Current and Future Techniques for Investigating Wheel-Rail Wear and Damage

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Overview

Wheel wear prediction

- **Wheel profile damage model**
- **Tuning and validation**
- **Case study – economic tyre turning**

Future research areas

- **Bogie dynamics, rolling contact, adhesion and braking rig**

WPDM Background & Development

University of HUDDERSFIELD
Institute of Railway Research

RSSB

KTH VETENSKAP OCH KONST

Wear Modelling

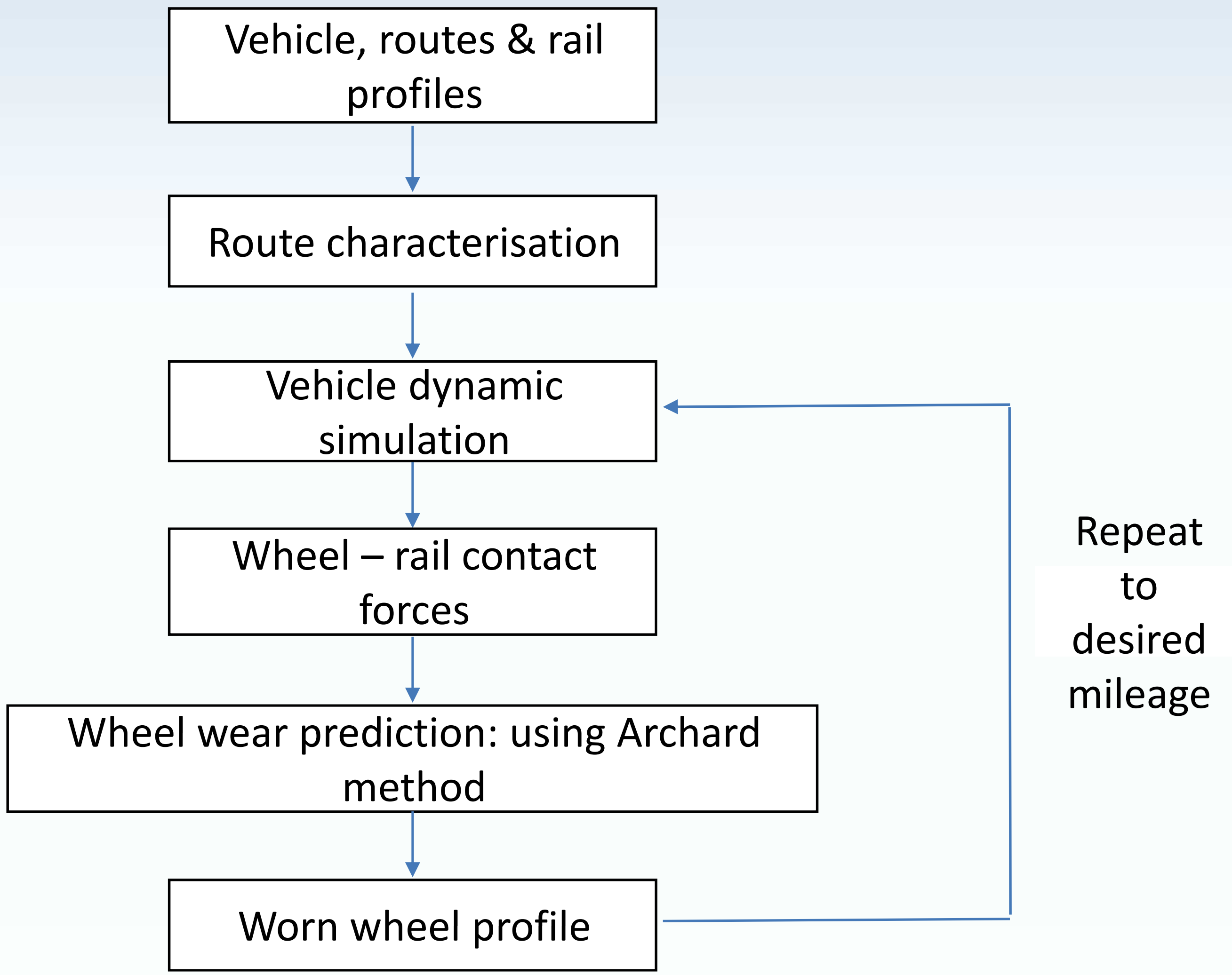
- Long history of research in this area based on lab test and field trials

- Complex physical phenomenon with many influencing factors:
  - Suspension type
  - Environmental conditions
  - Lubrication, contamination
  - Contact conditions
  - Material properties and hardness
  - Route characteristics
  - Traction / braking

Wheel Profile Damage Model

- Originally developed under RSSB T792 and subsequently refined further
- Objective - to predict wheel wear for real vehicles under a range of operating conditions and typical service mileages
- Expected to provide both Fh, Ft and worn wheel shape
- Implies the need to characterise the wheels duty cycle

WPDM Methodology



Route Characterisation (1)

- Route characterisation routine:
  - reads in several track files to represent different route sections of a vehicles diagram
  - reads in traction and braking profiles for each route section
  - weights each route section be service pattern of the vehicle
  - characterises the duty cycle of vehicle in terms of curve radius, cant deficiency, traction and braking, track irregularities
  - automatically generates VAMPIRE track and forcing files

- VAMPIRE results weighted to represent the whole route simulations

Route Characterisation (2)

Calculate cumulative distribution of curves

↓

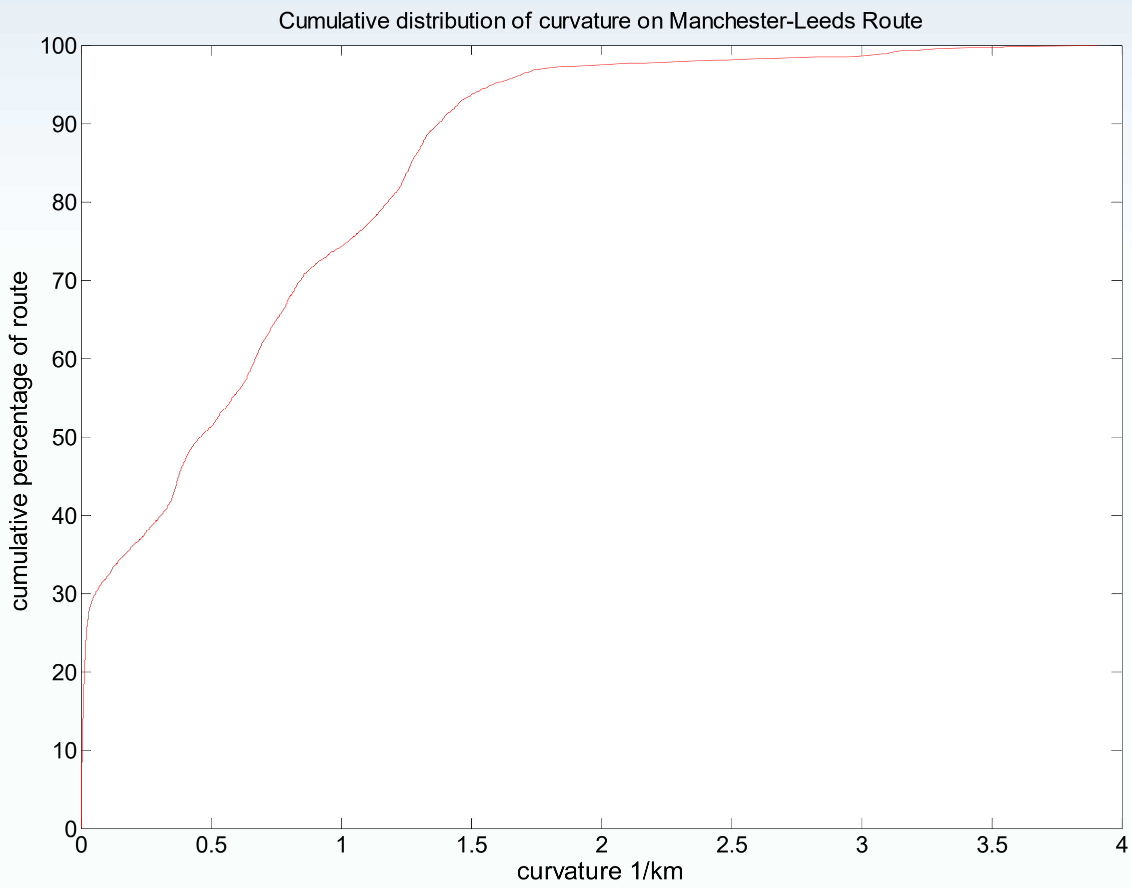
Calculate gradient of the distribution:
(steep gradient = common curve radius)

↓

Sharp curves do more damage ~ prioritise by gradient x curvature

↓

Identify peaks in distribution of gradient x curvature



Route Characterisation (3)

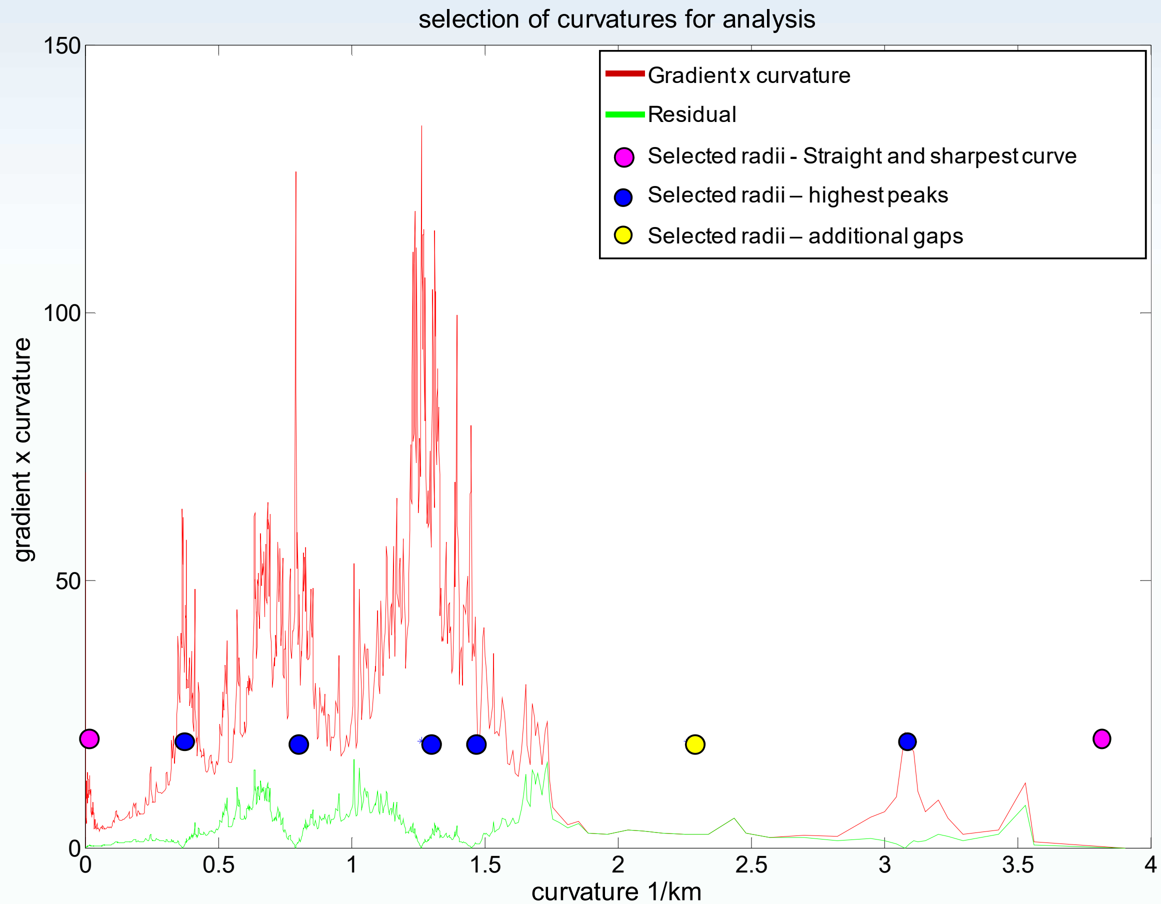
Select straight and sharpest curve cases

Select radii based on highest peaks
- where not close to those already selected

Select radii to fill any large gaps

Typically 6-8 radii selected

Categorise route into bins represented by these radii



Route Characterisation (4)

For each radius bin, repeat characterisation process to select cant deficiencies for that bin

Typically 2-4 cant deficiencies for each radius bin

Create input files for VAMPIRE runs:
- Curvature and Cant
- Speed (not to exceed max veh/line speed)
- Irregularities (scaled based on SD of route)
- Weighting factors to apply to each case

Cant Deficiency (mm)

Curve Radius (m)	Cant Deficiency Case (mm) 1	2	3	4
-360	-14.24	81.22	0.00	0.00
-581	-3.65	74.99	0.00	0.00
-1507	102.36	117.27	130.00	0.00
-1940	74.25	92.39	120.43	0.00
-2368	-0.46	46.92	62.88	88.36
-2994	40.85	61.19	73.68	0.00
-4088	20.11	32.01	55.50	0.00
0	0.00	0.00	0.00	0.00
4088	20.11	32.01	55.50	0.00
2994	40.85	61.19	73.68	0.00
2368	-0.46	46.92	62.88	88.36
1940	74.25	92.39	120.43	0.00
1507	102.36	117.27	130.00	0.00
581	-3.65	74.99	0.00	0.00
360	-14.24	81.22	0.00	0.00

Route Distance (m)

Curve Radius (m)	Cant Deficiency Case (mm) 1	2	3	4
-360	72	288.4	0	0
-581	317.4	288.8	0	0
-1507	2610.8	1465.6	1848.8	0
-1940	2845.6	2055.4	1931.2	0
-2368	1112.2	876.4	1601.6	4998.4
-2994	2108.6	3172.2	2670.8	0
-4088	6911.4	5347.4	6888	0
0	204495.8	0	0	0
4088	4601.4	5351.6	6475.4	0
2994	3263.6	6782.6	2054.4	0
2368	778.6	1389	2612.8	2263
1940	703.8	1508.4	1296.6	0
1507	3771	1287	2729	0
581	198.4	0	0	0
360	312.4	0	0	0

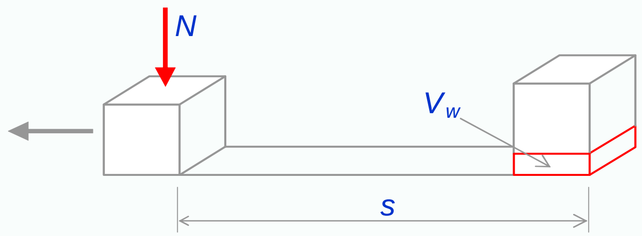
Traction / Braking Forces

- Route characterisation program also reads in traction/braking profile for each route section

- This can either be:
  - User generated from OTMR data etc.
  - Created using a simplified traction/braking profile generator using Davis equations for rolling resistance and vehicle speed profile

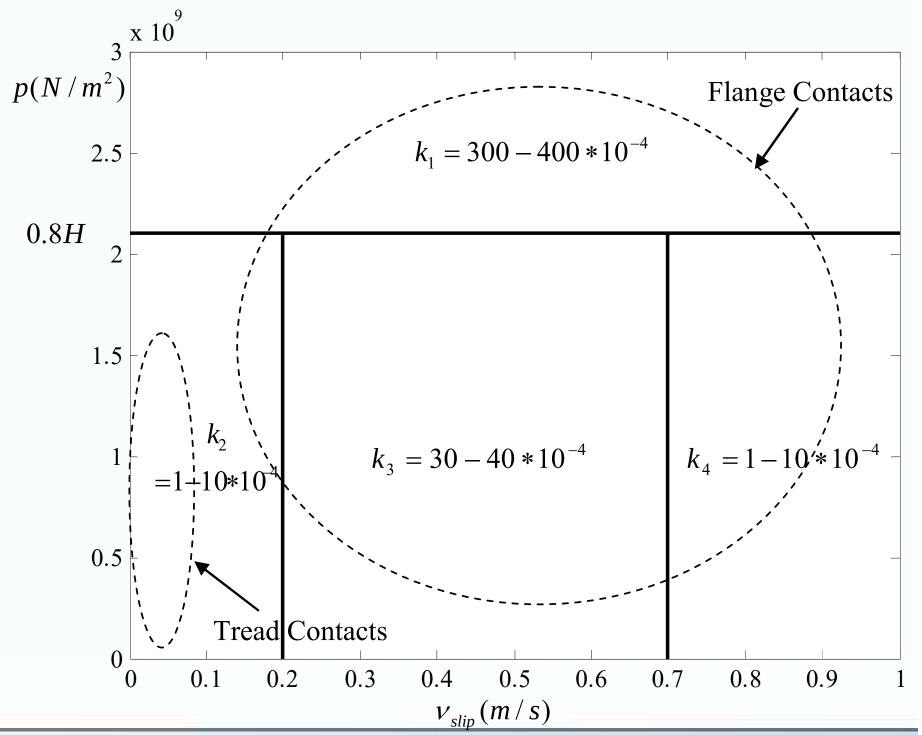
Archard's Wear Model

- Volume of material removed predicted based on the normal force, tangential forces, creepages and material properties



$$V_w = k \cdot \frac{N \cdot s}{H}$$

V_w = Volume of wear
s = Sliding distance
N = Normal force
H = Hardness
k = Wear coefficient



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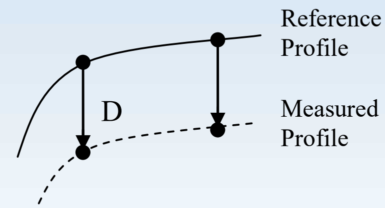
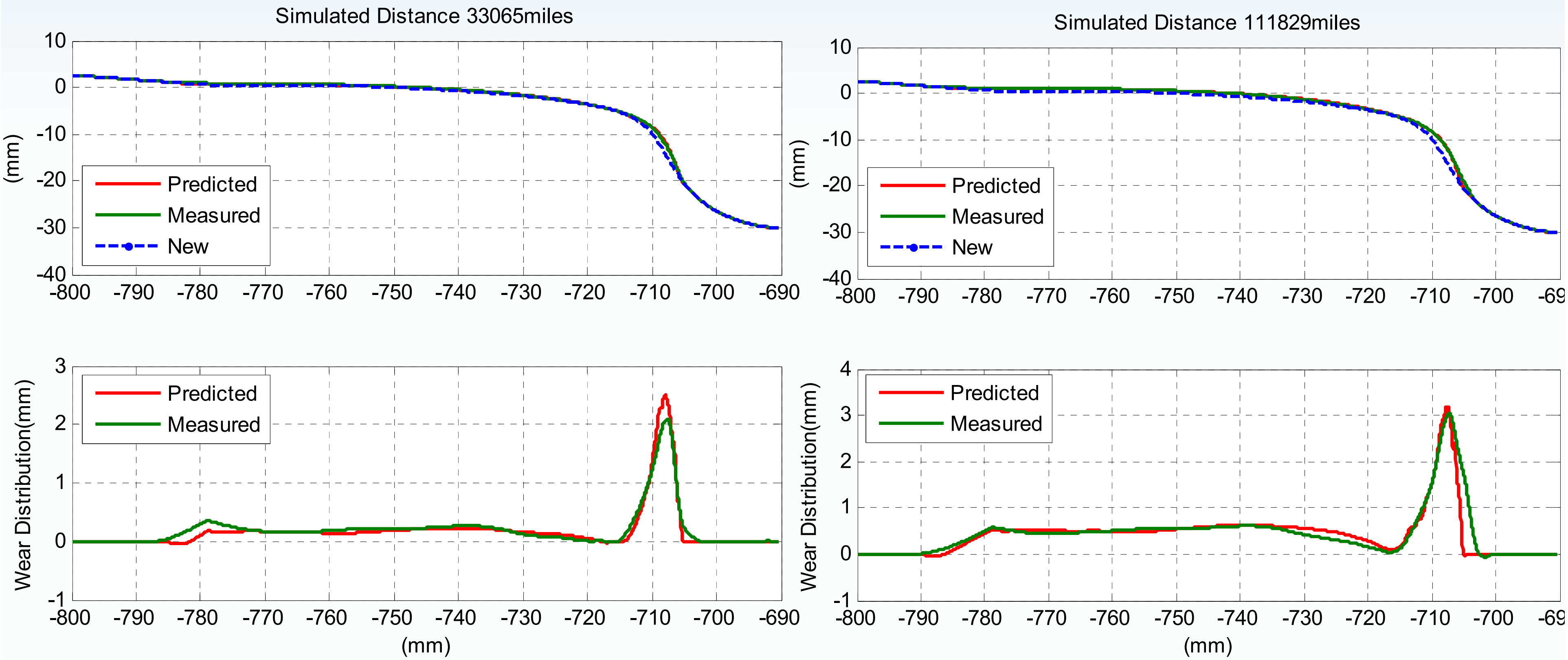
Measured Profile Comparison

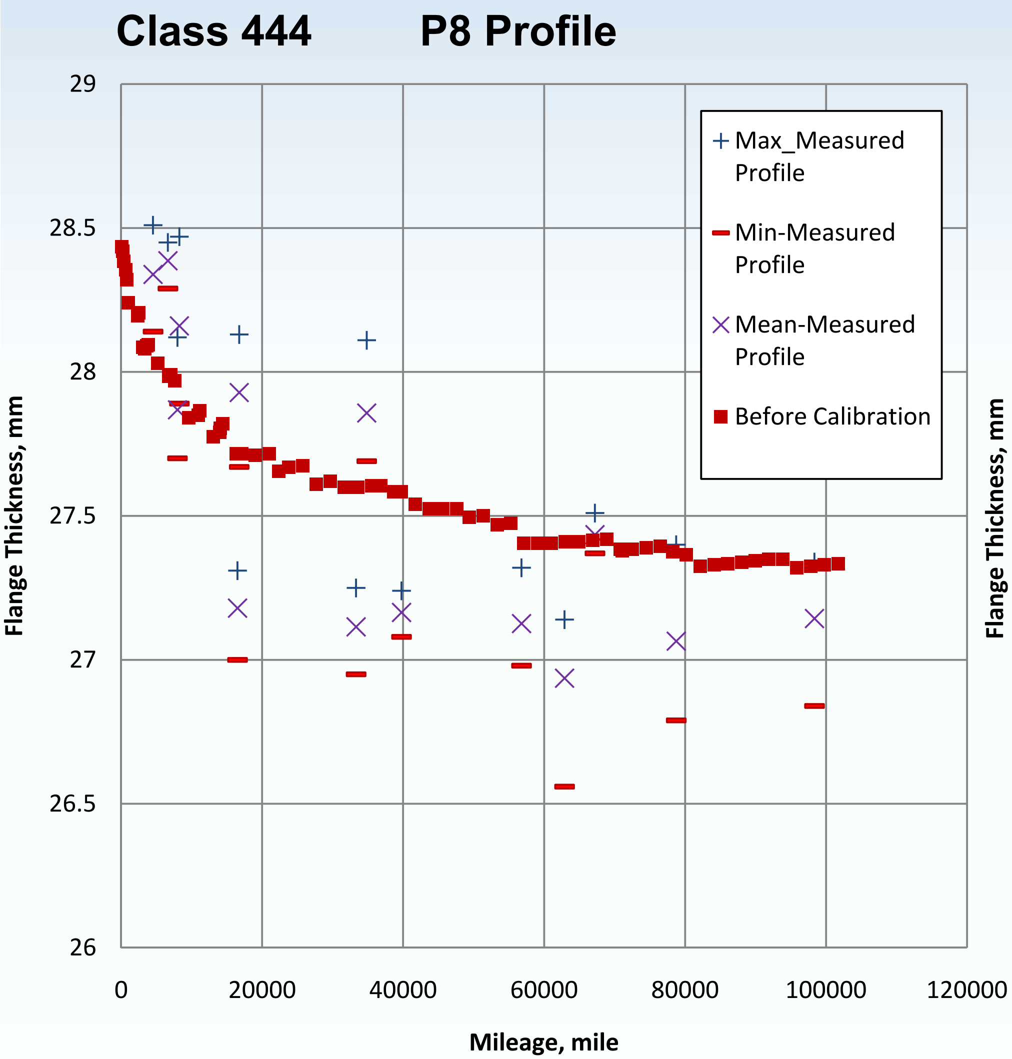
- Profile shape and wear distribution

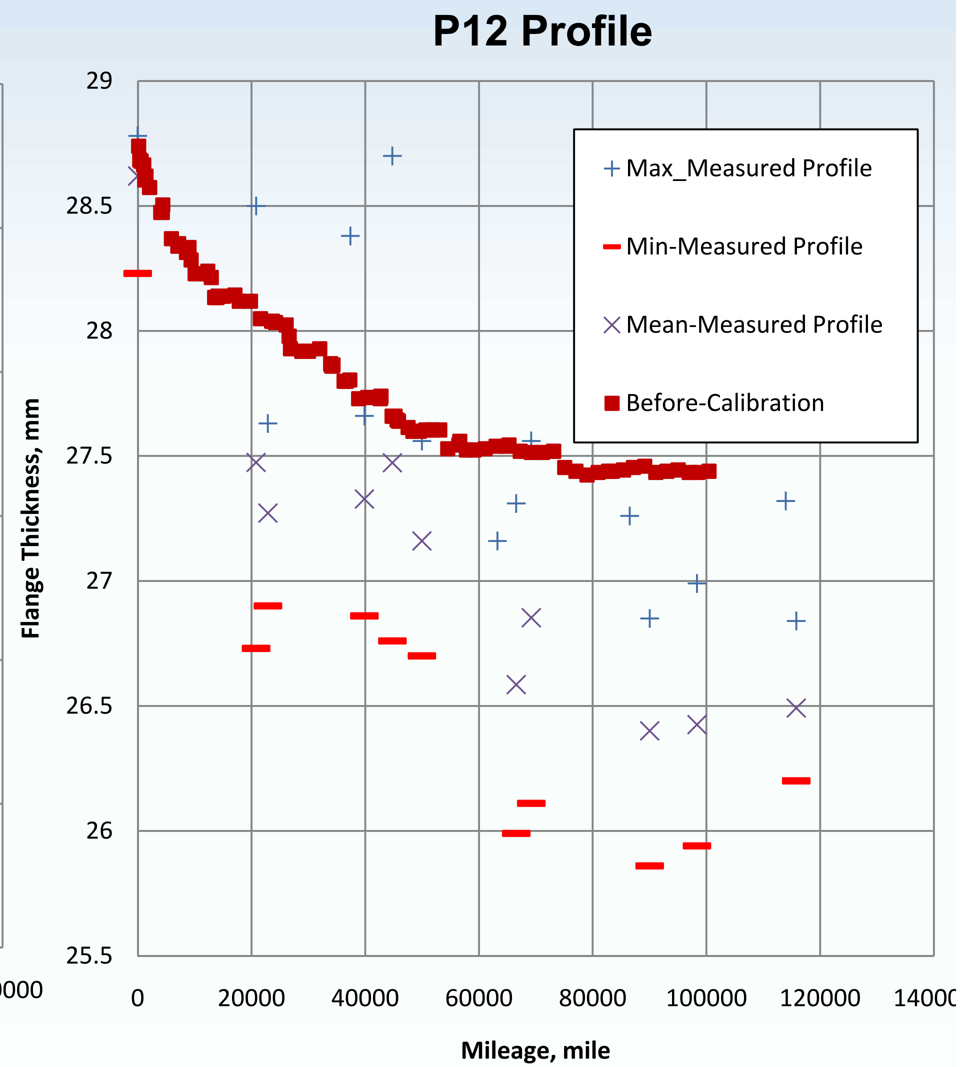




Wear Coefficient Tuning

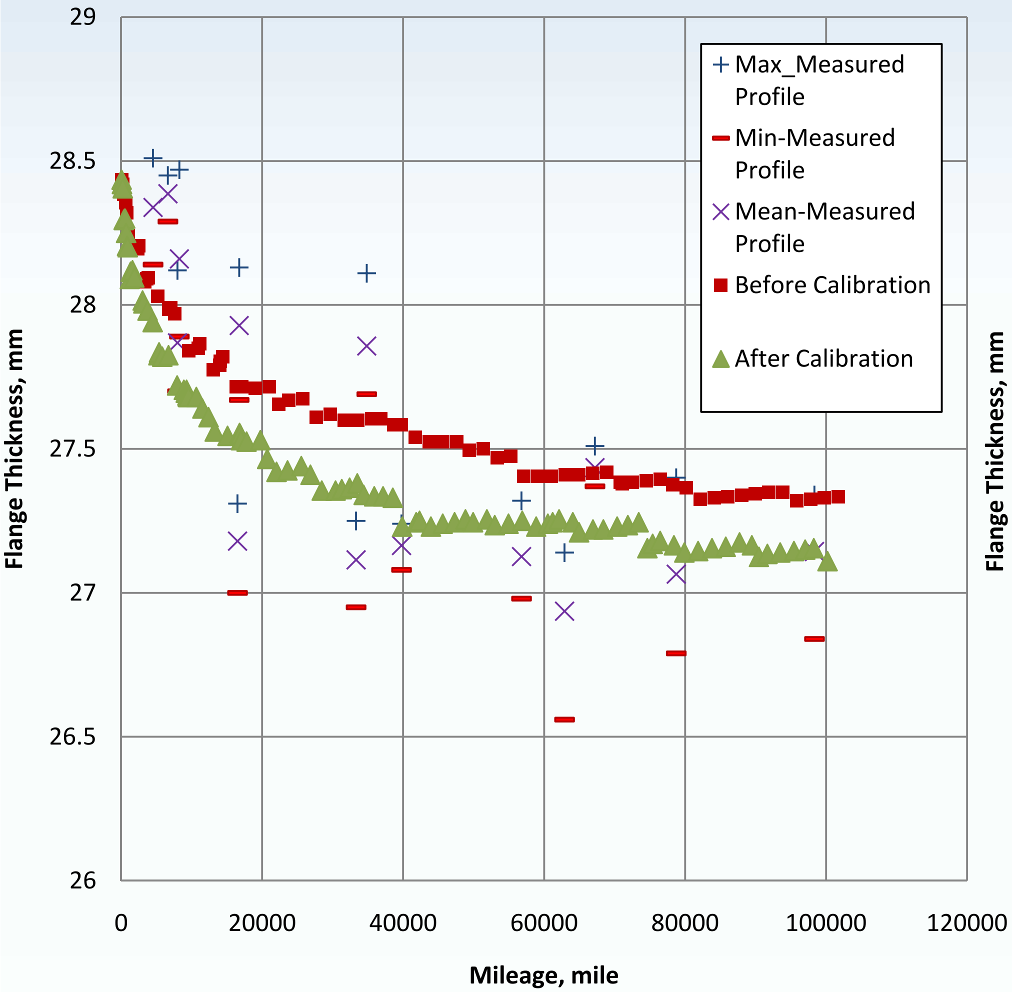
Class 444



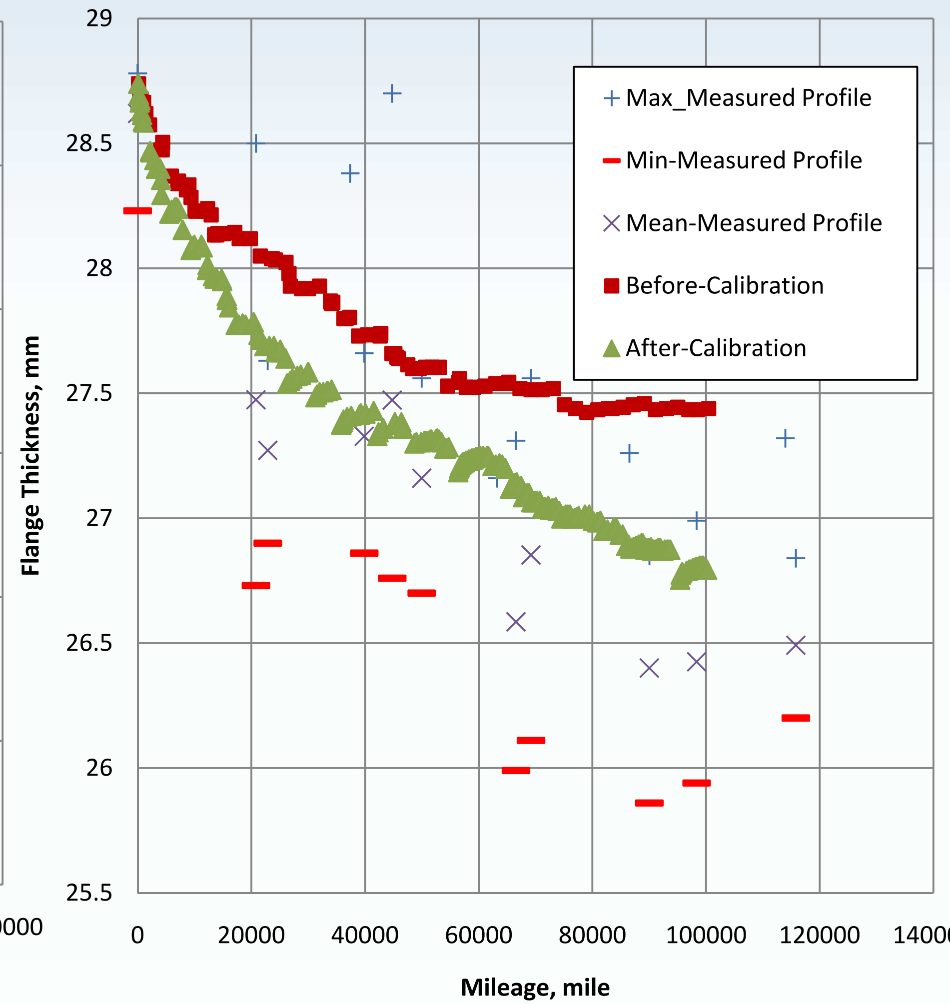


Wear Coefficient Tuning

Class 444 P8 Profile

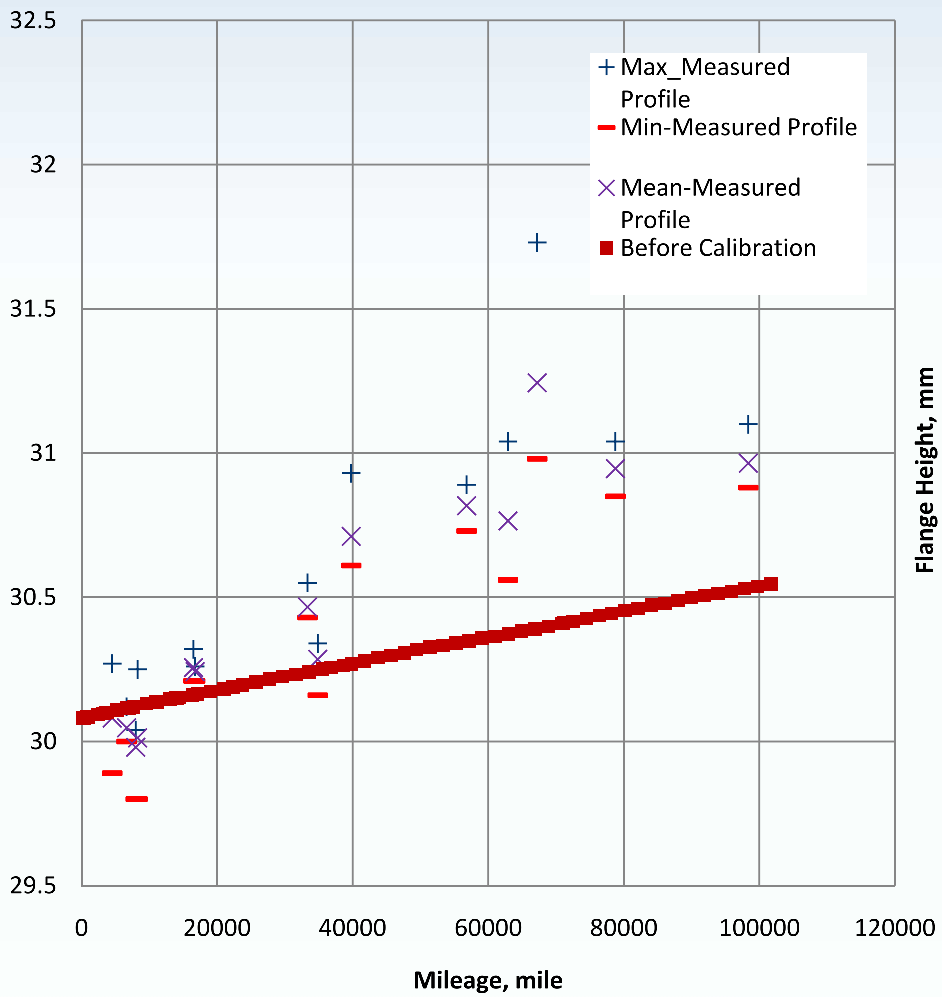


P12 Profile

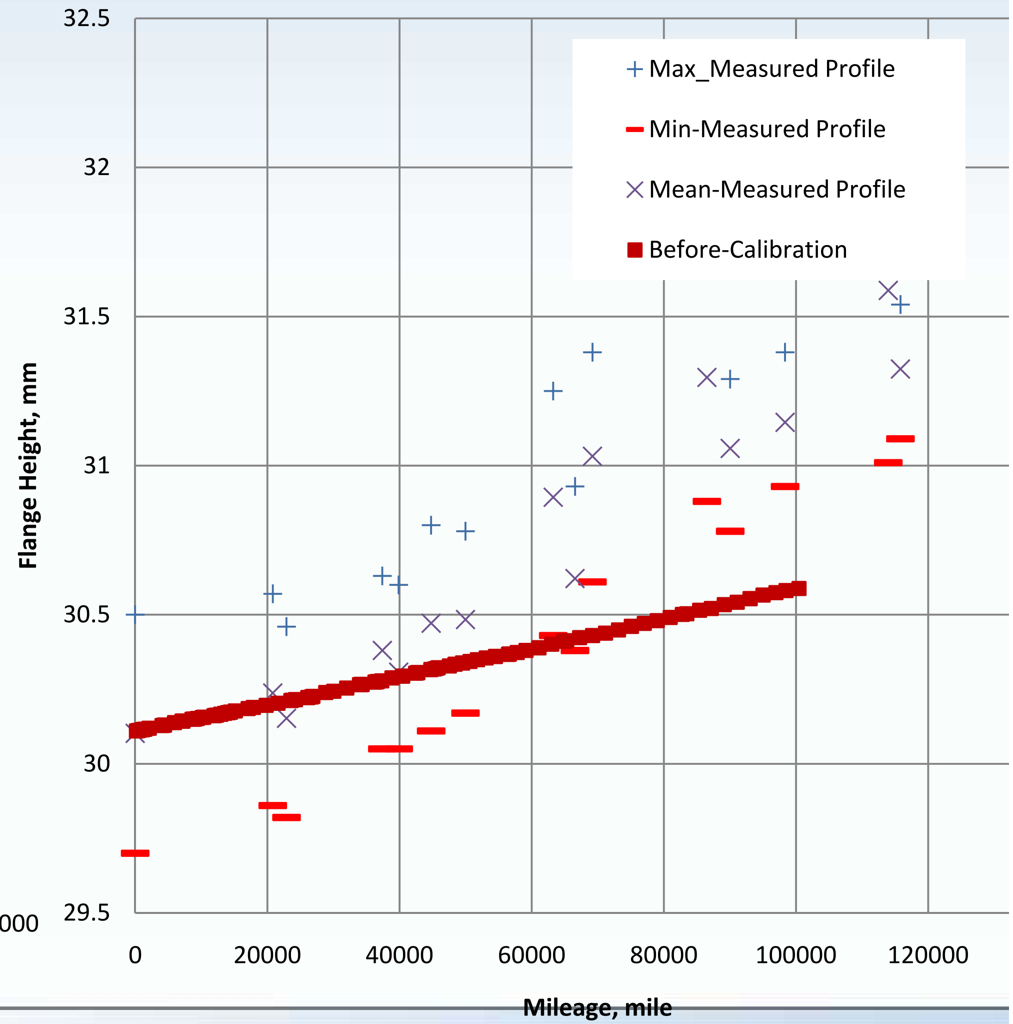


Wear Coefficient Tuning

Class 444 **P8 Profile**

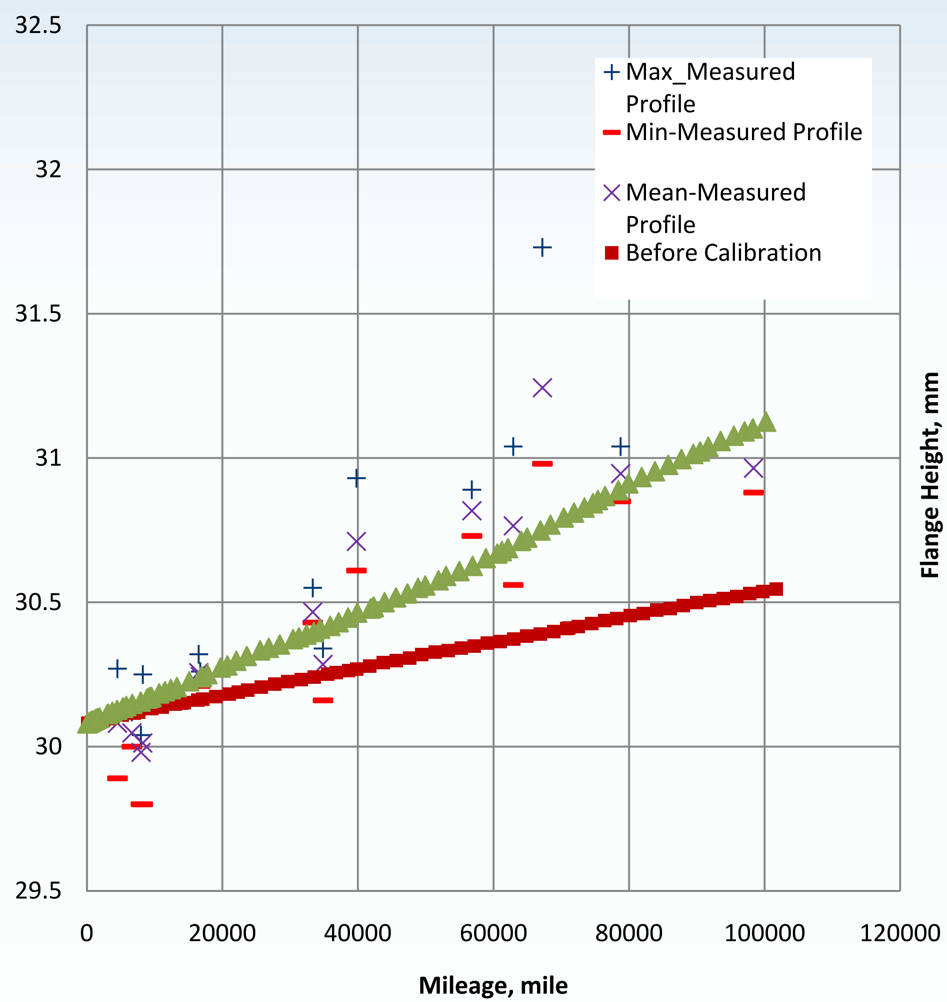


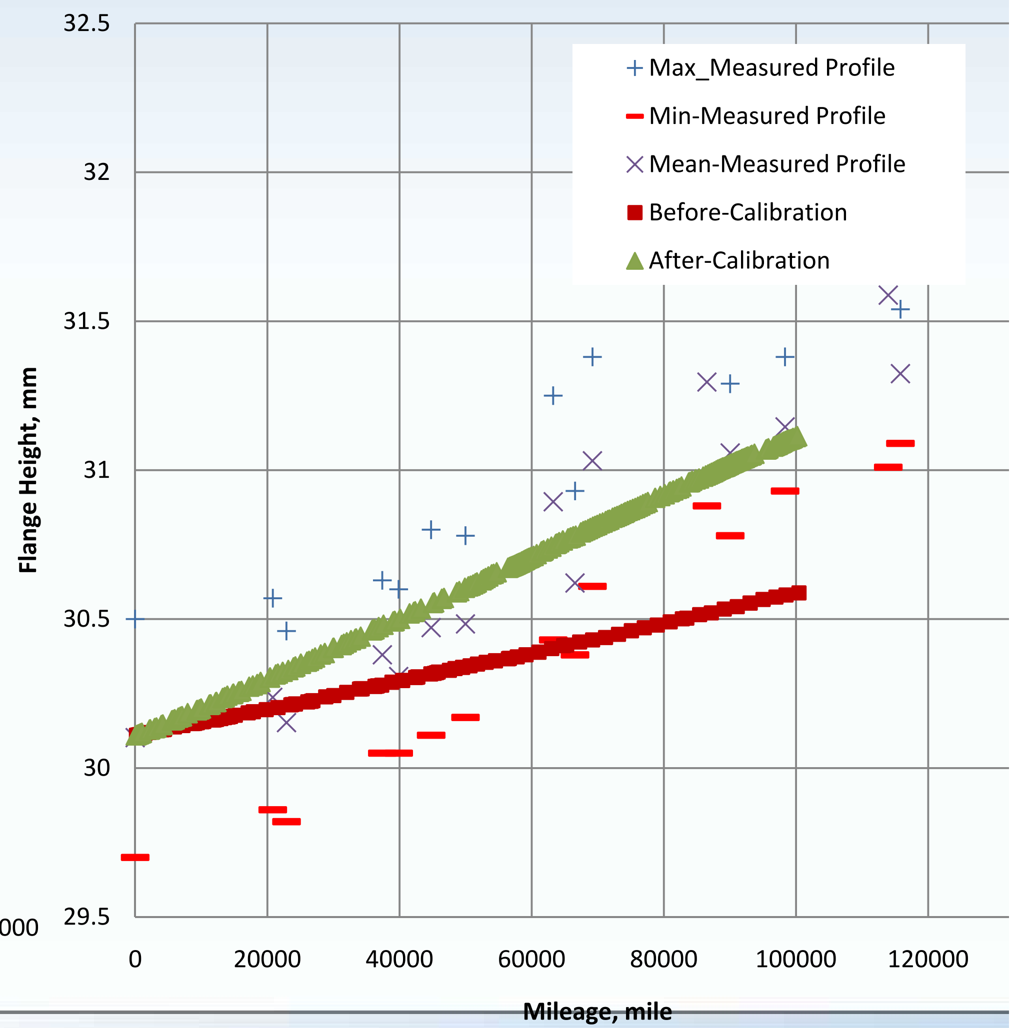
P12 Profile



Wear Coefficient Tuning

Class 444 **P8 Profile** **P12 Profile**





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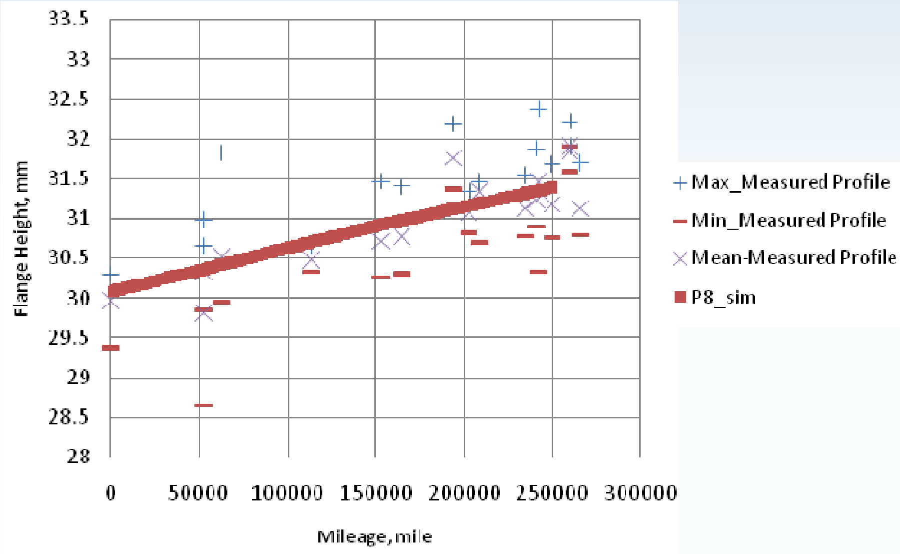
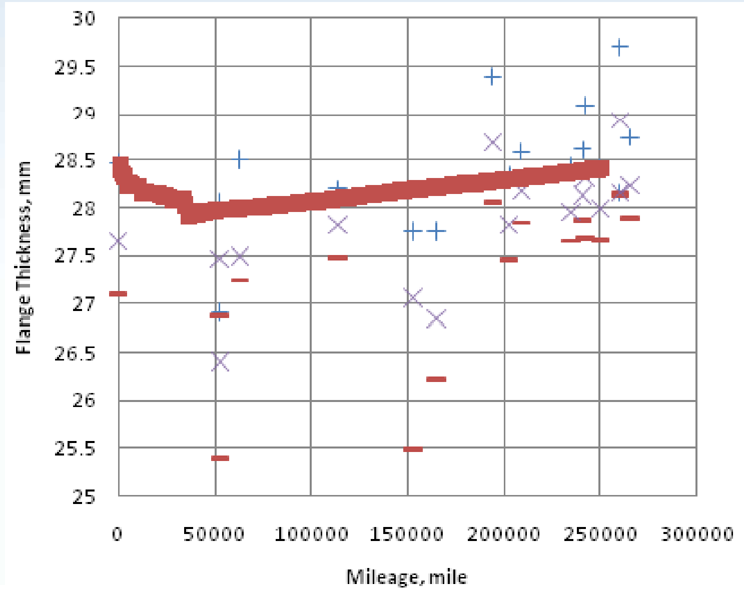
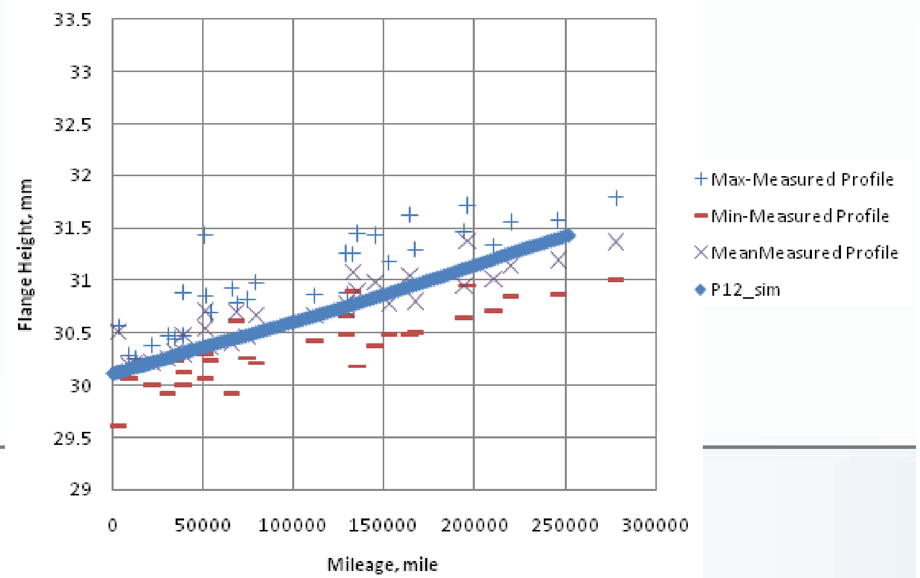
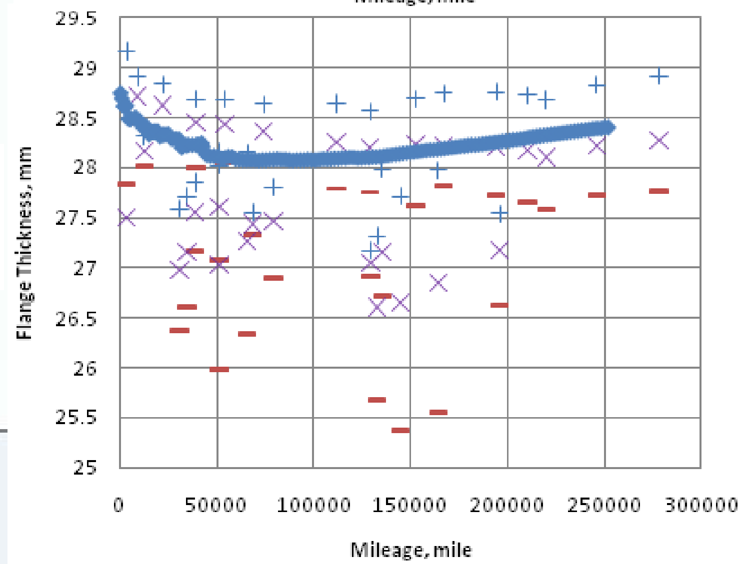
Measured Profile Comparison

Wear model validation: Class 390







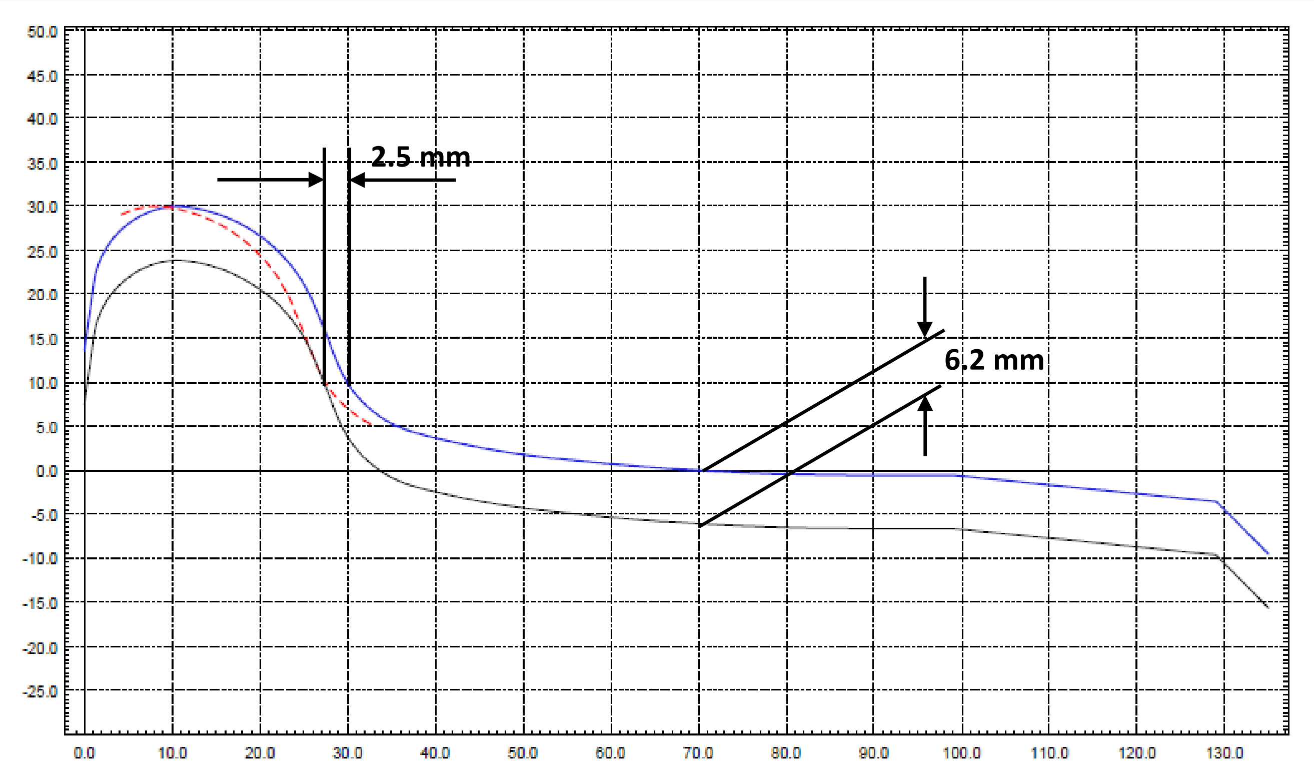


Case Study

The project has been undertaken under the Strategic Partnership between the University of Huddersfield and RSSB

Economic Tyre Turning (ETT)

ETT: re-profiling wheels to the design profile using a thinner flange



Aims

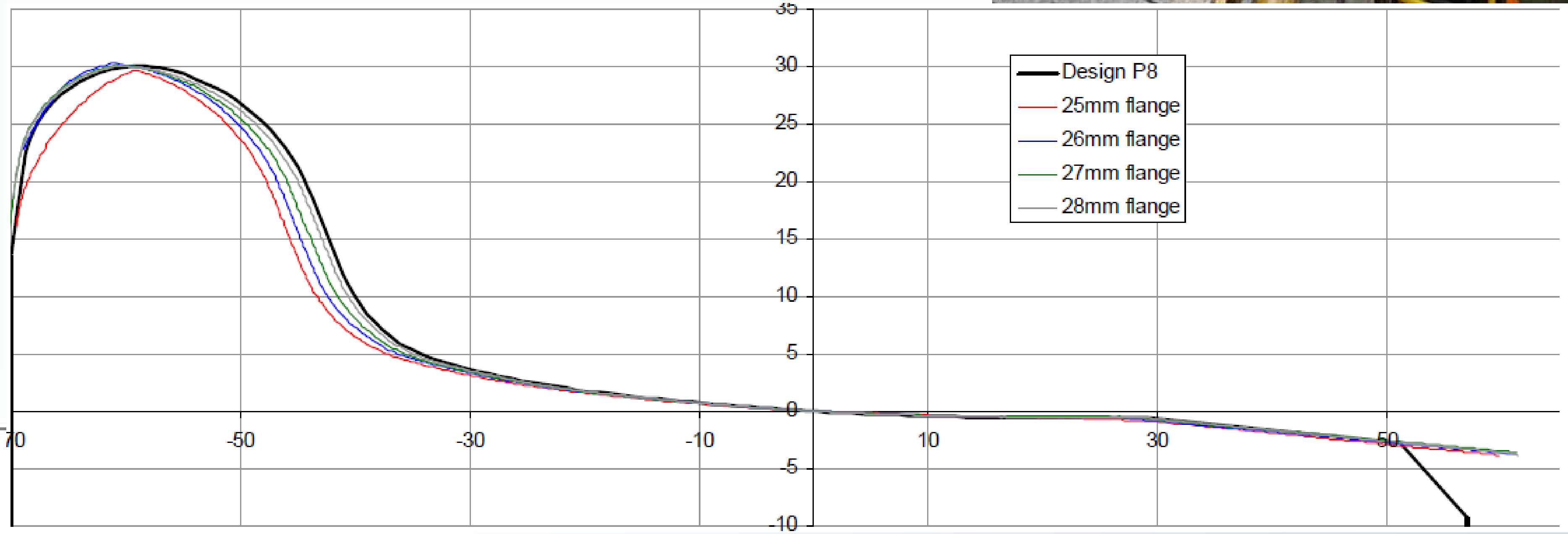
To help build a case for standards change by investigating:

- The difference in wear rates/patterns between thin flange and design case wheel profiles
- The effect of using the thin flange profiles on rail RCF & damage

Measured Thin Flange Profiles

- Thin flange profiles supplied by NR from Leeds Midland Rd lathe
- F_t in 1mm intervals from 28mm to 25mm

Both pictures courtesy of Mark Burstow, Network Rail



Vehicles and Routes

- **Class 444**

- Hounslow Loop
- Waterloo to Woking
- Waterloo to Windsor & Eton

- P8, P12 profiles

- **Class 390**

- Euston to Manchester Piccadilly
- Crewe to Glasgow Central
- Rugby to Wolverhampton

- P8, P12 profiles

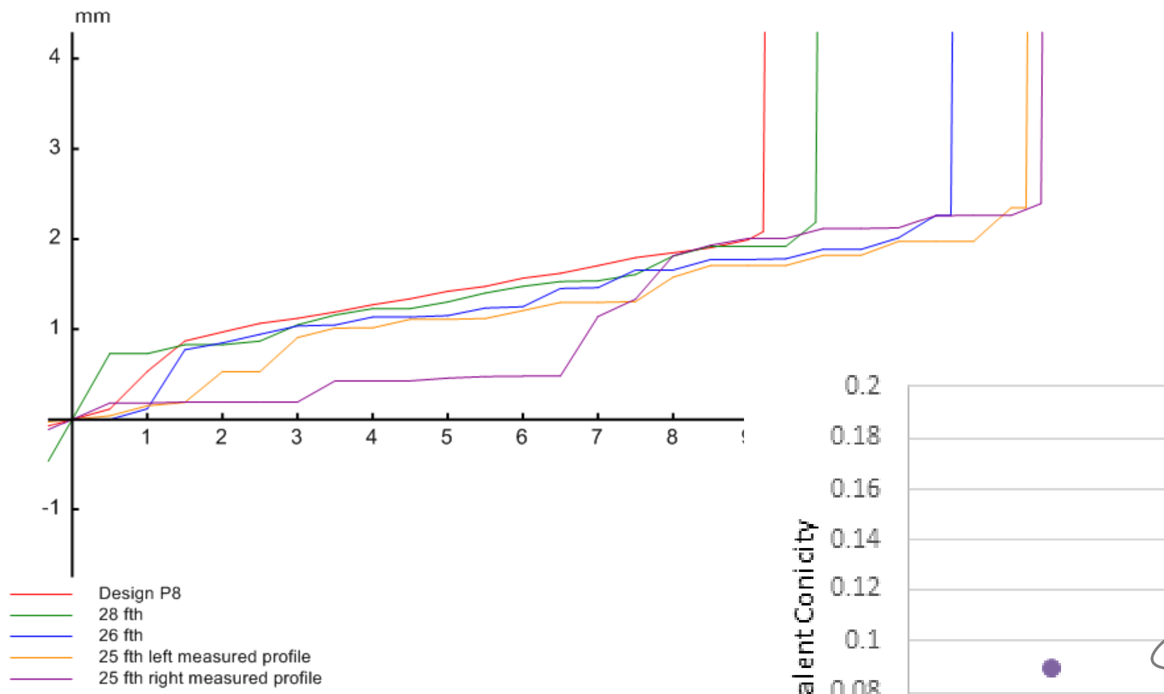
- **Bulk cement tank**

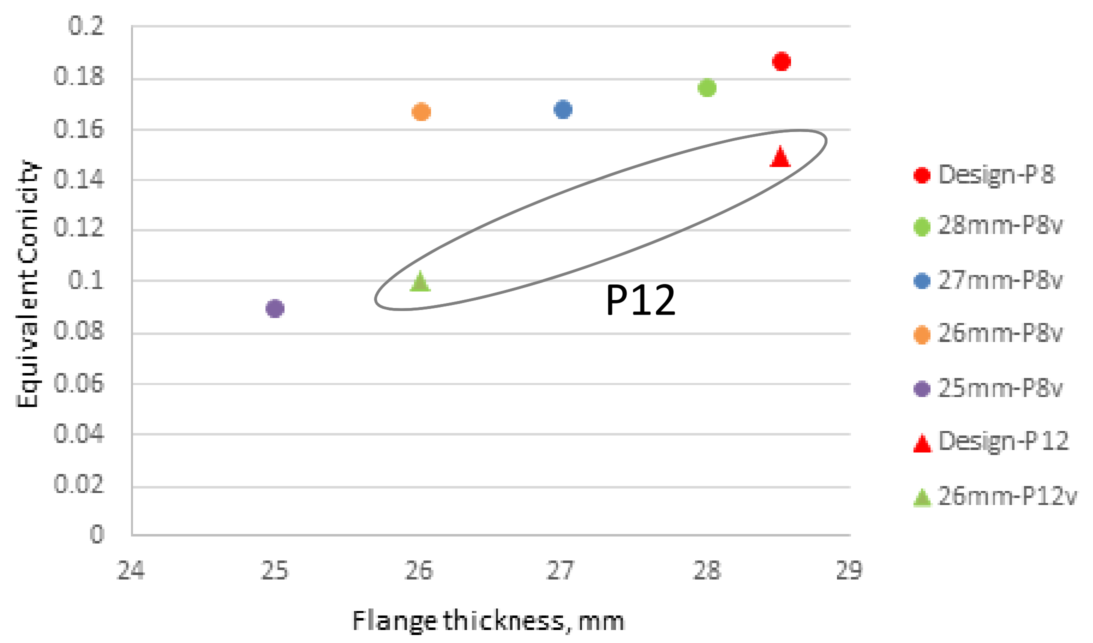
- Lafarge Cement – Earles Sdgs
- Hope Valley – Stockport
- Stockport – London via WCML slow lines

- P6 profiles

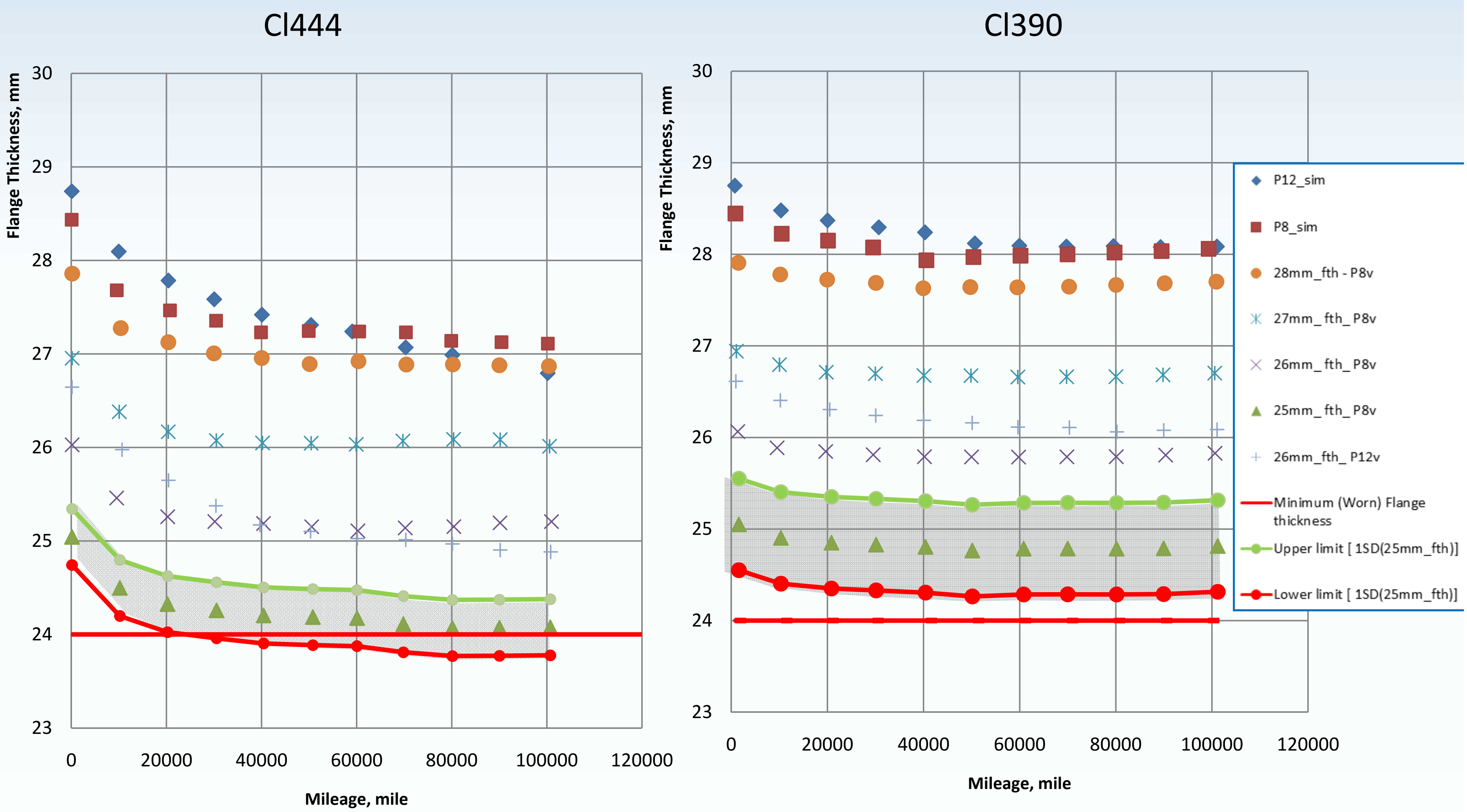
Contact Conditions

Rolling radius difference & equivalent conicity (56E1 rail)

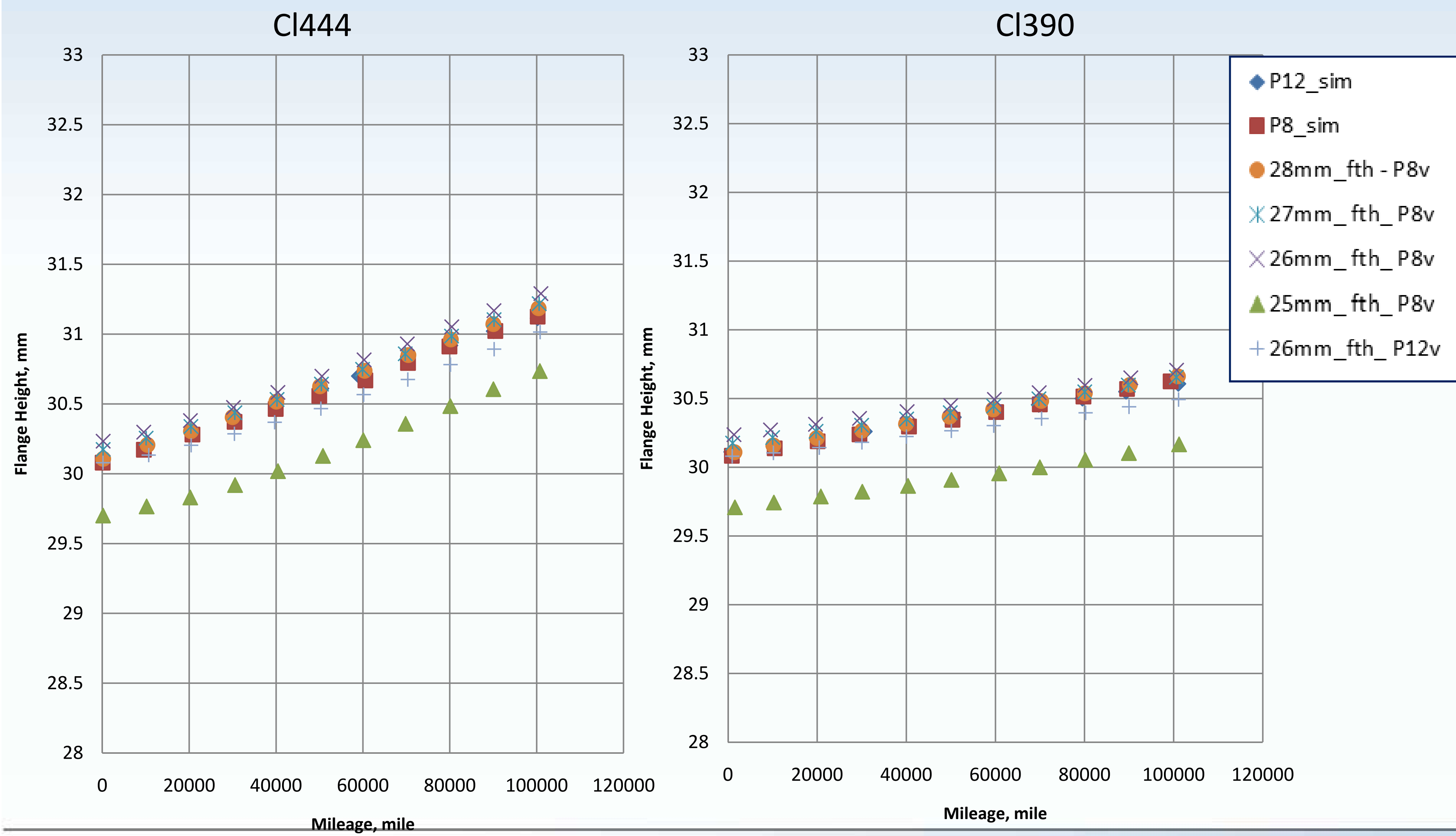




Flange Wear: P8, P12 Profiles

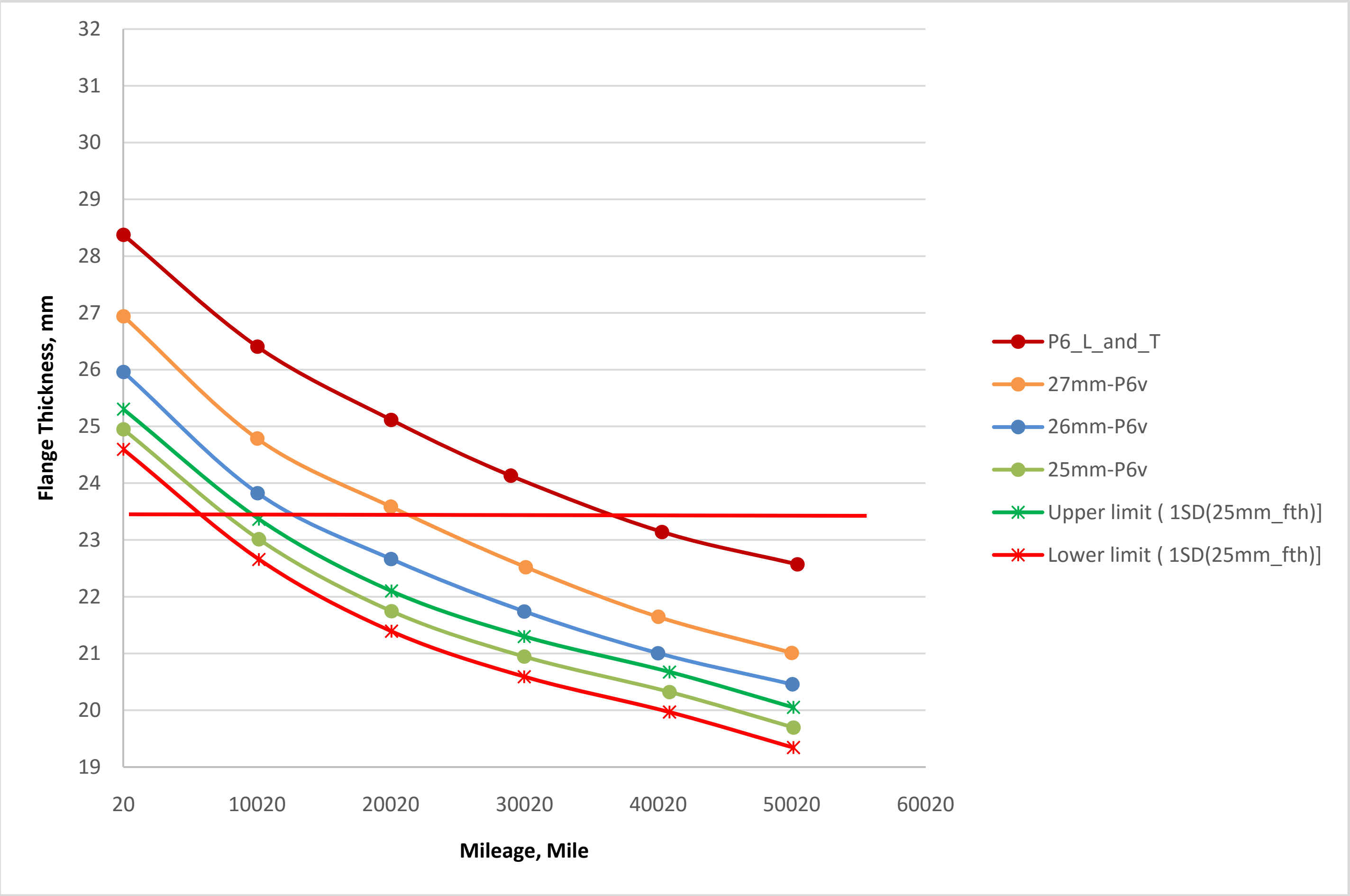


Tread Wear: P8, P12 Profiles



2-Axle Tank Wagon: P6 Profiles

Flange wear



Conclusions

Wear modelling:

- The WPDM is capable of providing good predictions of wheel wear to mileages >150,000 miles (Ft, Fh and profile shape)
- Further developments include:
  - Developing wear maps for different materials
  - Applying the same techniques to rails

Economic Tyre Turning:

- Thin flange profiles have almost a same wear pattern as full flange P6, P8 and P12 profiles
  - The tread wear rate was almost identical to design case profiles
  - The flange wear rate was marginally lower
- The wear modelling adds to a substantial body of evidence to support a change to RGS to allow ETT

Future WRI Research

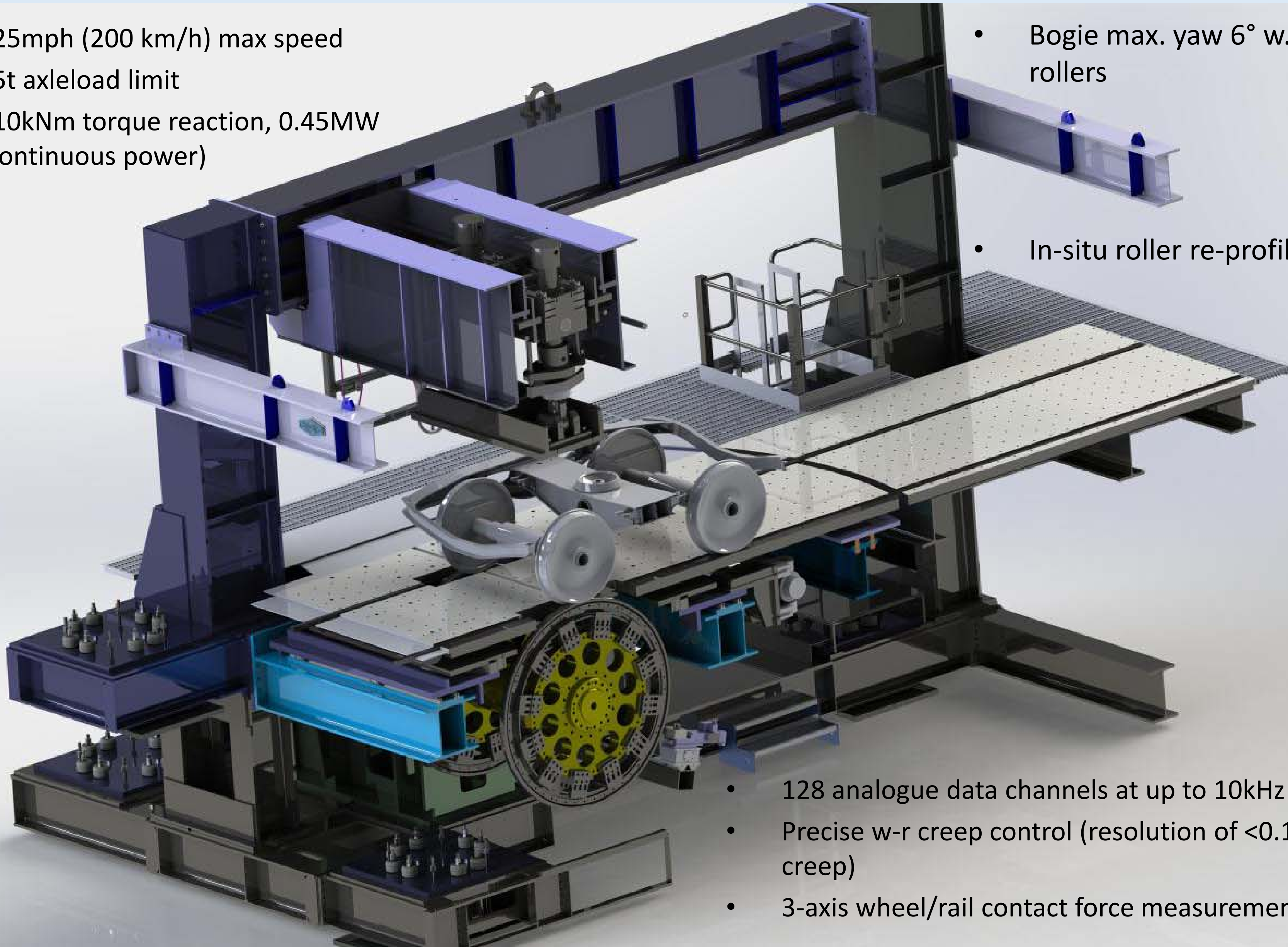
IRR Bogie Dynamics, Rolling Contact, Adhesion and Braking Rig

Research Test Rig Design

- 125mph (200 km/h) max speed
- 25t axleload limit
- 110kNm torque reaction, 0.45MW (continuous power)

- Bogie max. yaw 6° w.r.t. rollers

- In-situ roller re-profiling



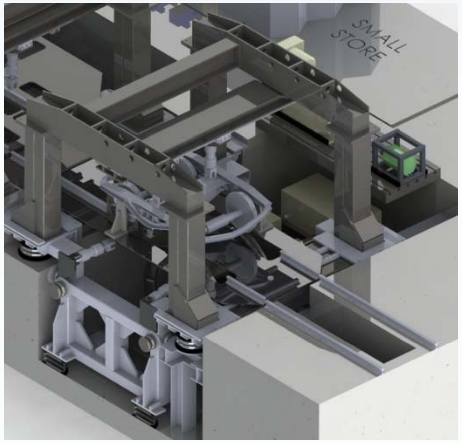
- 128 analogue data channels at up to 10kHz
- Precise w-r creep control (resolution of <0.1% creep)
- 3-axis wheel/rail contact force measurement

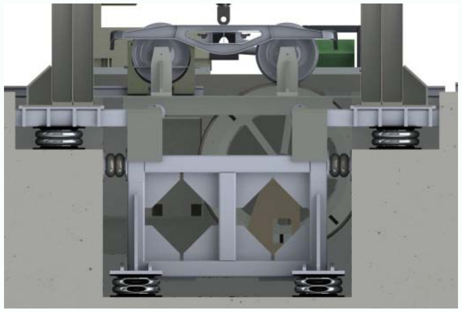
Research Test Rig Design

Research Test Rig Design

Potential Research Applications

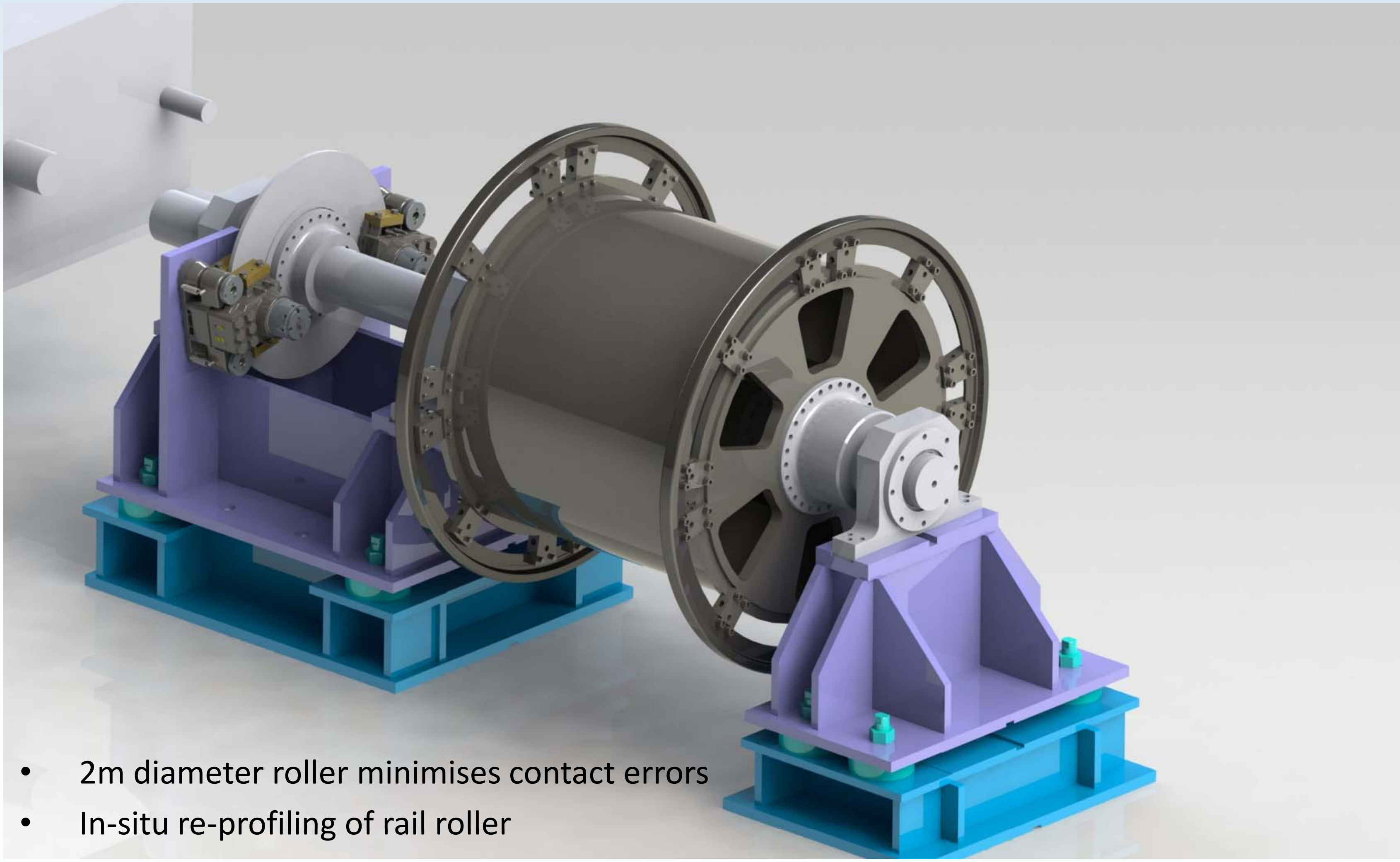
- Bogie dynamics
  - Wheelset yaw suspension optimisation
  - Vertical bogie dynamics; optimisation of primary and secondary suspension
  - Analysis of novel wheelset and bogie technologies
- Adhesion and braking research
  - Effect of wheel-rail contaminants on interface performance
  - Wheel-rail friction modifier evaluation
  - Traction and braking/WSP performance optimisation
  - Brake pad material development
- Wheel and rail profile design evaluation
  - Assessment of new & existing wheel and rail profiles
  - Wheelset life estimation and extension
  - Minimisation of contact forces – reductions in wear and RCF
- Materials research
  - 4 segment rail roller to include effects of rail bending and testing of different rail steels





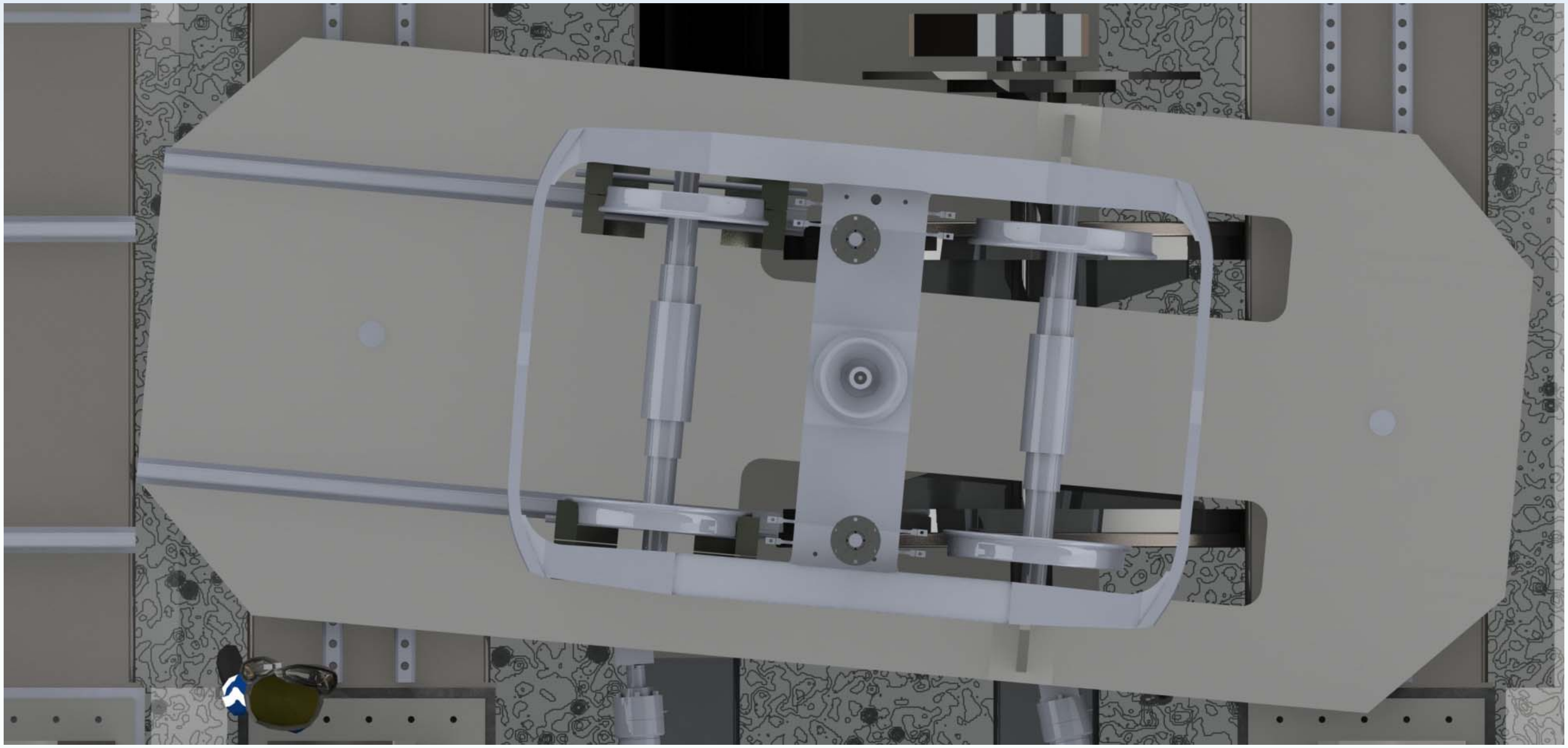
Thank You

Bogie Rolling Contact Rig



- 2m diameter roller minimises contact errors
- In-situ re-profiling of rail roller

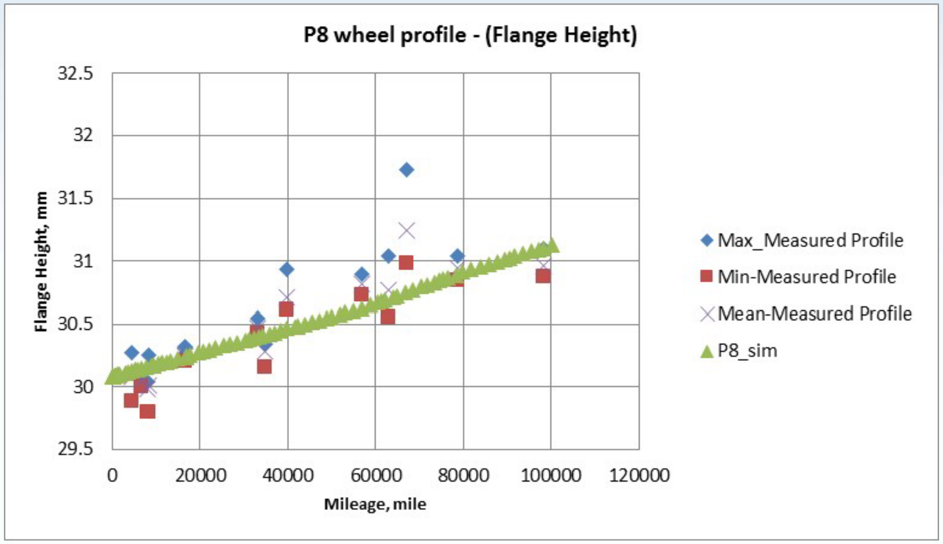
Bogie Rolling Contact Rig

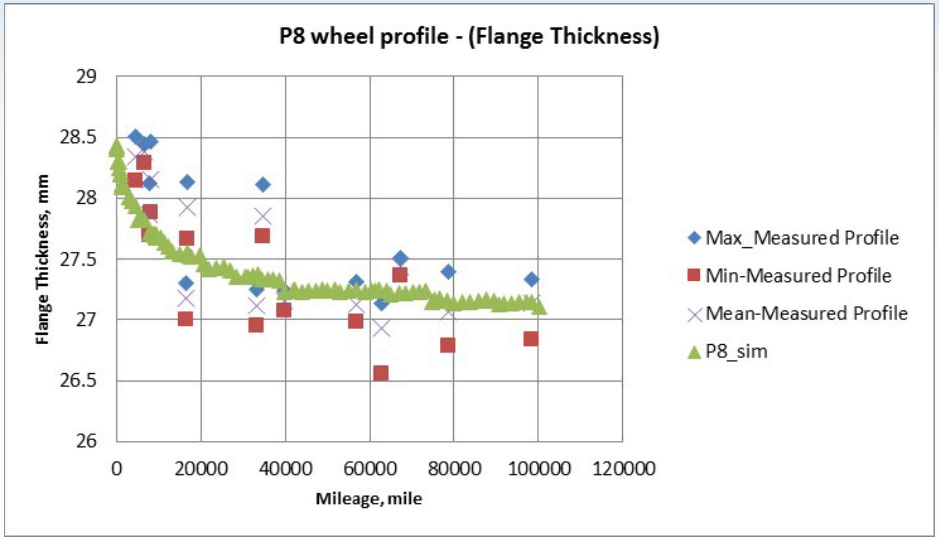


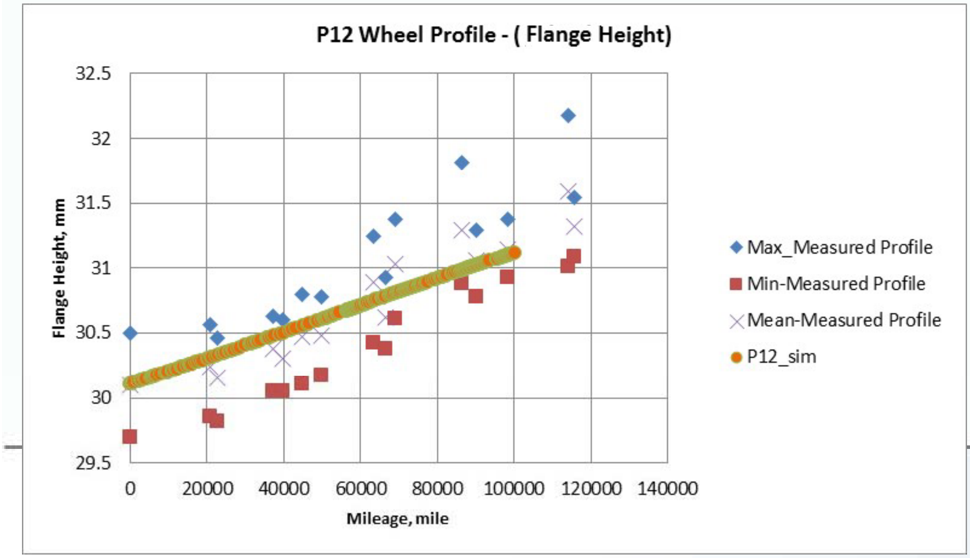
- Bogie max. yaw 6° w.r.t. rollers

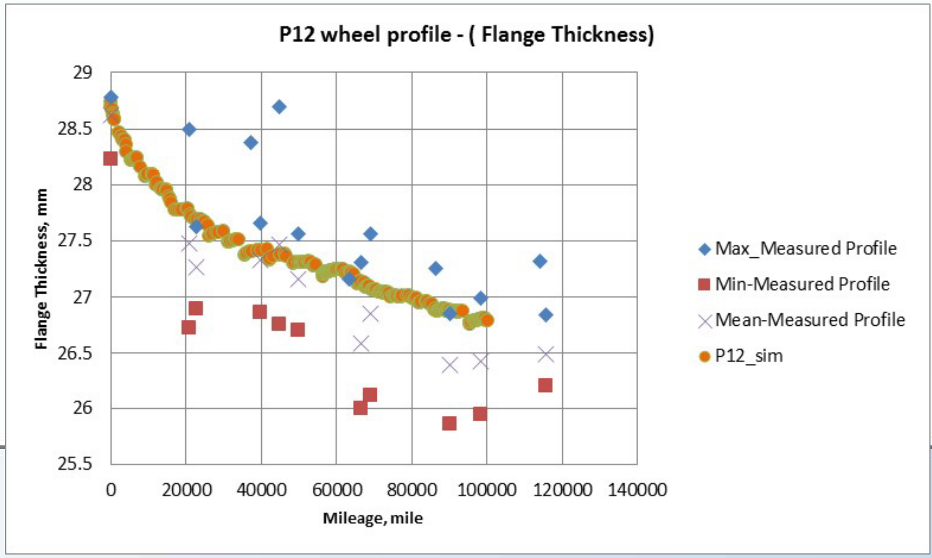
Measured Profile Comparison

Wear model validation: Class 444





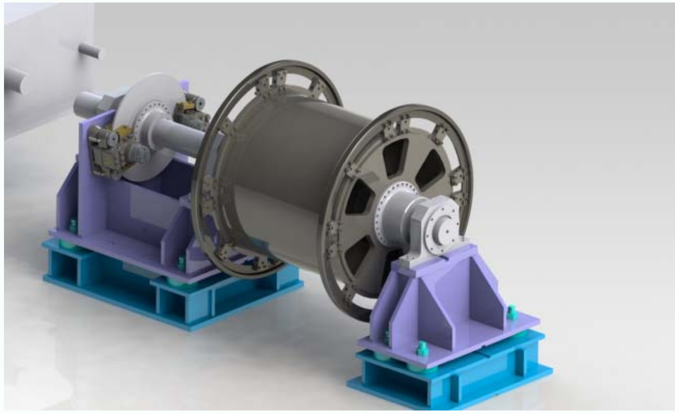


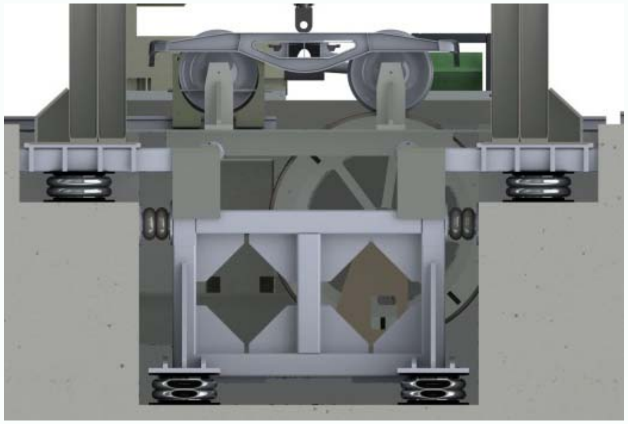


3-Axis Force Measurement

– Wheel rail interface load and measurement range specification (**Values per wheel**)

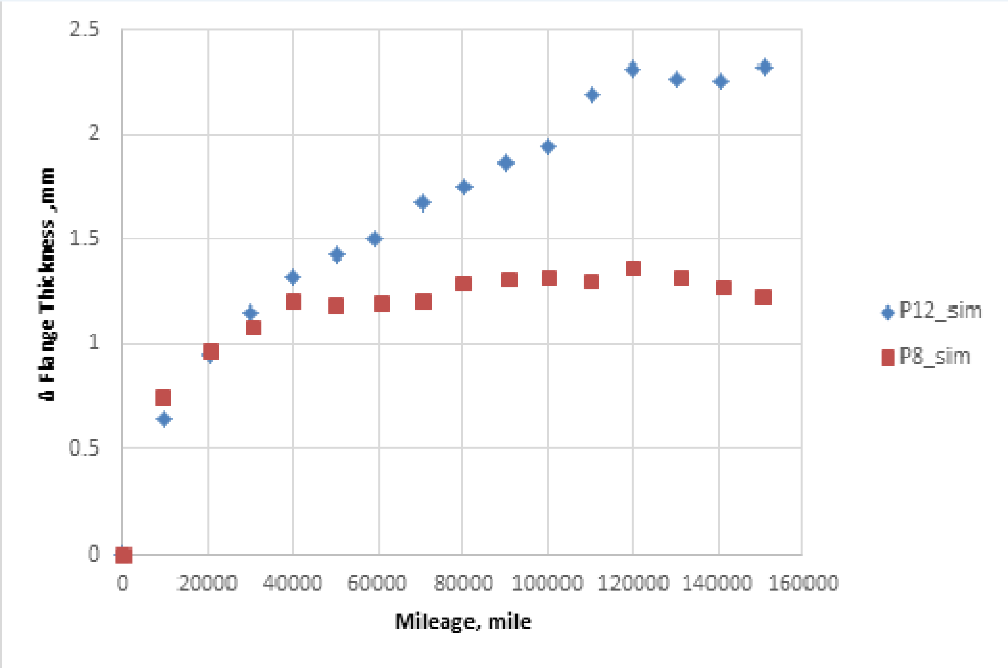
	Lateral	Vertical	Longitudinal
Measurement range (kN)	-100 to 100	0 to 150	-100 to 100
Accuracy (N)	±100	±100	±100
Resolution (N)	10N	10N	10N

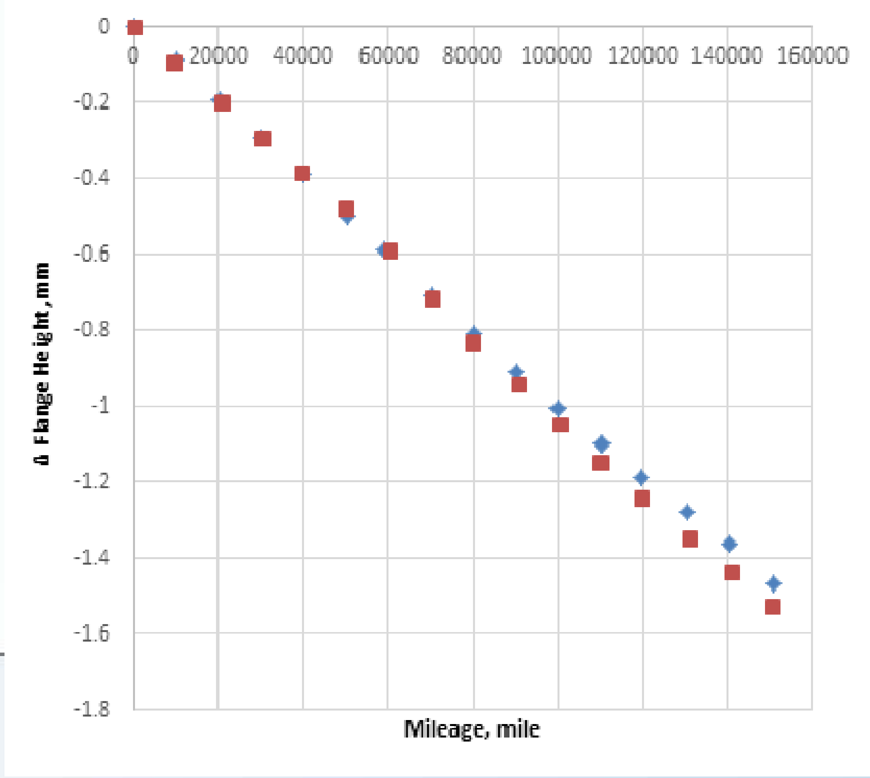




Comparison P8:P12

Class 444





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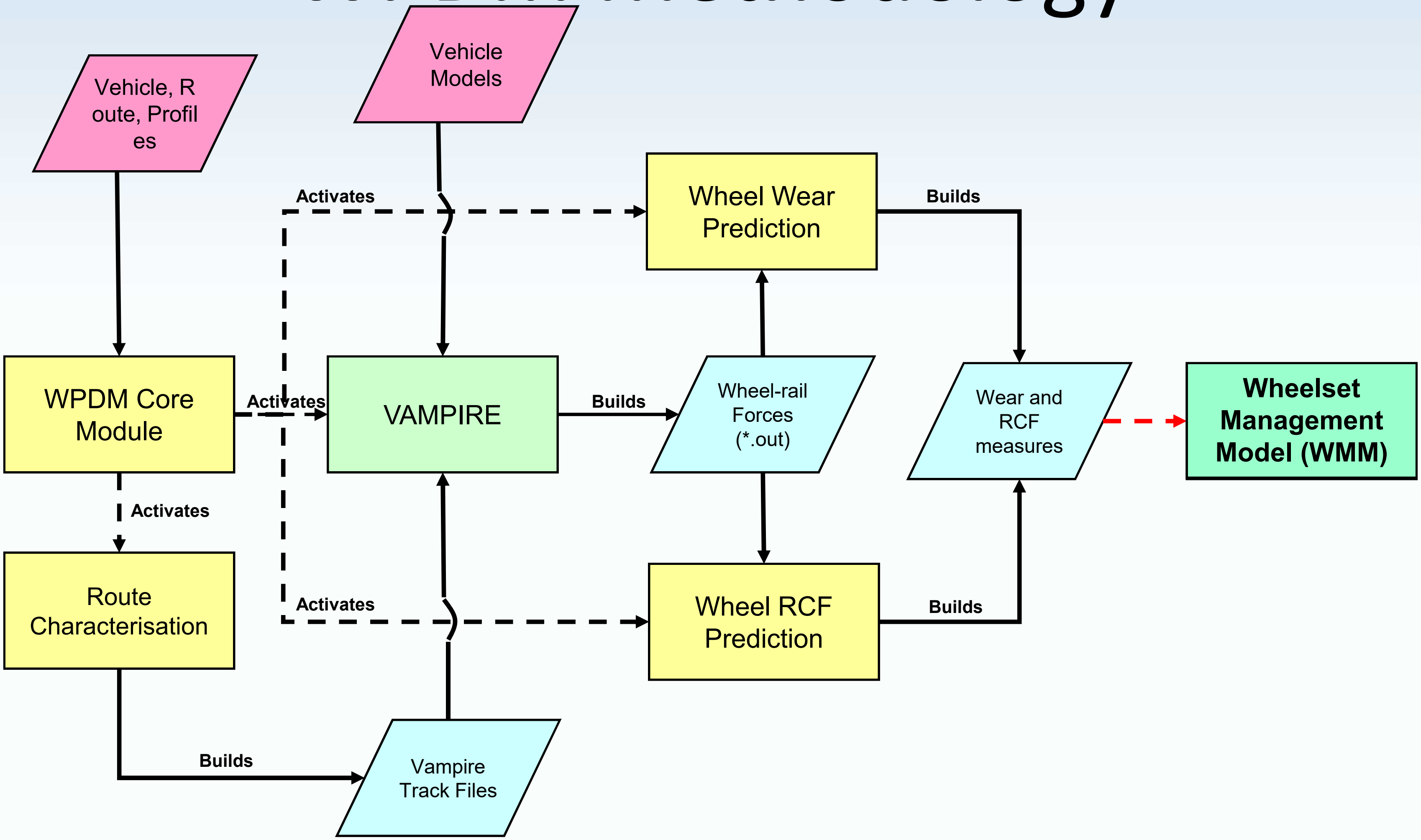
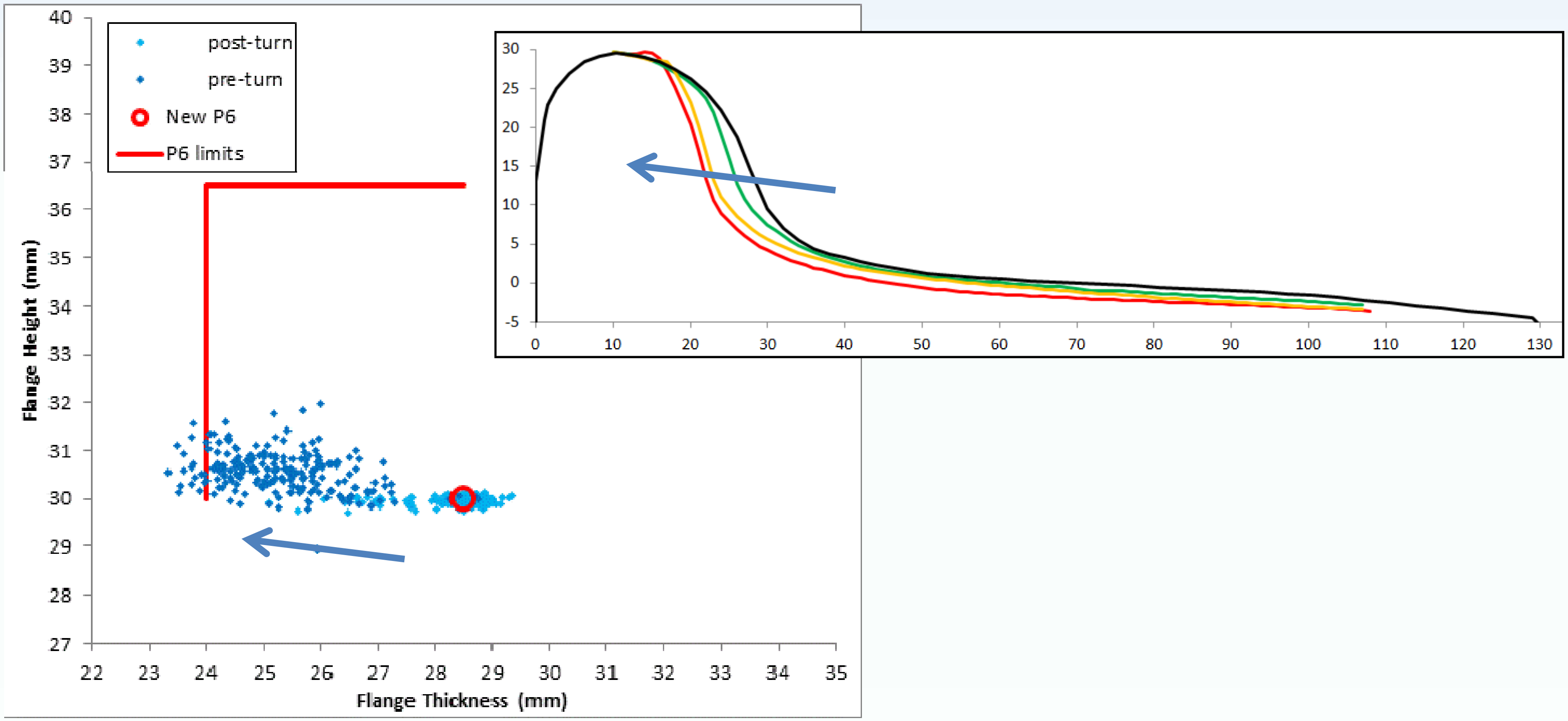
WPDM Methodology



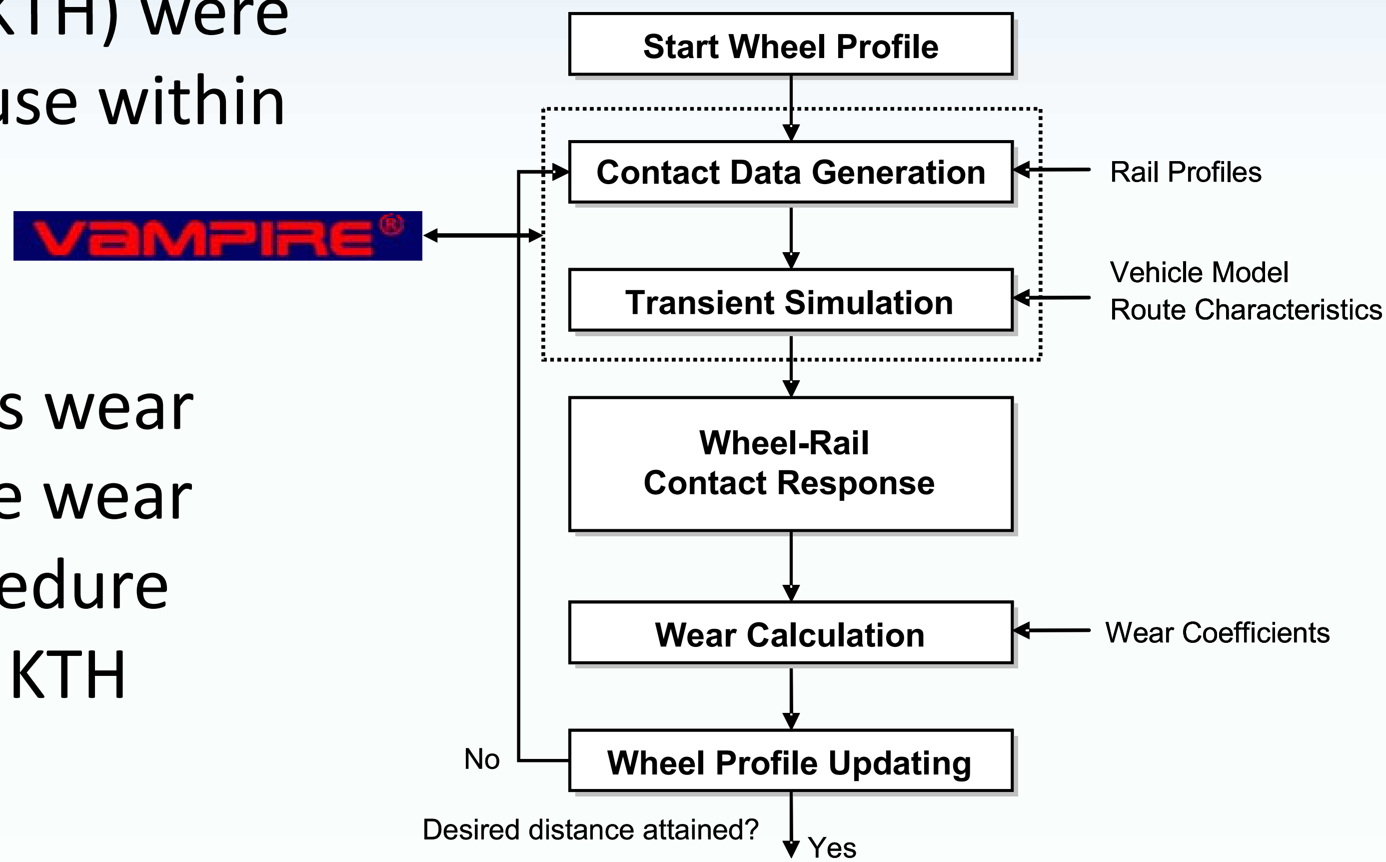
2-Axle Tank Wagon

- 2-axle pedestal suspension, P6 profile, disc brakes



Wheel Wear Prediction (1)

- Tools developed during T547 (MMU/KTH) were modified for use within the WPDM



- Uses Archard's wear model and the wear iteration procedure developed by KTH (Sweden)