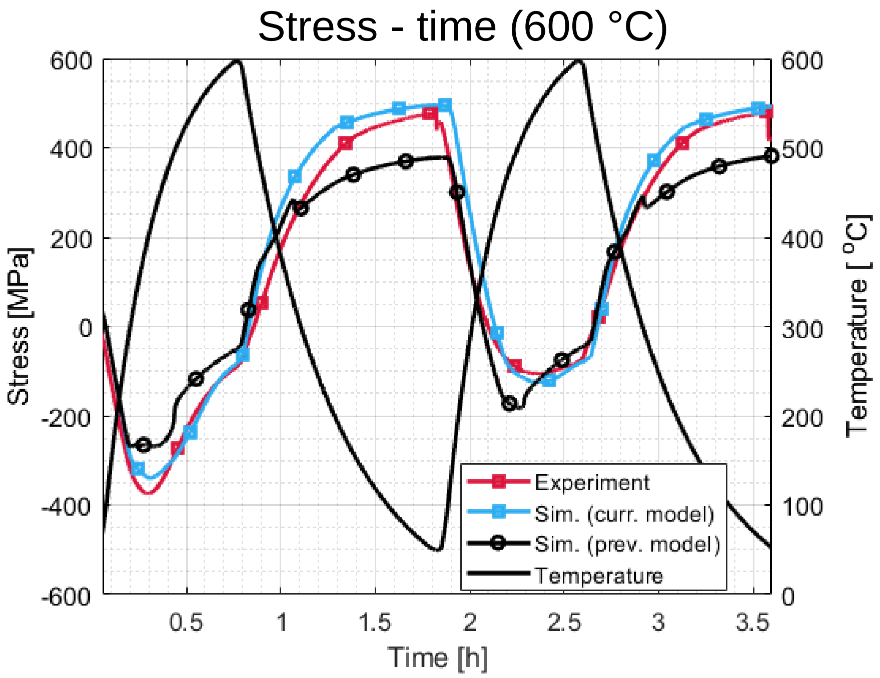


Adapting model to varying temperature

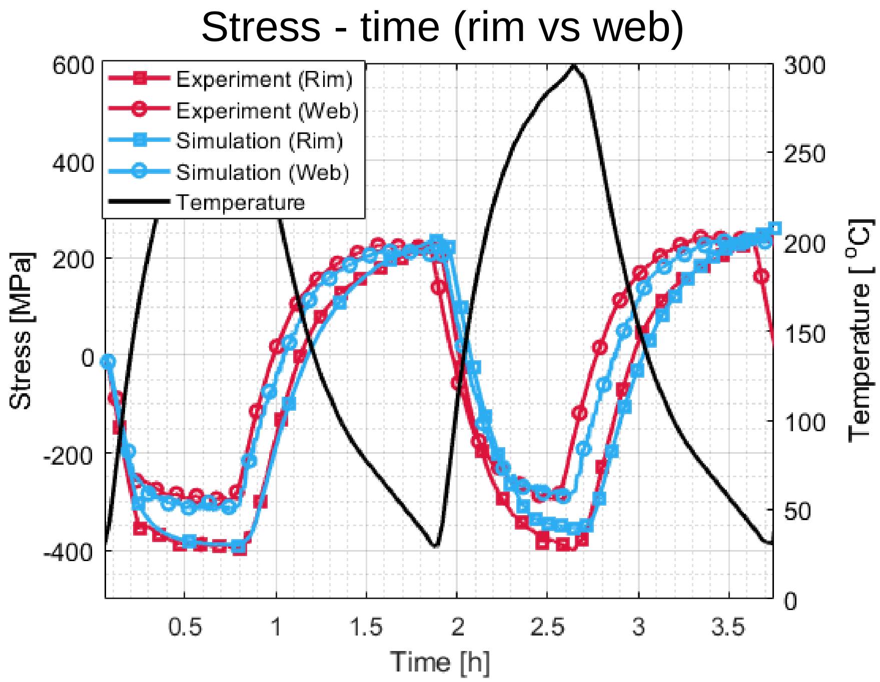
- Recalibration of model to smoothen anisothermal stress curve
- Adding material degradation to capture hardness reduction
- General improvements in anisothermal behaviour (no relaxation during straining etc.)

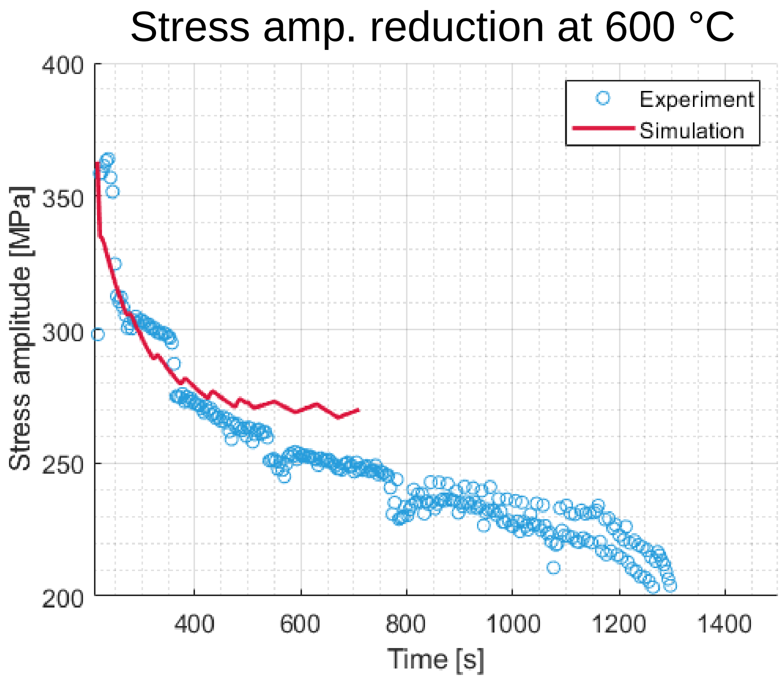
Anisothermal results



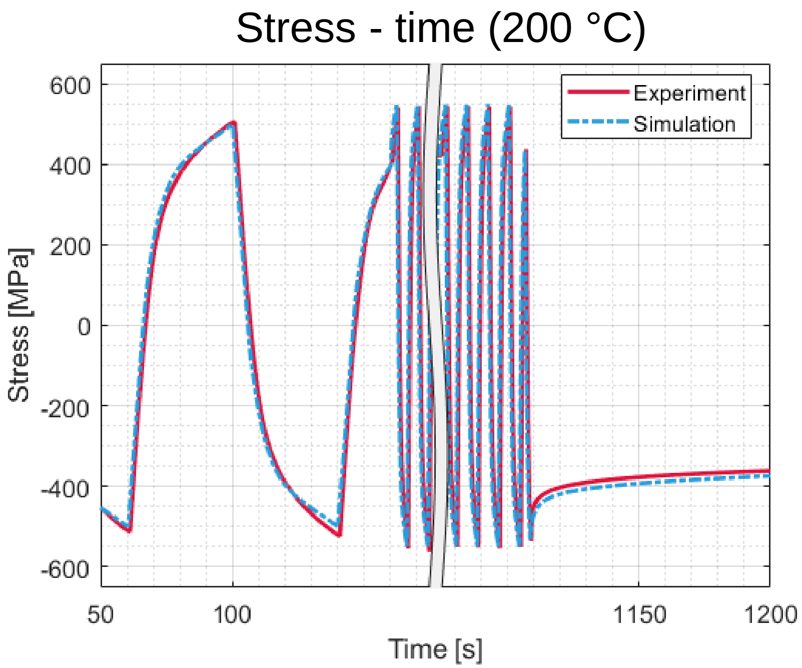


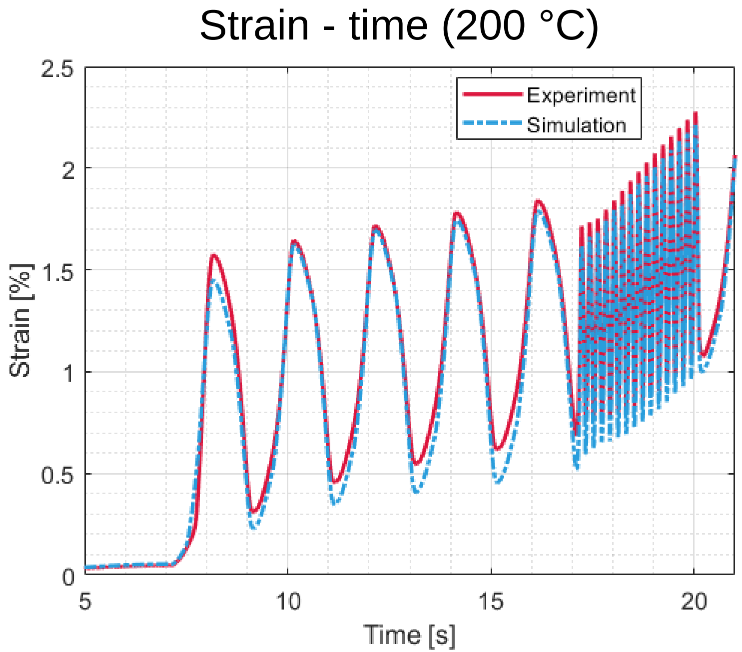
Anisothermal results





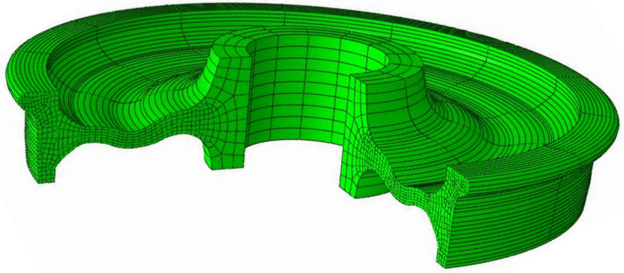
Isothermal Results





Application to full model

Model will need to be evaluated with respect to behaviour of full-scale wheel behaviour and measurements

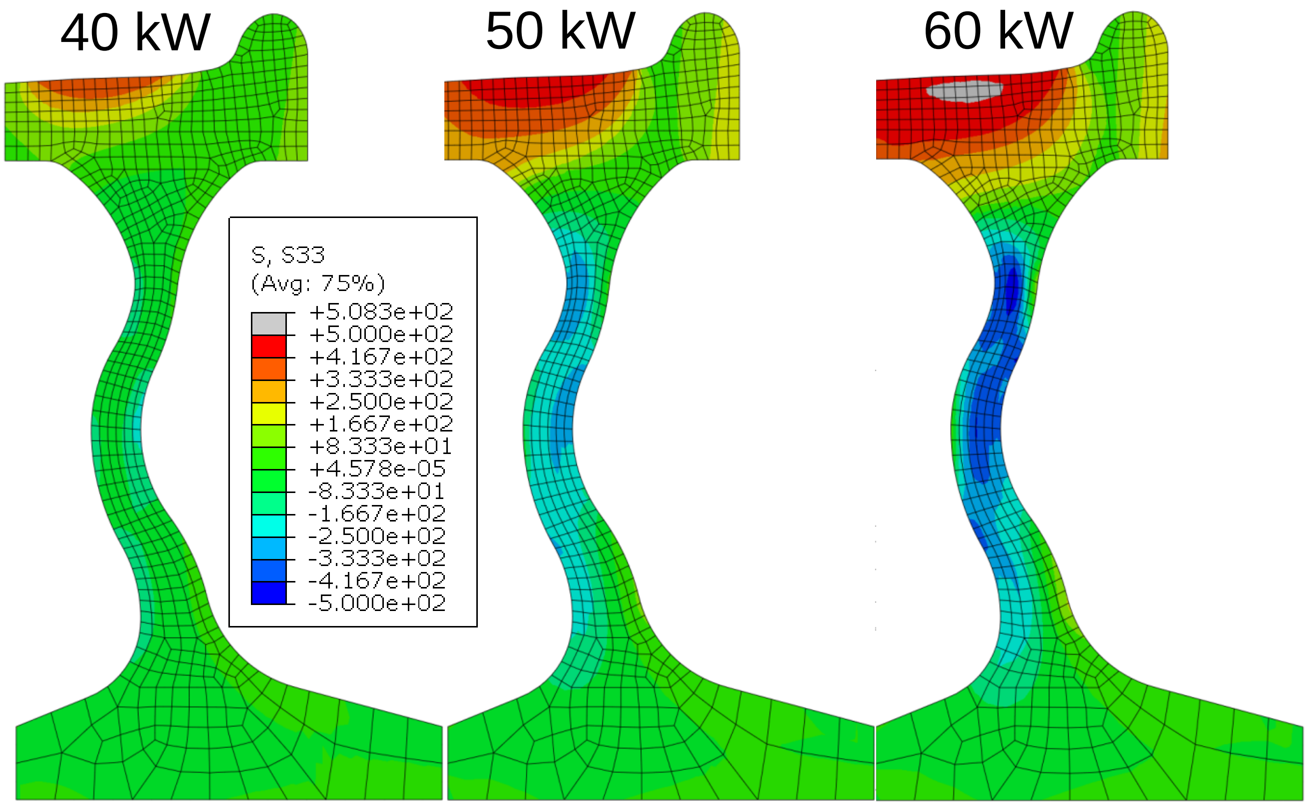


- Residual stress by elasto-acoustic effect
- Deflection of wheel rim
- Point-measurements (rosette gauges etc.)
- Destructive testing for circumferential stress

Numerical model results

3 braking cycles at brake power of:

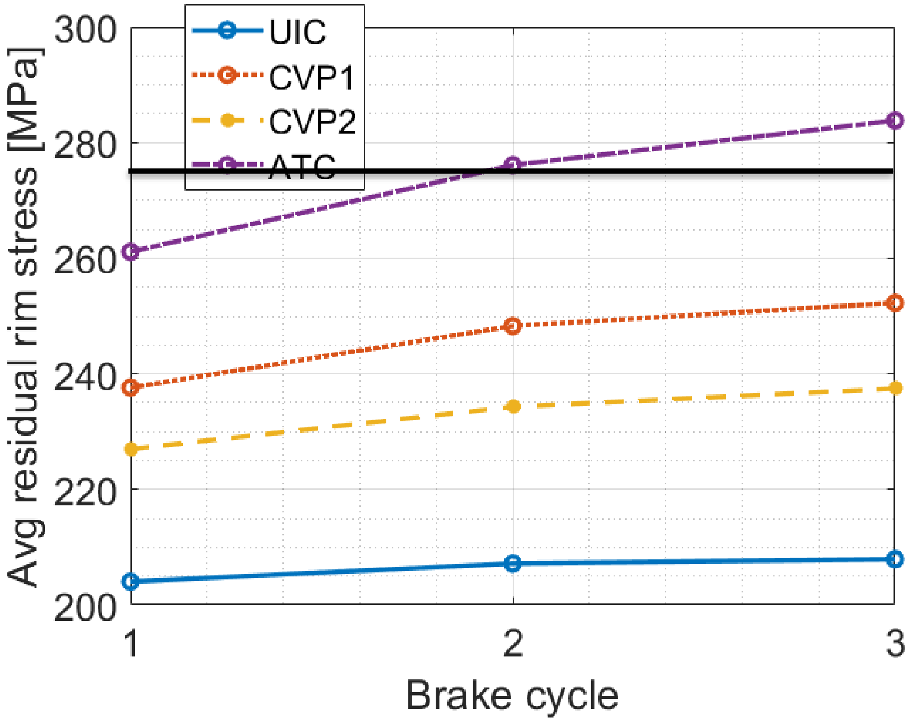
Overall behaviour is reasonable with increasing residual stress as brake power increases



Full model results

Residual stress should remain below 275 MPa (EN13262)

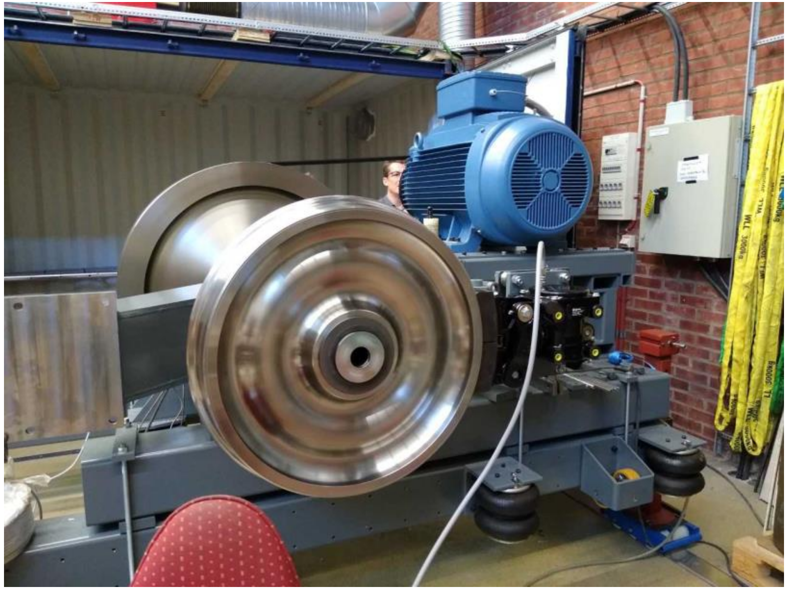
The older 57H design expected to exceed this limit (new model only one to achieve this)

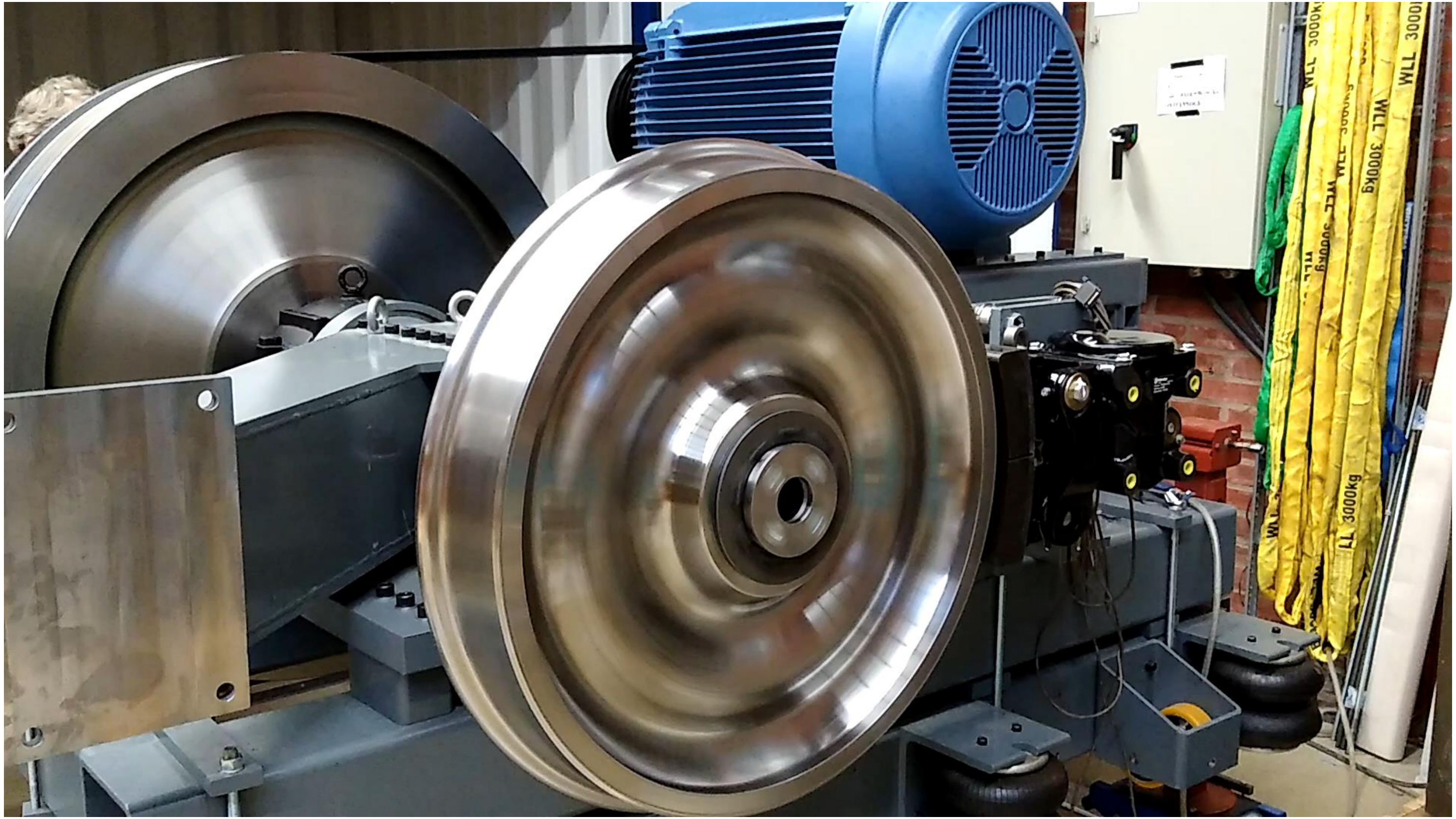


Disclaimer

Results from brake rig were promised. Delays made attaining actual results unachievable in time for seminar.

- First results likely during summer (July – August)
- Detailed results early autumn




WLL 3000kg

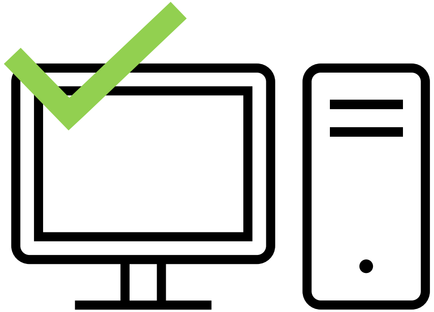
Future Plans

Full-scale verification of material model using in-house designed and assembled brake rig

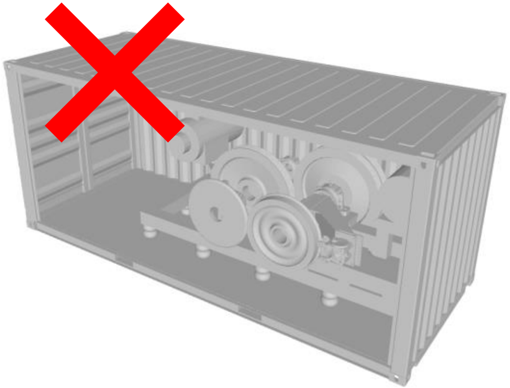
Testing and modelling of e.g. rolling contact fatigue planned to begin late 2022

Final thoughts

If the material model can predict wheel behaviour with sufficient accuracy, it would be a big step towards reduction of experimental requirements.



For a conservative industry, this may be a big improvement.



Questions?

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