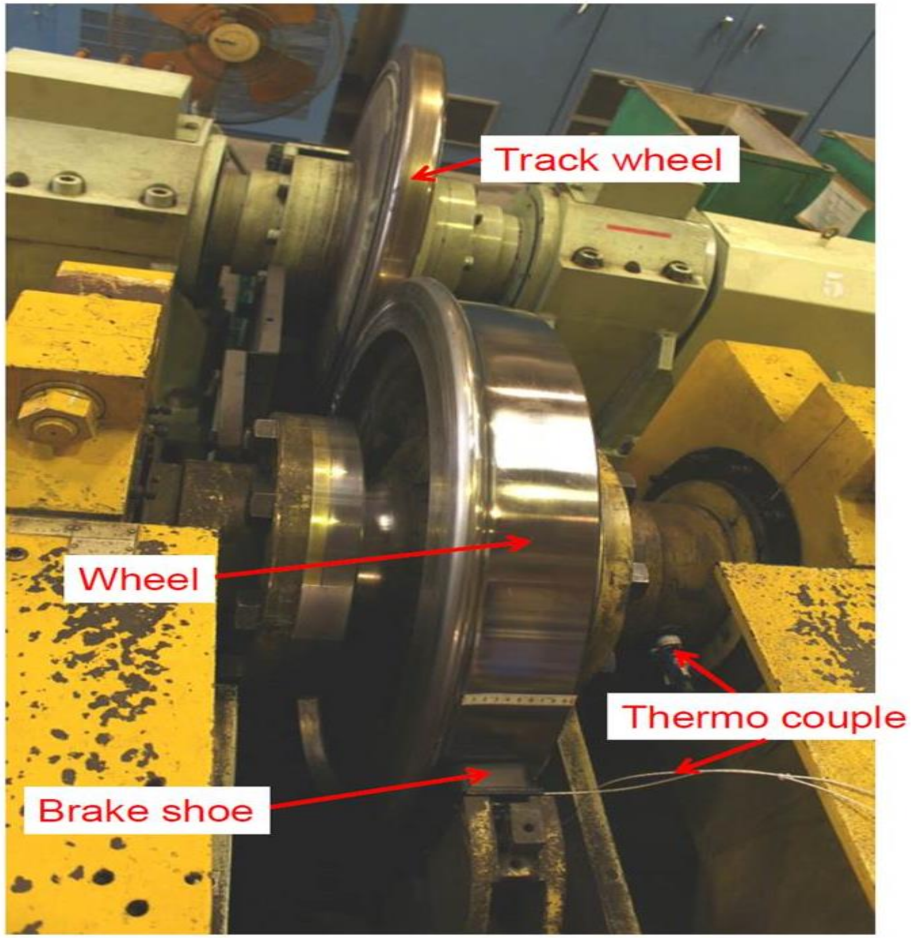
Wear of wheel treads and brake blocks at railway tread braking

21st Nordic Seminar on Railway Technology

Roger Lundén, Chalmers / CHARMEC
Mandeep Singh Walia, Green Cargo
Tore Vernersson, Chalmers / CHARMEC

Part 1: Brake rig experiments and simulations

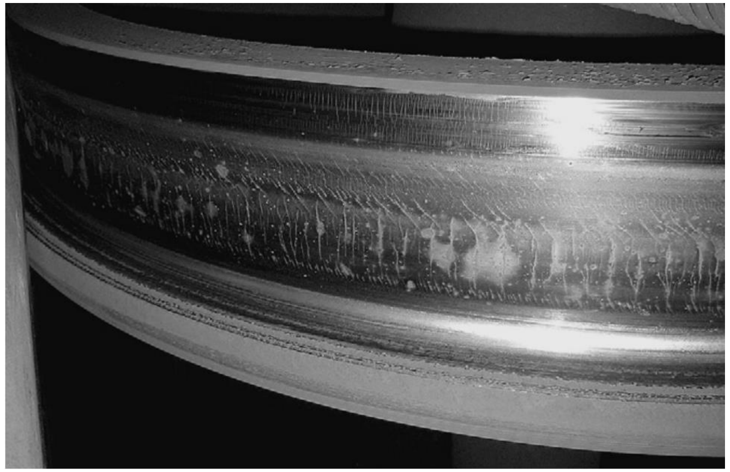


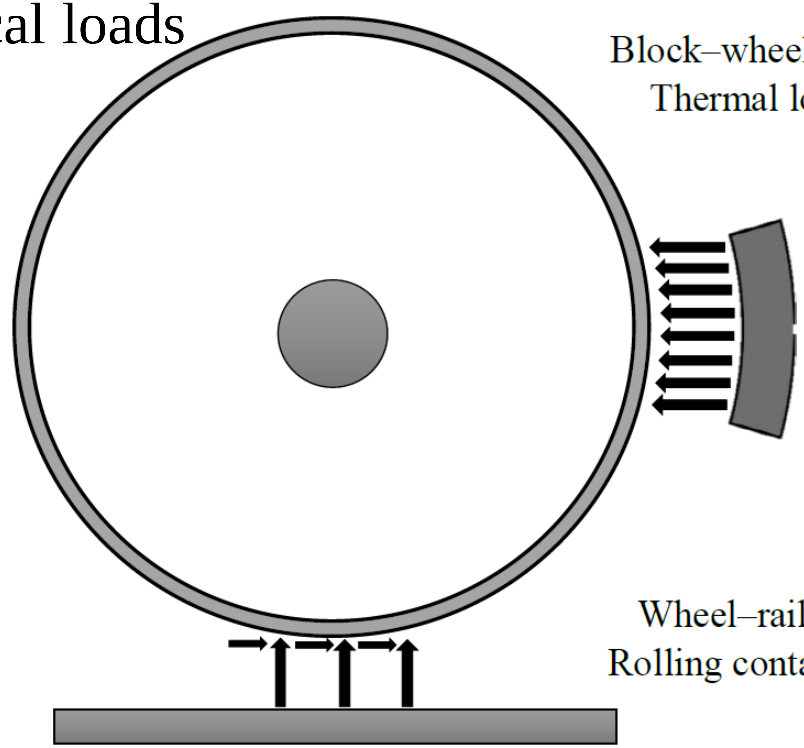
Outline

- Background
- Experimental setup
- Results Experiments
- FE modelling
- Simulations results
- Concluding remarks

Background

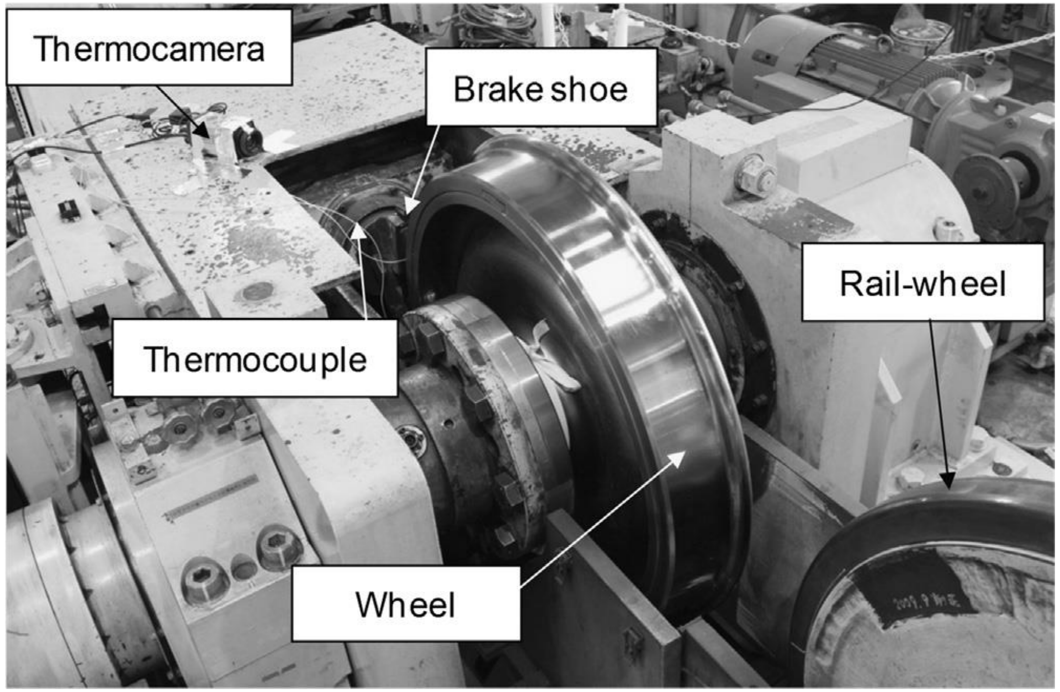
- At tread braking, wheels are subjected to thermomehcanical loads
- Material removal as sliding wear and plastic deformation
- Initiation of cracks at high temperatures





- Important to understand the influence of temperatures on tread plasticity due to tread braking.

Experimental Setup



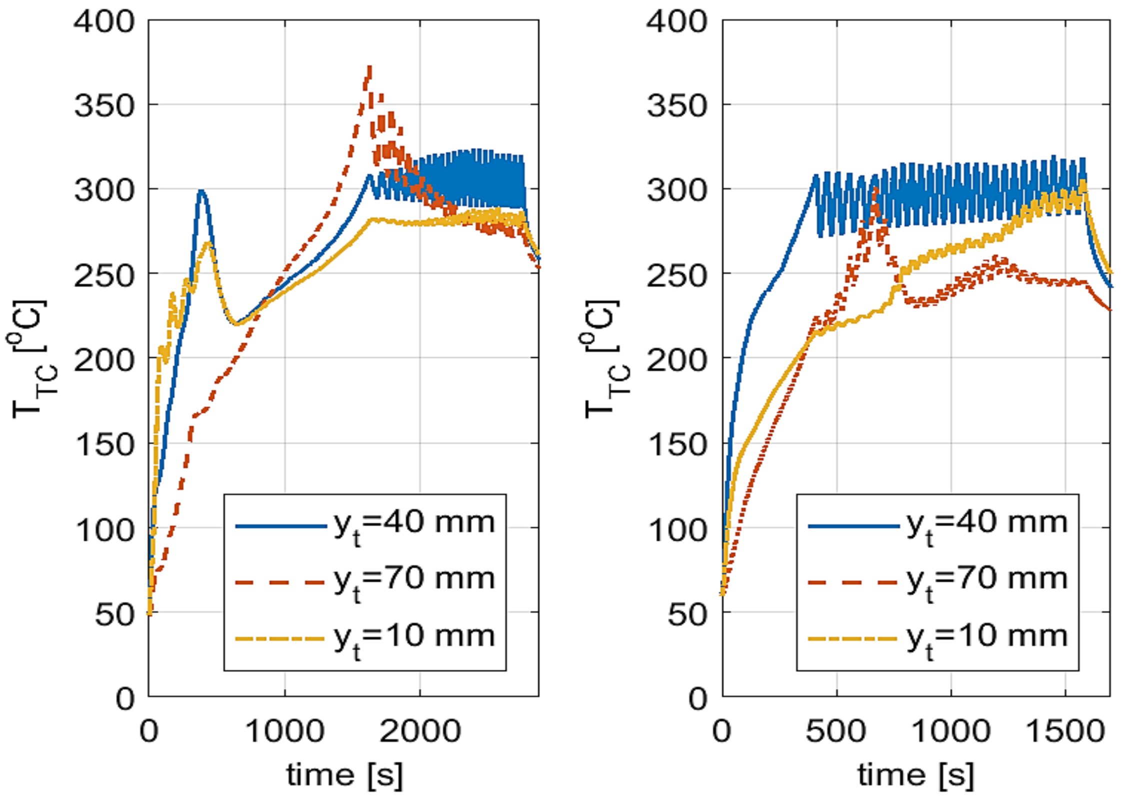
Set-up of brake rig employed in test

Constant temperature rolling

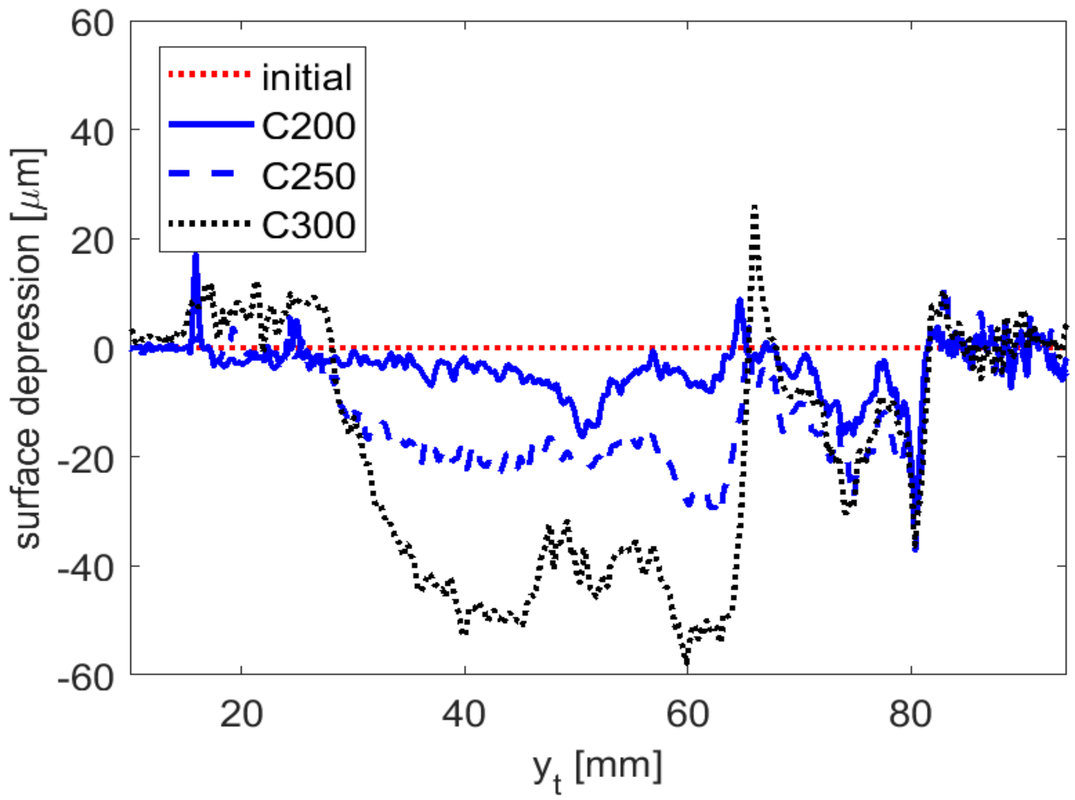
Wheel type	"B type", diameter 860 mm
Wheel material	ISO1005-6:1994 C64GW-T
Brake block	Sintered
Wheel load	60 kN

	200 °C	**250 °C**	**300 °C**
Speed	60 km/h	60 km/h	60 km/h
Block force	6 kN	6 kN	8 kN
Block application conditions	Apply at 190 °C Release at 210 °C	Apply at 240 °C Release at 260 °C	Apply at 290 °C Release at 310 °C
Number of times	20 min × 3		
Wheel initial temp.	Cooled to 60 °C after each 20 min braking		

Results from experiments: Temperatures and wear



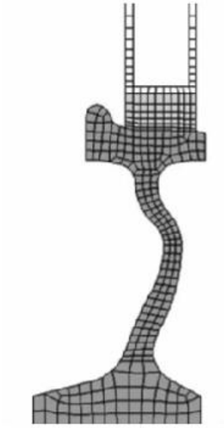
Examples of histories of thermocouple temperatures during two constant temperature rolling sequences. Co-ordinate y_t is lateral distance from field side of rim.



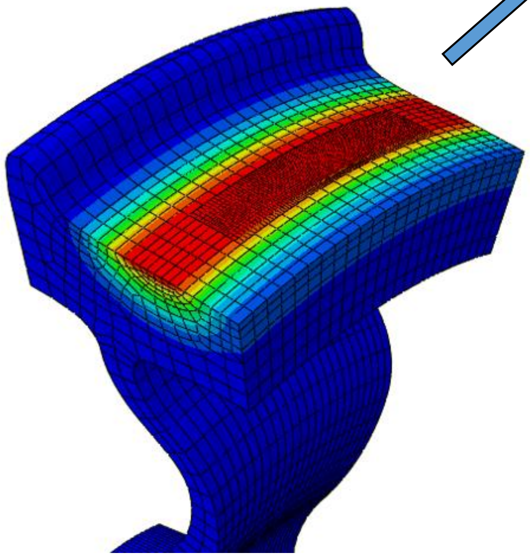
Change of tread profile as measured after each of the three constant temperature rolling sequences.

FE Model

Heat partitioning

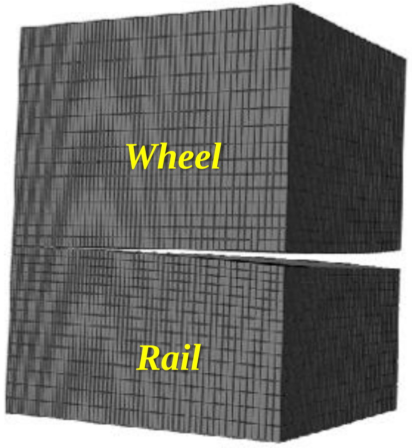


Wheel tread flux



Thermal simulation

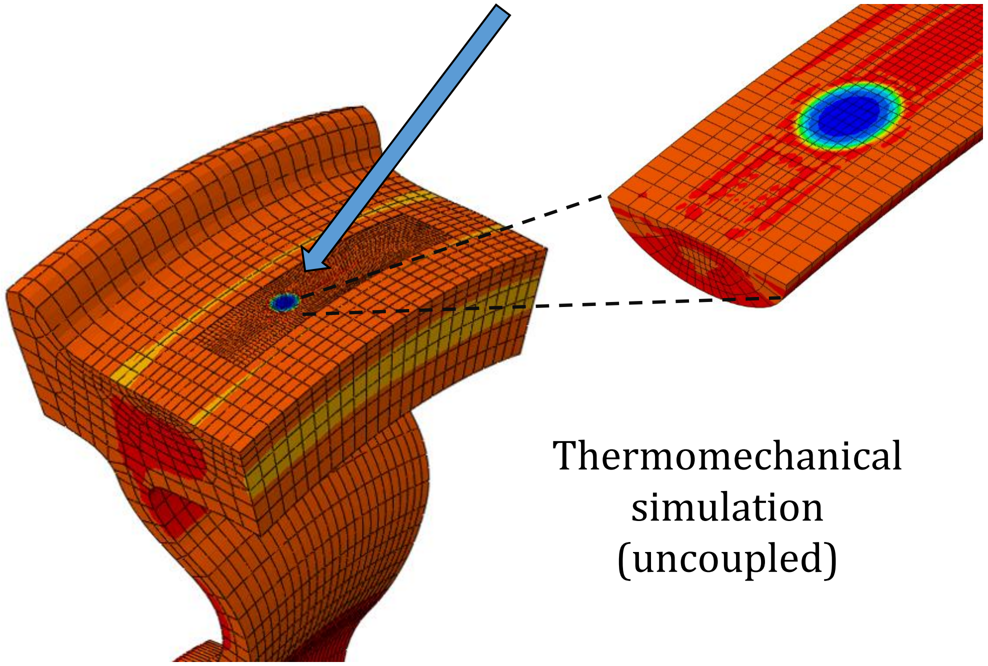
Temperatures at and below wheel tread



Wheel-rail contact
"Indentation"

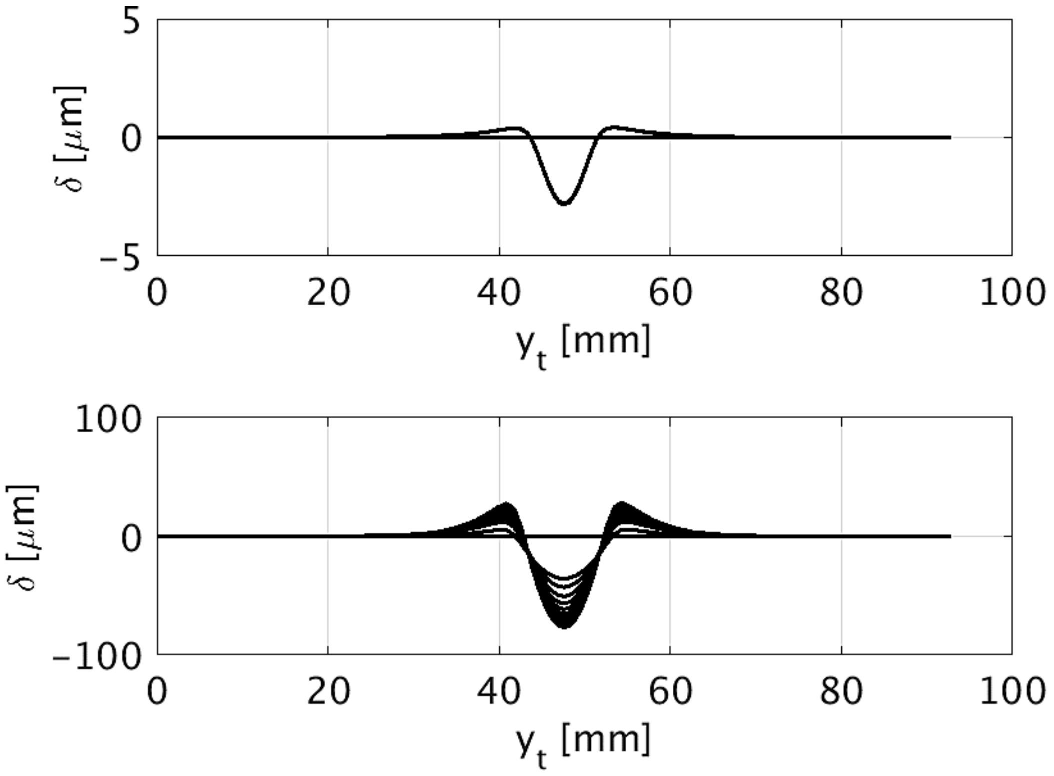
Wheel–rail contact loading parameters

Wheel temperatures

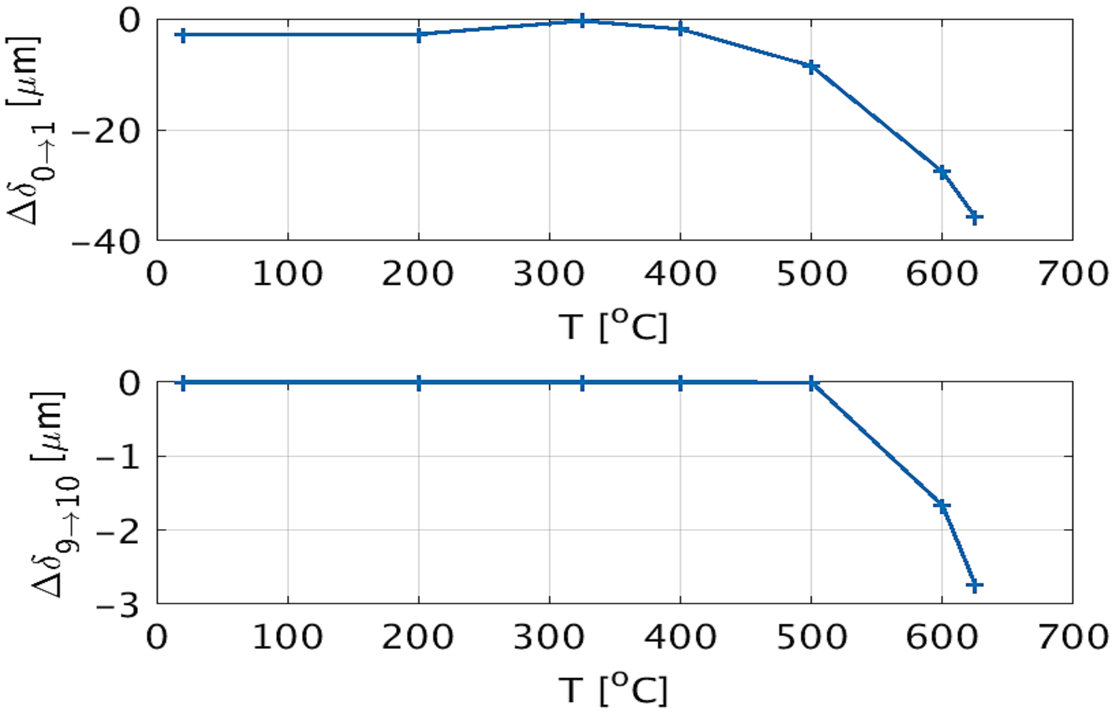


Thermomechanical simulation (uncoupled)

Simulations part 1: Investigations on material model response



Change of tread profile as calculated after each of ten load passages for 20 °C (upper) and for 625 °C (lower).

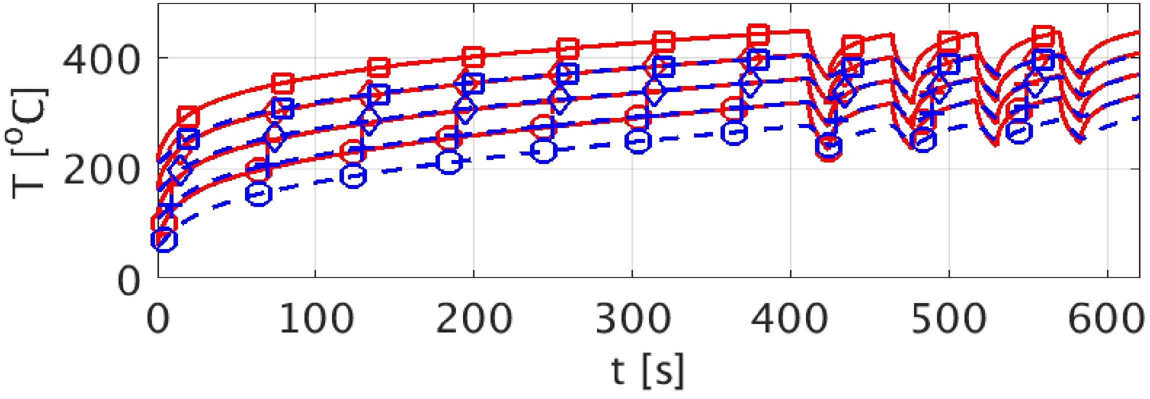


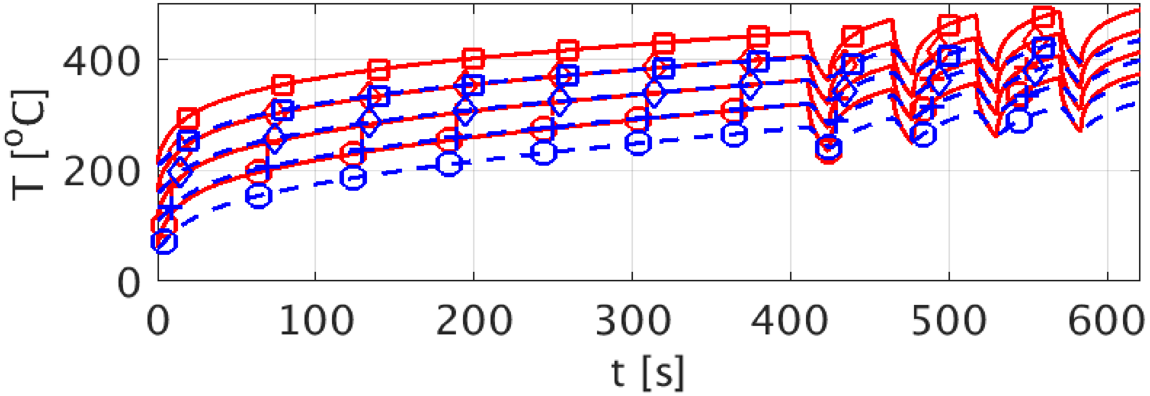
Change of tread profile at rolling circle as function of temperature. Results for first mechanical load passage (upper) and for the last passage (lower).

Simulations part 2: Contant temperature rolling at 300 °C

- Simulated temperature at tread surface and the thermocouple position (depth10 mm below tread surface and y_t 40 mm).
- Initial temperatures 60 °C, 110 °C, 150 °C and 210 °C
- Braking at 40 kW and 50 kW
- Braking 411 s + cooling for 13 s + braking 40 s and so on

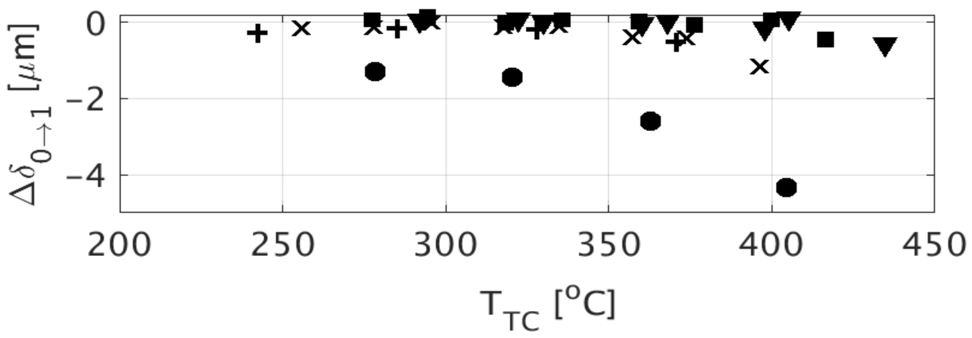
- Mechanical loading introduced at five chosen time instants:
- 1) after initial constant power braking (411 s)
- 2) after first short cooling (424 s)
- 3) after first short braking (464 s)
- 4) after the last short cooling (583 s)
- 5) at the end of the last short braking (620 s)



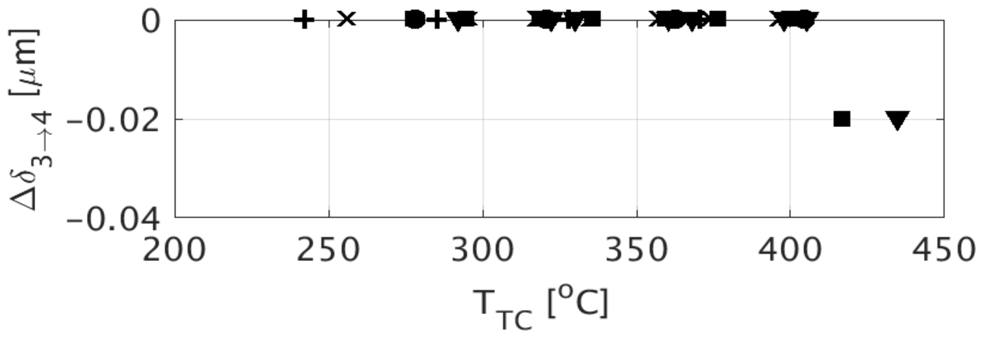


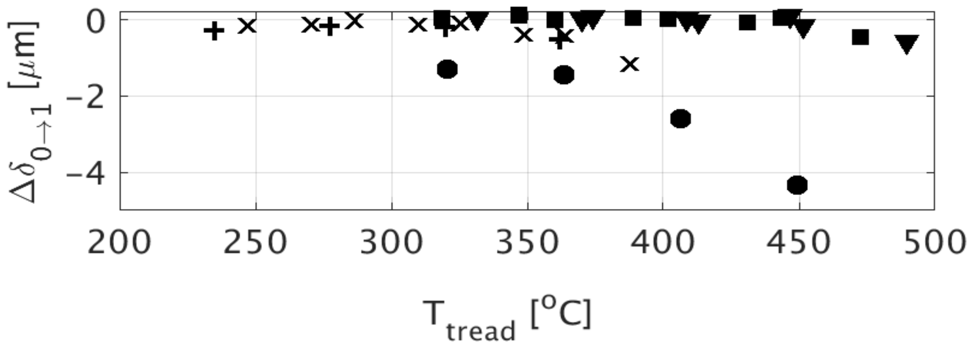
Solid red lines with square markers are for the tread temperatures and dashed blue lines with circle markers are for the thermocouple position.

Simulations part 2: Plastic deformations due to rolling

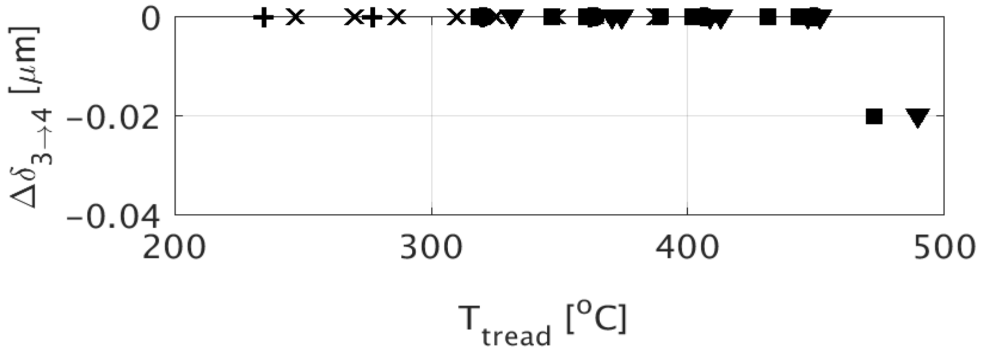


10 mm below





Tread



Simulated change of tread surface depression at rolling circle for first passage for all chosen time instances given as function of tread temperature

Simulated change of tread surface depression at rolling circle for last passage (surface ratchetting) for all chosen time instances given as function of tread temperature

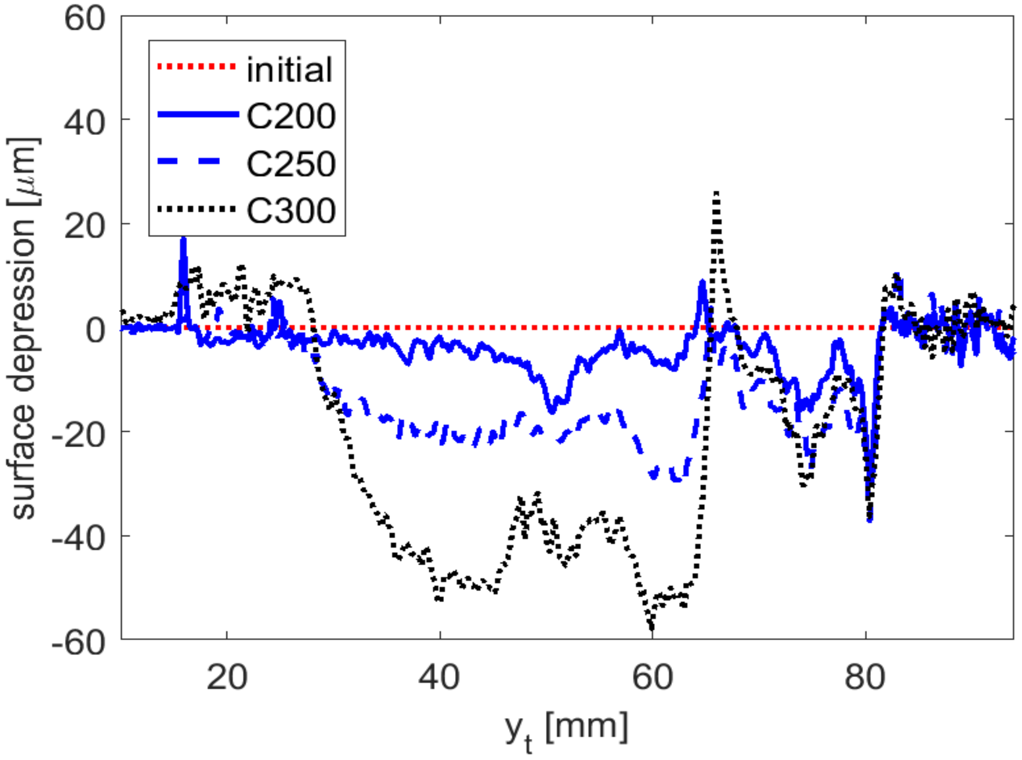
Simulations part 2: Plastic deformations due to rolling

For temperatures above 415 °C, the simulated surface depression is 0.02 μm per load passage (wheel revolution).

A rough estimate for 200 s of braking at 60 km/h with wheel diameter 0.86 m, gives

0.02×200×60/3.6×1/(πd) = 25 μm.

This can possibly be compared to the measured surface depression for 300 °C which is about 50 μm in average over the rolling circle.



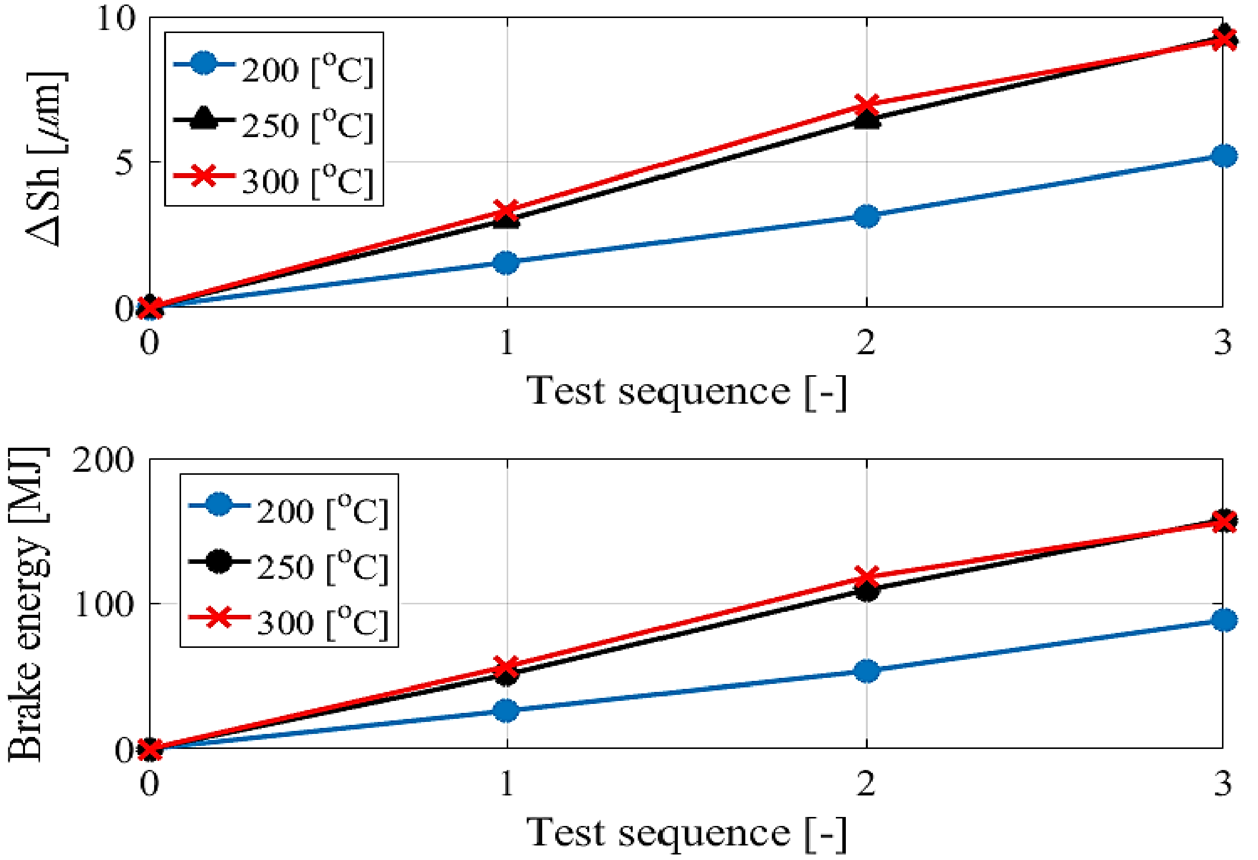
Change of tread profile as measured after each of the three constant temperature rolling sequences.

Tread wear due to wheel-block contact

$$\dot{w} = k_{\mathrm{w}}^{\mathrm{tread}} \mu p v$$

$k_{\mathrm{w}}^{\mathrm{tread}}$ [m^2/N] is a temperature-independent
μ is friction coefficient
p is normal contact pressure
v is sliding velocity
$k_{\mathrm{w}}^{\mathrm{tread}}$ is calibrated for field tests

The calculated average wear is 0.065 [μm/MJ] for all braking sequences.

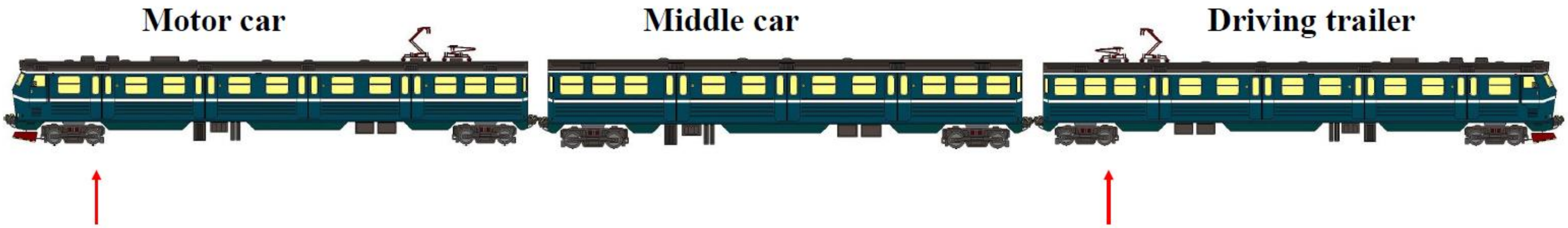


Concluding remarks: Part 1

- Temperatures were recorded using thermocouples fitted 10 mm below tread, over tread-block contact width.
- Measurements indicate presence of hot spots on wheel tread.
- Simulations indicate high tread surface depression on first load passage.
- For tread temperatures below 400 °C, surface depression is negligible at last load passage.
- For tread temperatures above 400 °C, ratchetting type of surface depression was observed for each repeated load cycle.
- The tread plastification can be estimated in an average sense by the current simulation methodology for constant temperature rolling at 300 °C.
- For tests at 300 °C, the sum of simulated tread plastification and calculated tread wear is close to the measured surface depression.
- For tests at 200 °C and 250 °C, additional studies, are required to investigate the tread plastification during braking.

Part 2: Field experiments and simulations

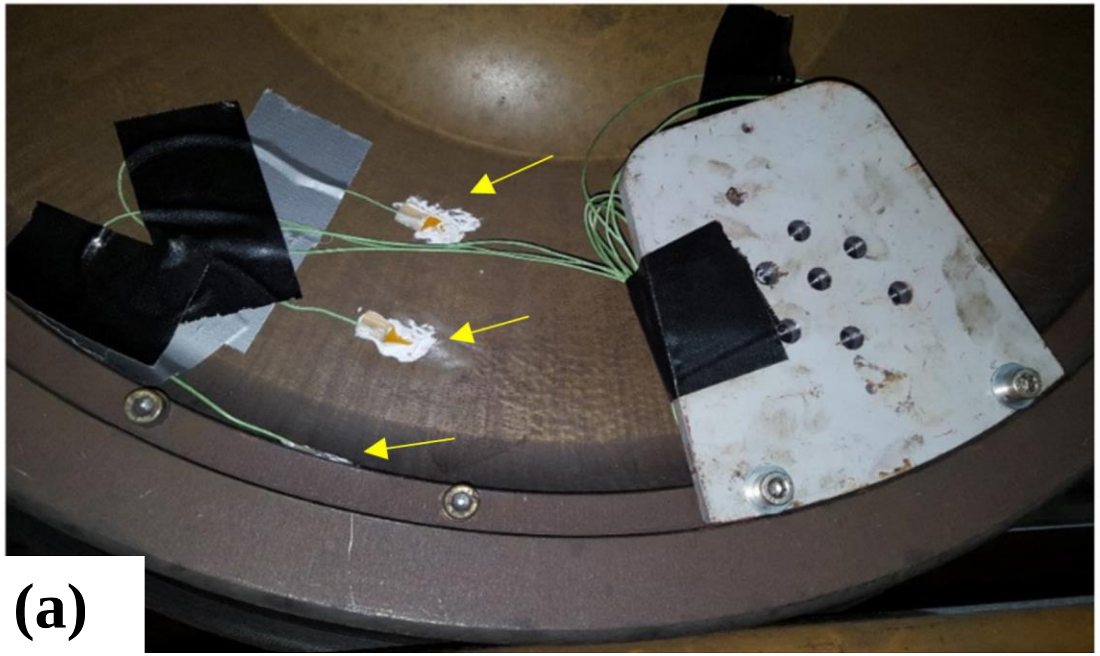
Field experiments



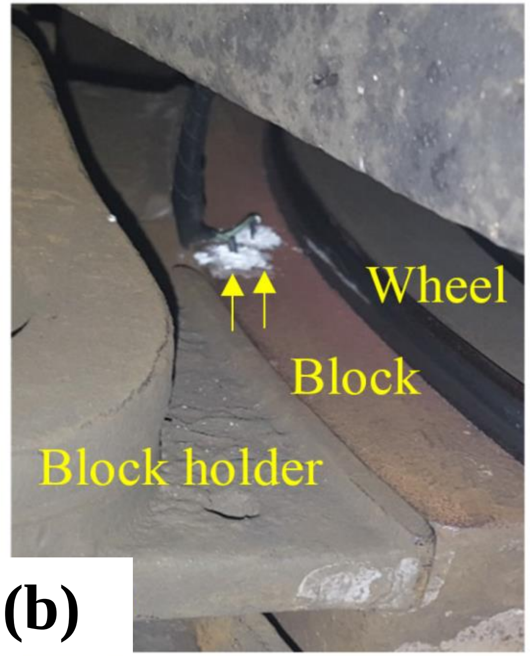
- Commuter train: Roslagsbanan, Stockholm
- Maximum operating speed 80 km/h
- Brake system – electrodynamic brakes (motor car) & tread brakes (all cars)
- Motor car – cast iron brake blocks
- Other two cars – organic composite brake blocks (summer) and cast iron brake blocks (winter)

Field experiments

(a) *Wheel web*
(b) *Brake block*



(a)



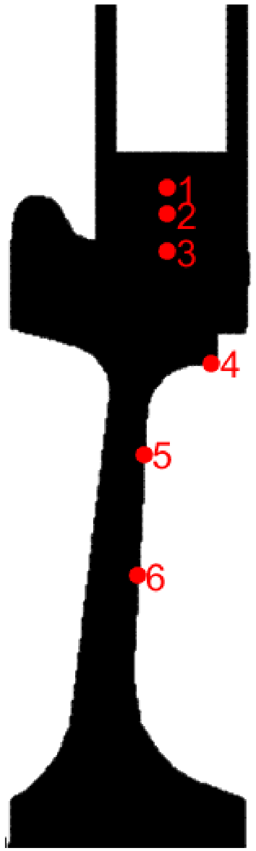
(b)

(c)

(d)

(c) Wheel tread
(d) Data logger

Braking temperatures



Solid line – Simulation

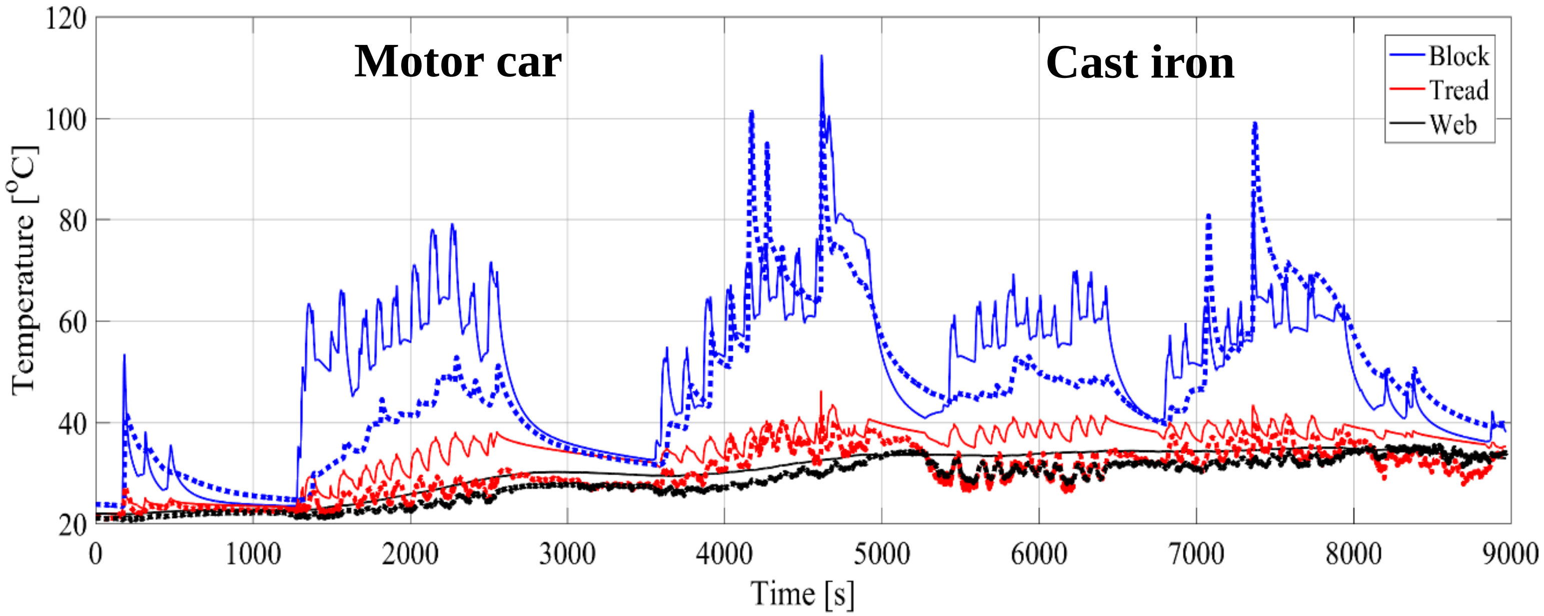
Dashed line – Measured

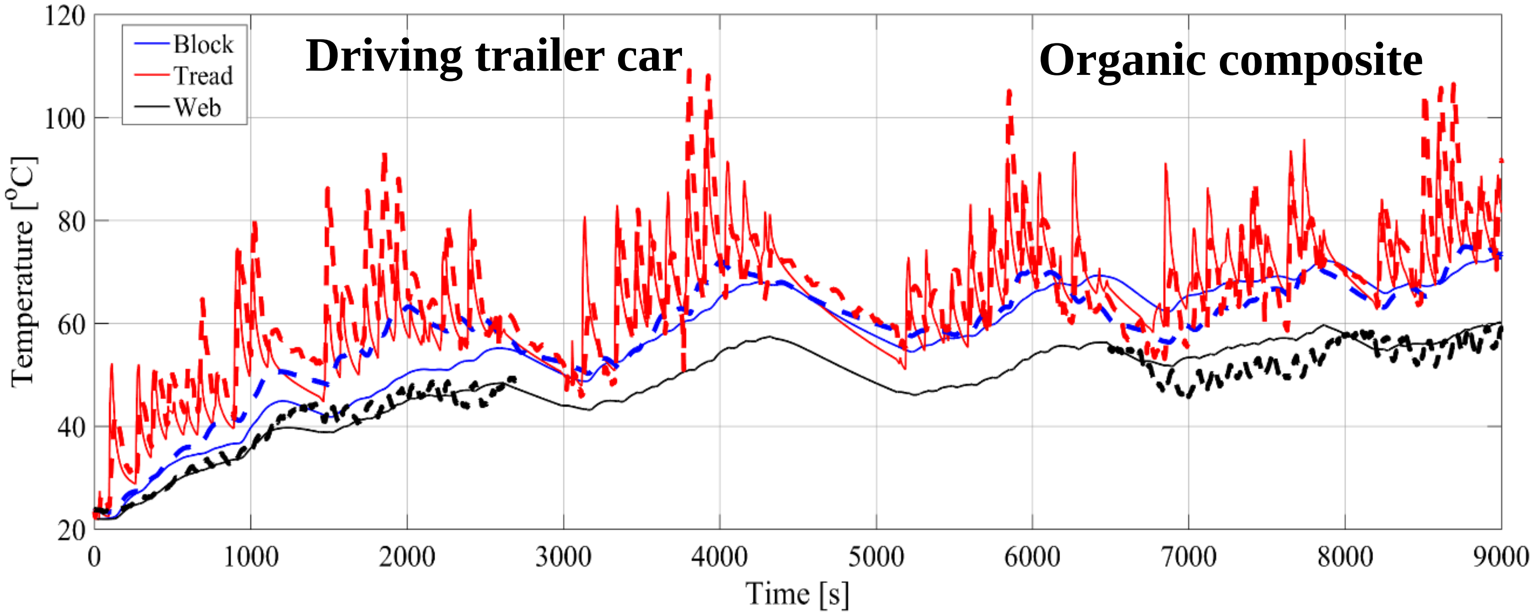
Brake block – 1, **2**

Wheel tread – **3**

Wheel web – 4, **5**, 6

Axisymmetric model





Block wear

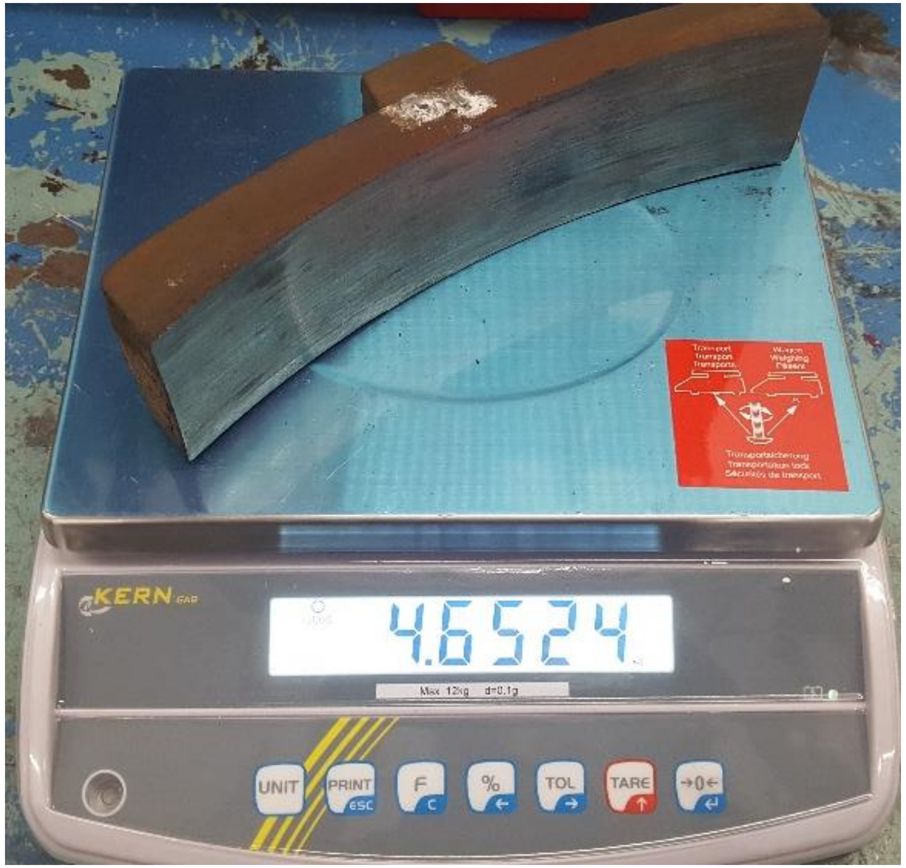
Based on Archard's wear model

$$\dot{w} = k_{\mathrm{field}} k_{\mathrm{w}}^{\mathrm{block}}(T)\mu p v$$

$k_{\mathrm{w}}^{\mathrm{block}}(T)$ temperature-dependent
k_{field} scaling factor
μ coefficient of friction
p normal contact pressure
v sliding velocity

Density of cast iron 7100 kg/m³

Density of organic composite 2670 kg/m³

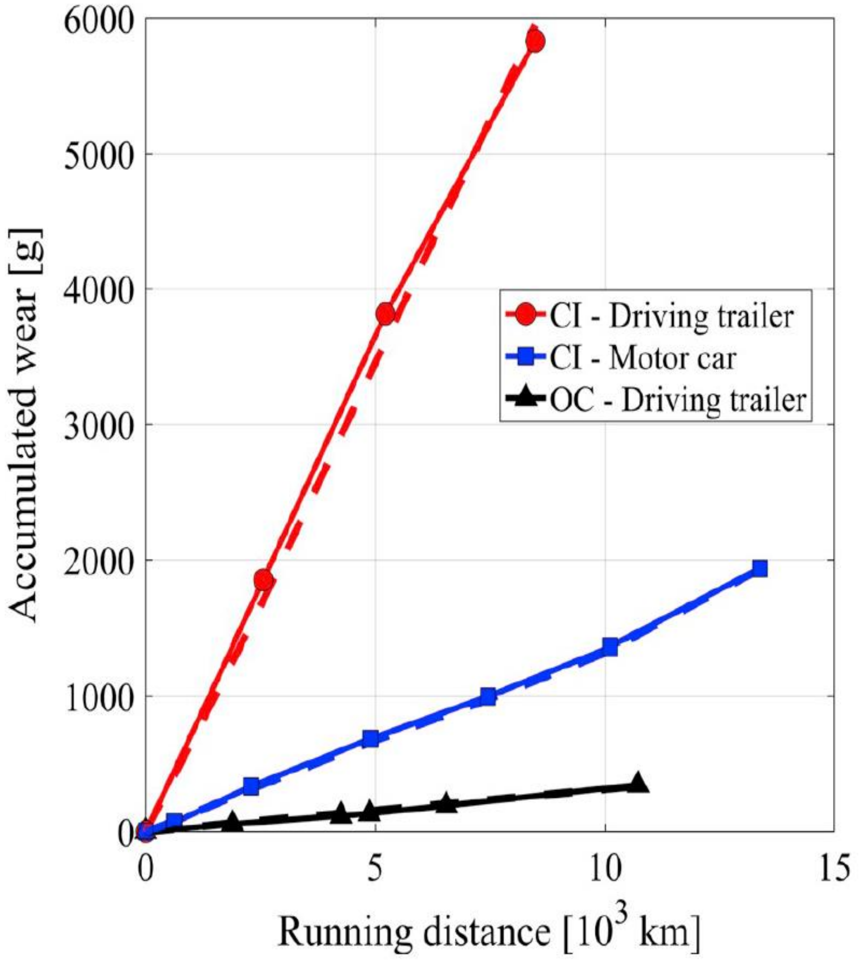


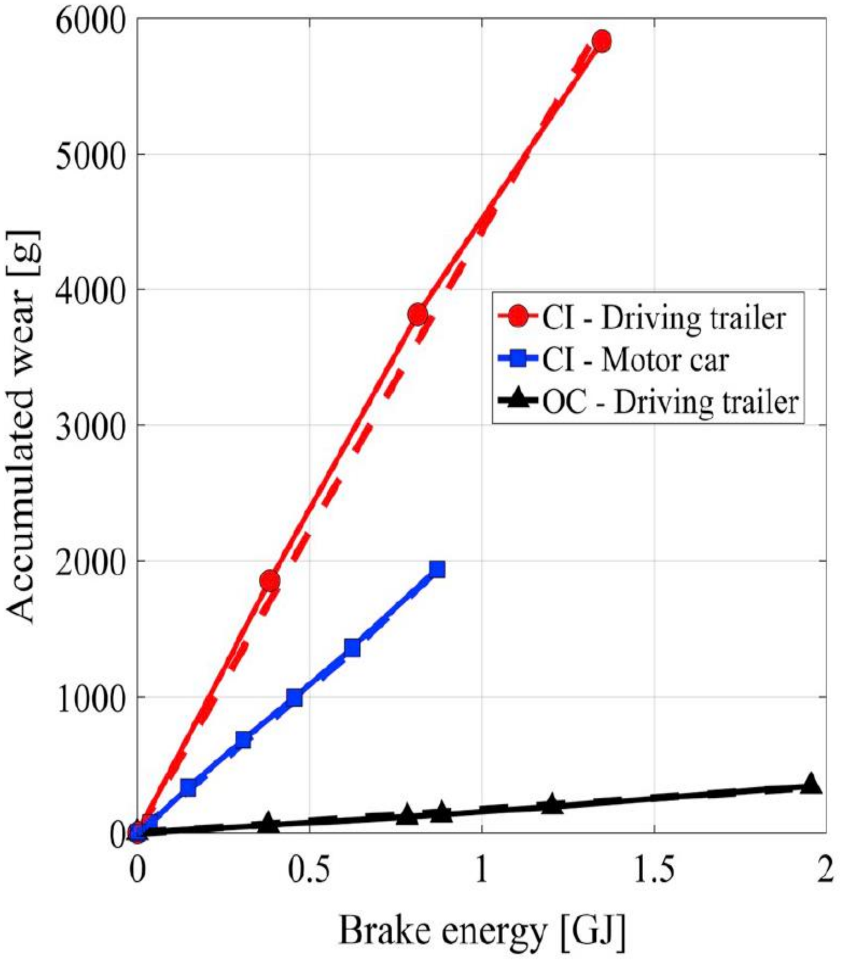
Cast iron (CI) brake block weighed using a high precision weighing scale

Block wear

Solid line with markers – Measured

Dashed line – Calculated





Total volumetric wear is 10 times higher for cast iron brake blocks

Wheel wear

Tread wear due to wheel–rail (USFD method):

$$Wear\ rate = K\frac{T\gamma}{A}$$

K wear constant
T tangential contact force (longitudinal)
γ creepage (longitudinal)
A wheel–rail contact area

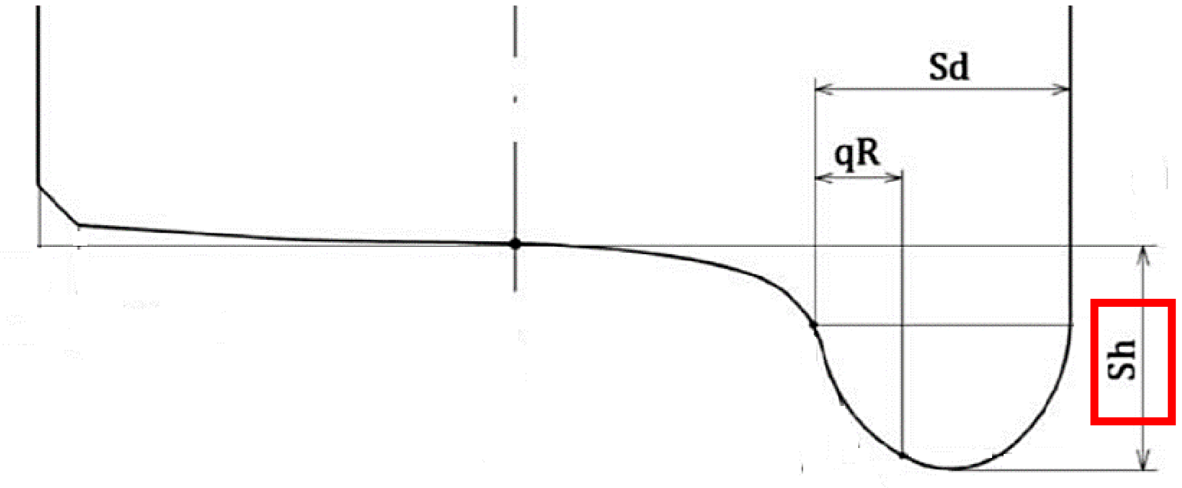
Tread wear due to wheel–block contact:

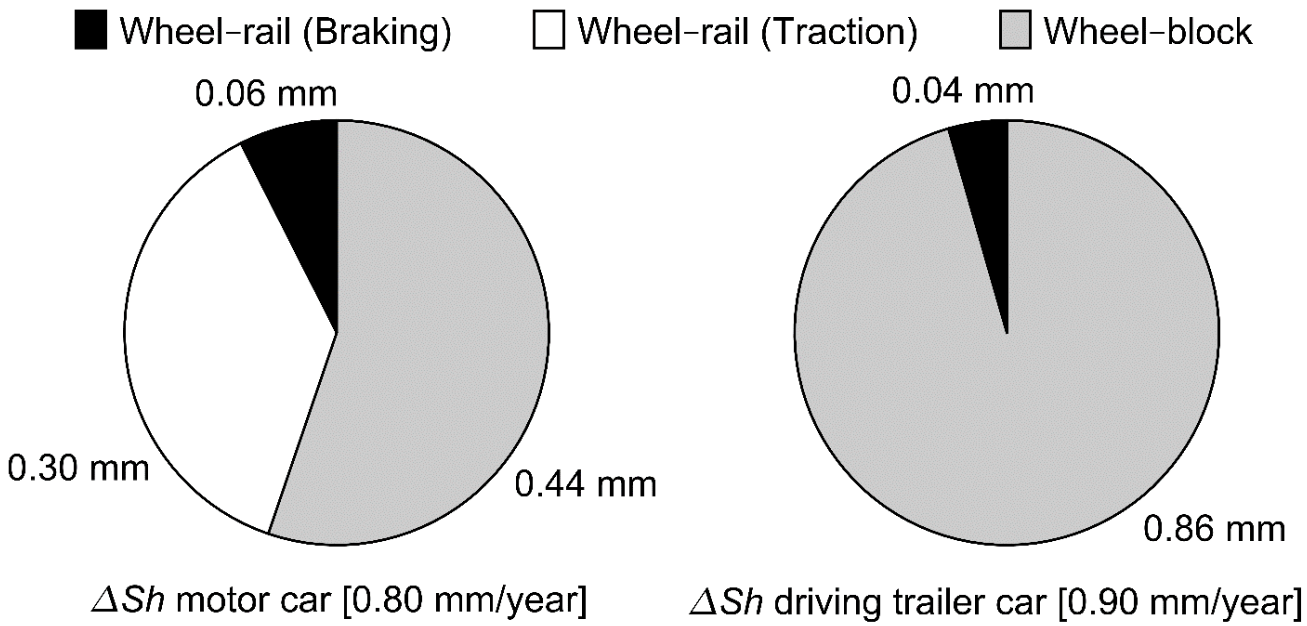
$$\dot{w} = k_{\mathrm{w}}^{\mathrm{tread}}\mu p v$$

k_w^{tread} temperature-independent

Wheel profile measured using a miniprof

Wheel wear: Sh





***Motor car**: wheel–block and wheel–rail contribute to wear equally*

***Driving trailer car**: wheel–block high contribution*

Main conclusions and contributions: Part 2

- Wear for cast iron brake block is 10 times higher as compared to organic composite
- Wear due to wheel–rail contact and wheel–block contact equally important for powered wheels
- For trailing wheels, wear due wheel–block contact is dominating

➢ Methodology for estimating long-term wear of both brake blocks and wheel tread

➢ Combined tread wear from wheel–rail contact and wheel–block contact

➢ Deeper understanding of actual utilization of braking systems at revenue traffic

Thank you

Roger Lundén
Full Professor at Mechanics and Maritime Sciences

Chalmers/CHARMEC, Gothenburg
Phone: +46317721511
E-post: roger.lunden@chalmers.se

Tore V Vernersson
Researcher at Mechanics and Maritime Sciences

Chalmers/CHARMEC, Gothenburg
Phone: +46317728501
E-post: tore.vernersson@chalmers.se

Mandeep Singh Walia
Technical Project Manager

Green Cargo AB, Solna, Sweden
Phone: +46104554219
Mobil: +46761023189
E-post: mandeep-singh.walia@greencargo.com