A simple method to determine conicity for managing wheel/rail performance

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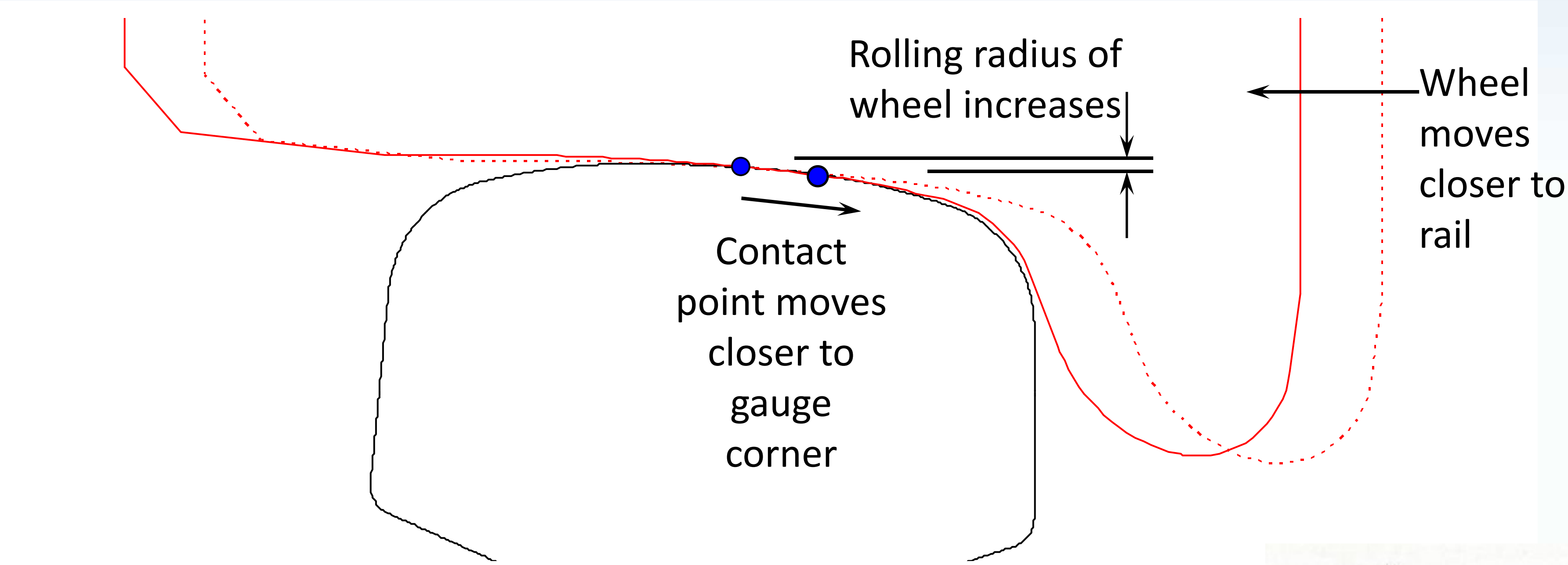
Overview

- What is equivalent conicity and why should we worry about it?
- How is it calculated?
- An alternative approach
  - Less accurate, simpler, but more useable?

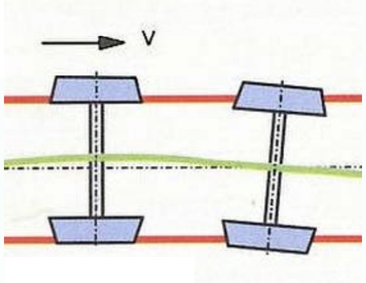
What is equivalent conicity?

- Equivalent conicity is a function of wheel and rail shapes
  - Quantifies the geometric interaction of the profiles
  - Requires detailed knowledge of shapes of wheels and rails
- It is at the heart of the wheel/rail interface
  - The infrastructure manager cannot manage equivalent conicity without knowing the shapes of the wheels running over the rails
  - The train operator cannot manage equivalent conicity without knowing the shapes of the rails on the routes operated over

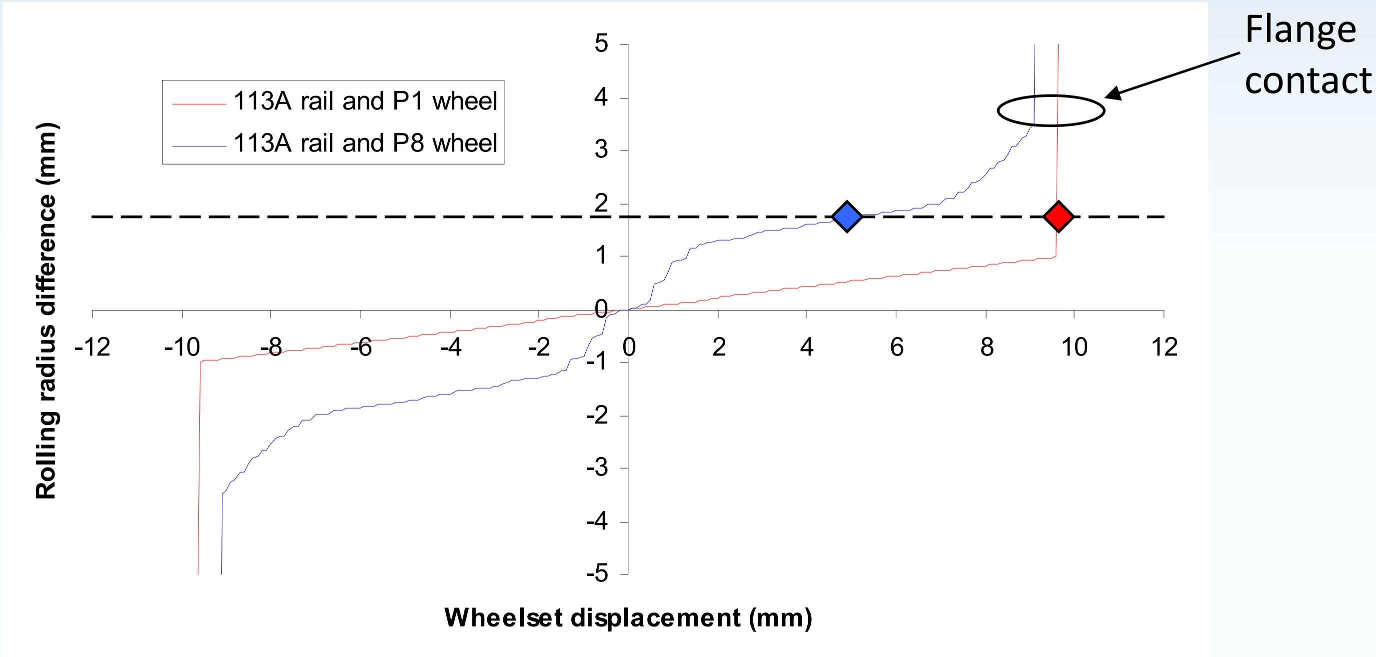
What is equivalent conicity?



- Increase in rolling radius of left wheel as wheel moves closer to rail causes wheelset to ‘yaw’ and ‘steer’ around a curve
  - Left wheel is large than right and will roll further



What is equivalent conicity?
The rolling radius difference graph

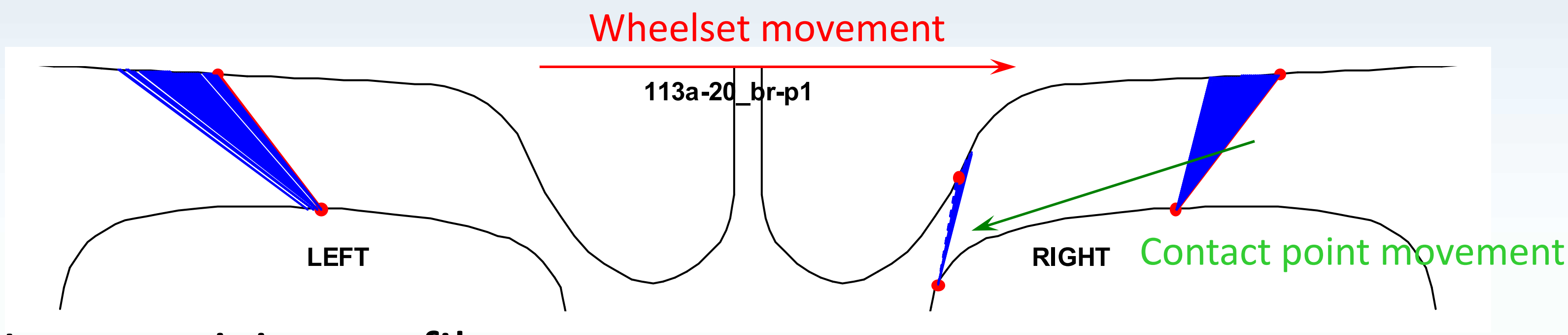


Rolling radius difference graph describes how the wheel rolling radius changes as the wheel moves over the rail

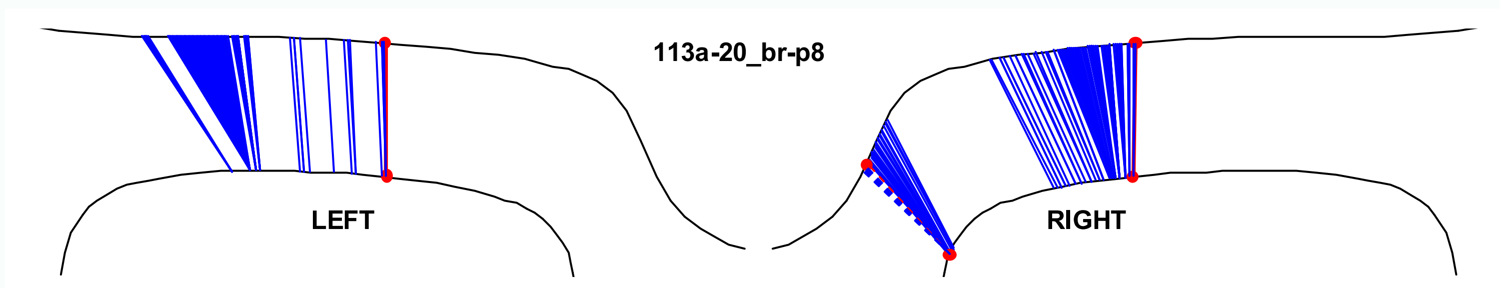
Equivalent conicity is defined from the gradient of the line

- P8 wheel on 113A rail has a steeper gradient, higher equivalent conicity, than P1 wheel

What is equivalent conicity? Wheel/rail contact positions



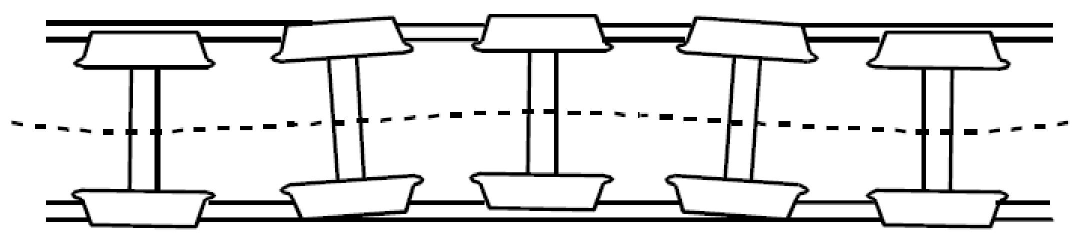
- Low conicity profile
  - Very small changes in contact position



- Moderate conicity profile:
  - Contact across wider area

Benefits and disbenefits

- Equivalent conicity is good!
  - It is required to allow wheels to steer around curves
  - Higher conicity allows vehicles to be guided round sharper curves without flange contact- reduced wear
- Equivalent conicity is bad!
  - High conicity leads to instability on straight track and shallow curves
    - Small perturbations in the track cause the wheelsets to oscillate



Why we should avoid high conicity

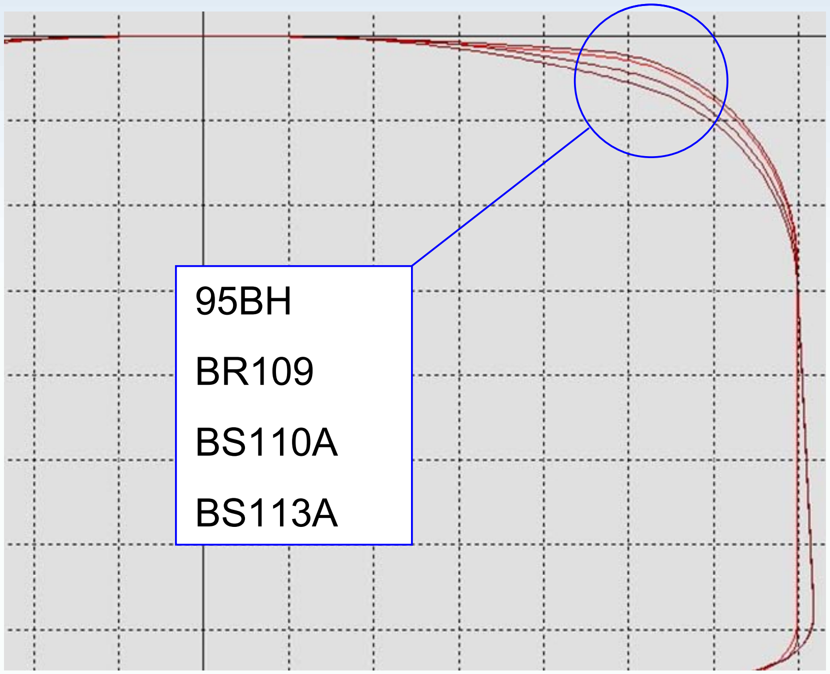
Why we should avoid high conicity

Why we should avoid high conicity

- Derailment of a 4-wheel wagon due to ‘hunting’
  - 45mph
  - Worn wheels
  - Before vehicle dynamics and stability full appreciated
  - Instability in some vehicles occurring at speeds as low as 30mph
- Derailed wagon struck by a passenger train on adjacent line

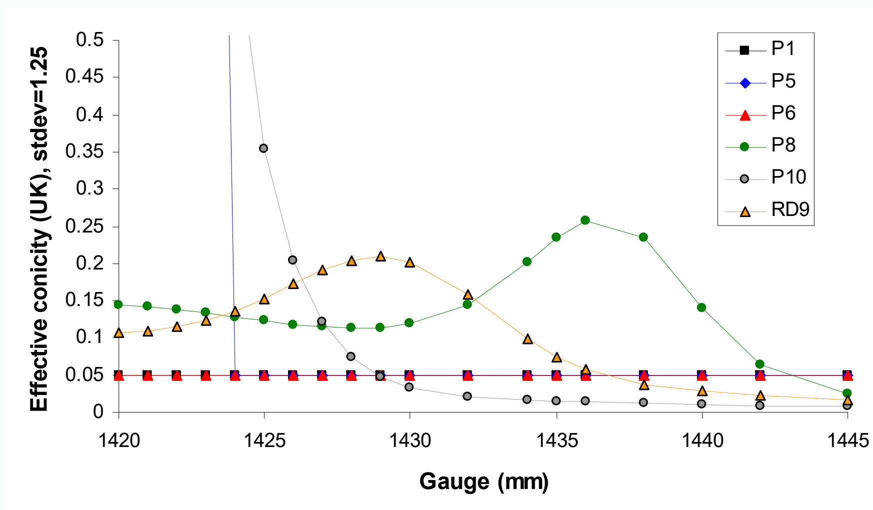
What affects equivalent conicity?

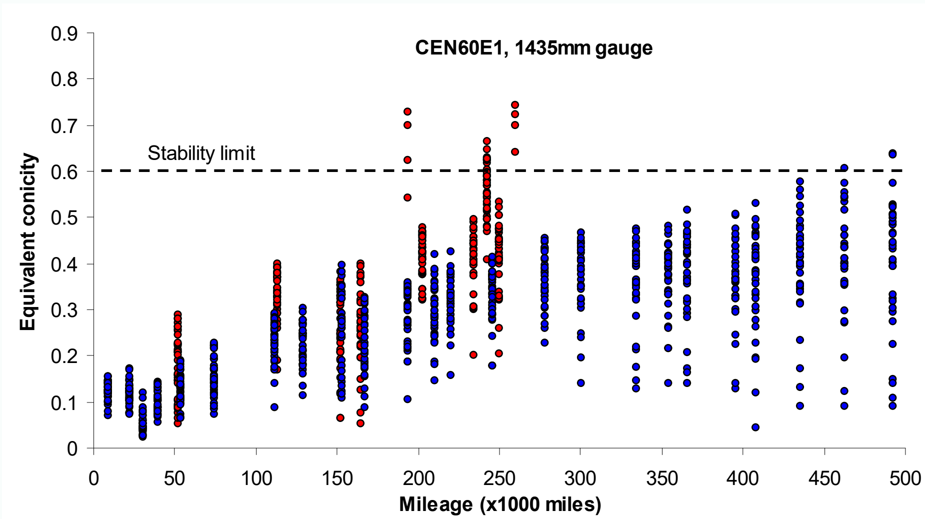
- 1. Rail profile
  - Profiles with high gauge corners have higher conicity
  - Ground rail profiles have lower conicity
- 2. Track gauge
  - Tighter gauge increases conicity
    - Contact is forced onto gauge corner earlier



What affects equivalent conicity?

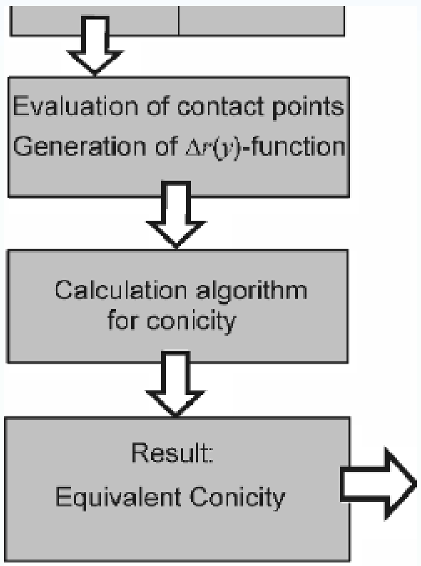
- 3. Wheel profile
  - Different design wheel profiles
  - Wear causes conicity to increase

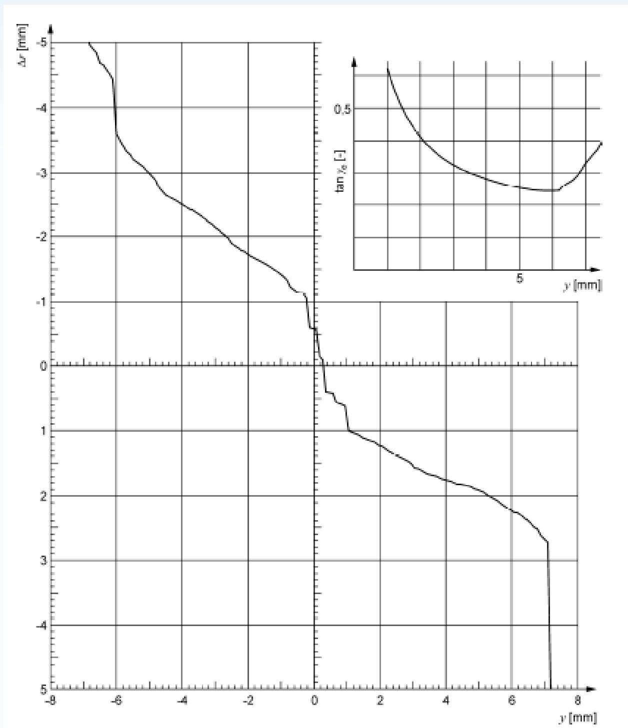


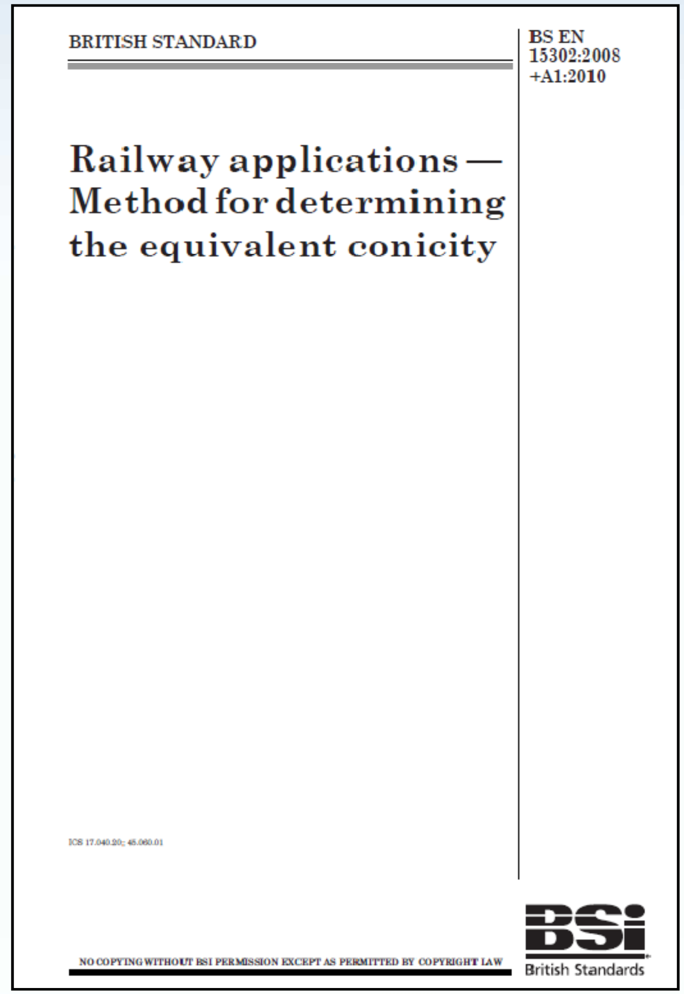


How do we calculate equivalent conicity?

- Procedure is specified in EN 15302






BRITISH STANDARD

BS EN 15302:2008 +A1:2010

Railway applications — Method for determining the equivalent conicity

ICS 17.040.20; 45.060.01

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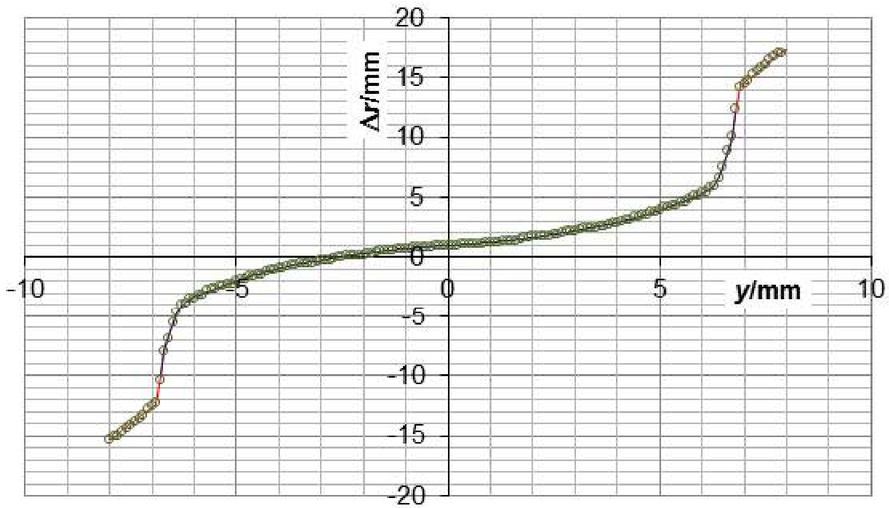
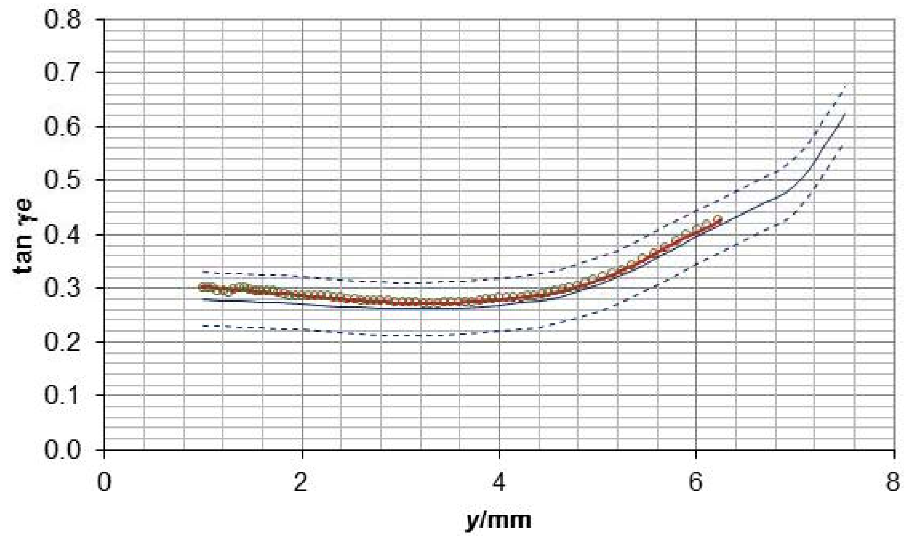
BSi British Standards

- This must be performed for each wheel/rail/track gauge combination

How do we calculate equivalent conicity?

- For a given displacement the equivalent conicity is the conicity of a cone which has the same wavelength
- The ENprovides ‘answers’ for reference profiles
  - Users can check their calculation methodology





What does the TSI say?

- For **design case**, assessment is relatively easy
  - Single calculation for design rail profile and track gauge, for a specified set of wheel profiles
  - 'Standard' rail profiles comply with the TSI *a priori*, so no assessment is needed

7.7.17.3.bis Equivalent conicity (4.2.4.5)

P cases

(1) Instead of point 4.2.4.5.(3) design values of track gauge, rail head profile and rail inclination for plain line shall be selected to ensure that the equivalent conicity limits set out in Table 32 are not exceeded

Table 32

Equivalent conicity design limit values

	Wheel profile	
Speed range [km/h]	S1002, GV1/40	EPS
v ≤ 60	Assessment not required	
60 < v ≤ 200	0,25	0,30
200 < v ≤ 280	0,20	0,20
v > 280	0,10	0,15

(2) Instead of point 4.2.4.5. (4) the following wheelsets shall be modelled passing over the designed track conditions (simulated by calculation according to EN 15302:2008+A1:2010):

(a) S 1002 as defined in Annex C of EN 13715:2006+A1:2010 with SR1.

(b) S 1002 as defined in Annex C of EN 13715:2006+A1:2010 with SR2.

(c) GV 1/40 as defined in Annex B of EN 13715:2006+A1:2010 with SR1.

(d) GV 1/40 as defined in Annex B of EN 13715:2006+A1:2010 with SR2.

What does the TSI say?

- For **<u>in-service</u>** conicity assessment is more complicated
  - Assessment required in response to allegation of problems
    - Is the track or the train the main contributor?
  - Assessment methodology is complicated
  - 'Joint investigation' with train operator to identify problem
- No easy method of monitoring or pro-active control of conicity

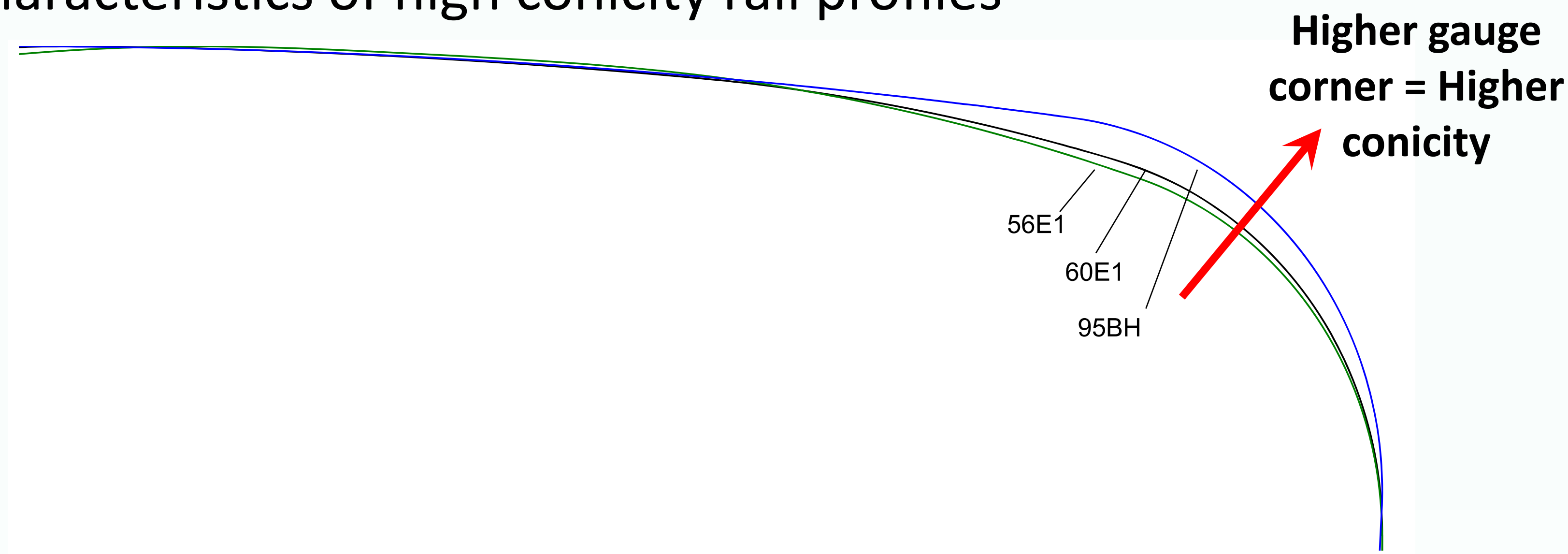
(2) If ride instability is reported, the railway undertaking and the Infrastructure Manager shall localise the section of the line in a joint investigation.

(3) The railway undertaking shall measure the wheel profiles and the front-to-front distance (distance of active faces) of the wheelsets in question. The equivalent conicity shall be calculated using the calculation scenarios provided in clause 6.2.3.6 in order to check if compliance with the maximum equivalent conicity the vehicle was designed and tested for is met. If it is not the case, the wheel profiles have to be corrected.

(4) If the wheelset conicity complies with the maximum equivalent conicity the vehicle was designed and tested for, a joint investigation by the railway undertaking and the infrastructure manager shall be undertaken to determine the characteristics reason for the instability.

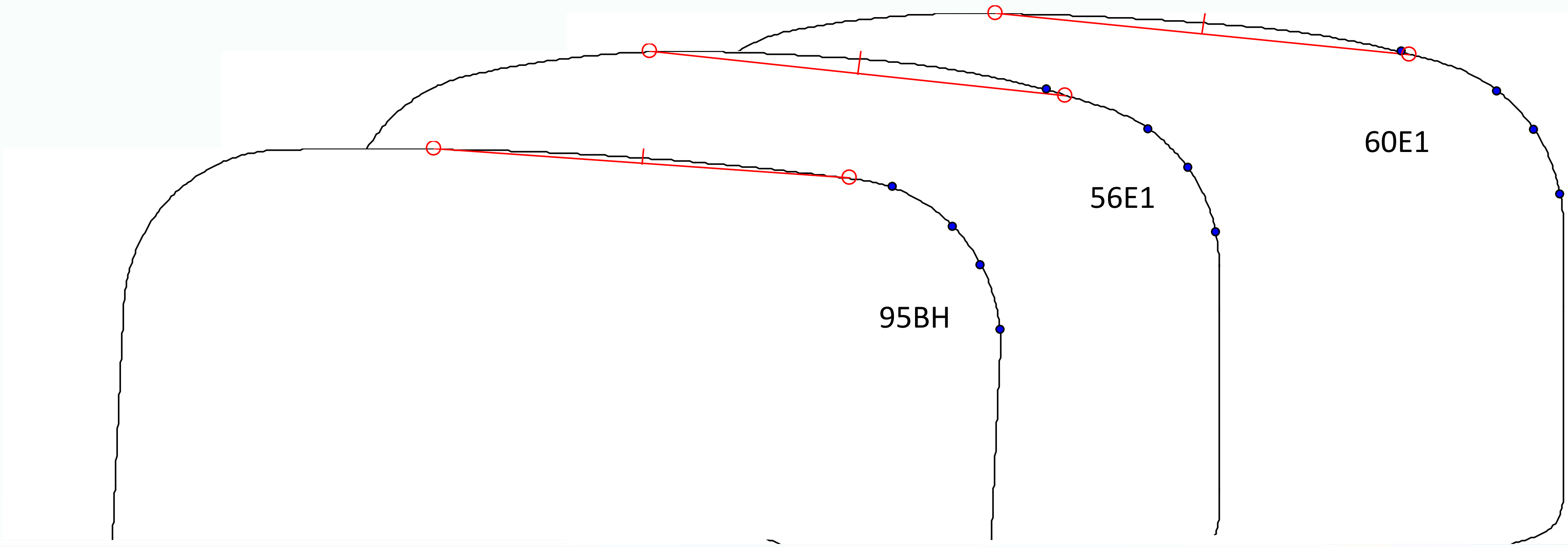
‘Quick’ conicity methods

- A method is needed to identify wheel and rail profiles which could lead to high conicity
  - Allow infrastructure managers and train operators to pro-actively manage equivalent conicity
- Characteristics of high conicity rail profiles



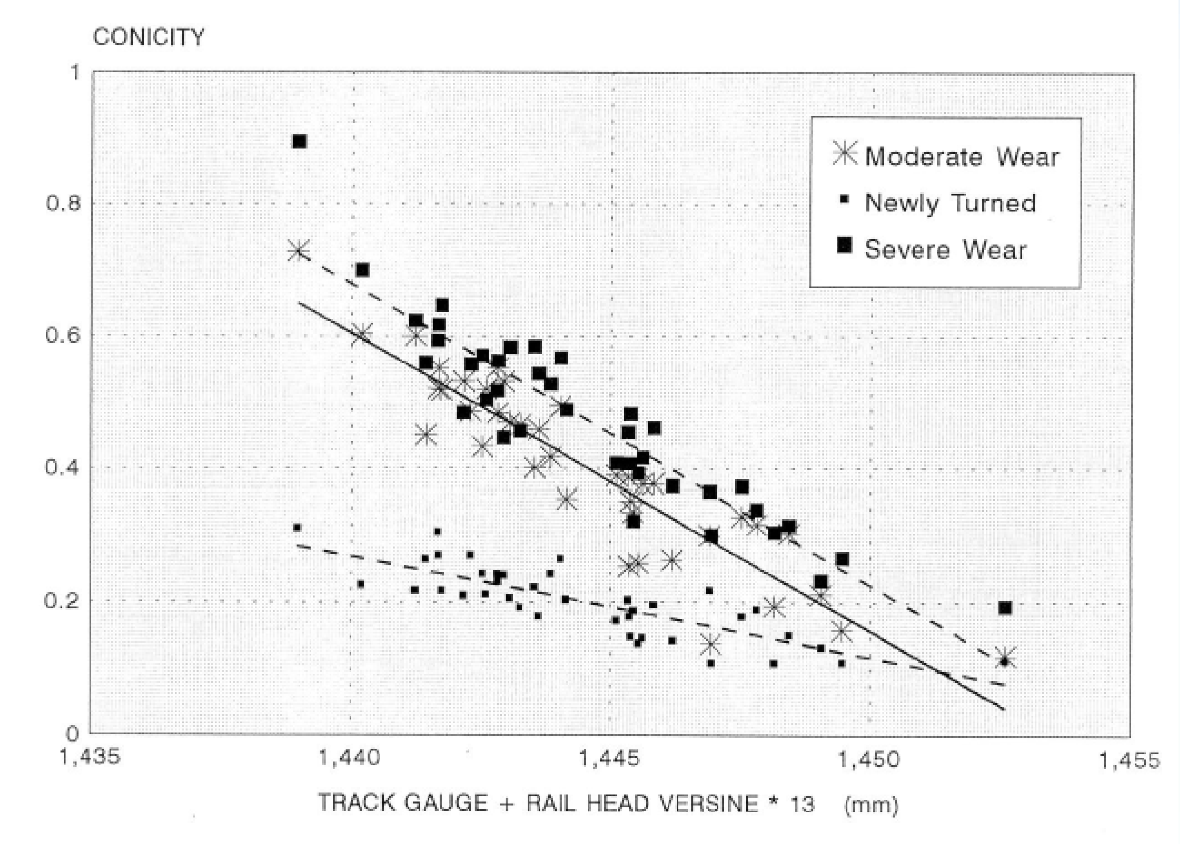
Quick conicity method- 1

- Method proposed in 1990s, but never developed further
- Versine of curvature of rail profile
  - Smaller versine indicates higher gauge corner, higher conicity



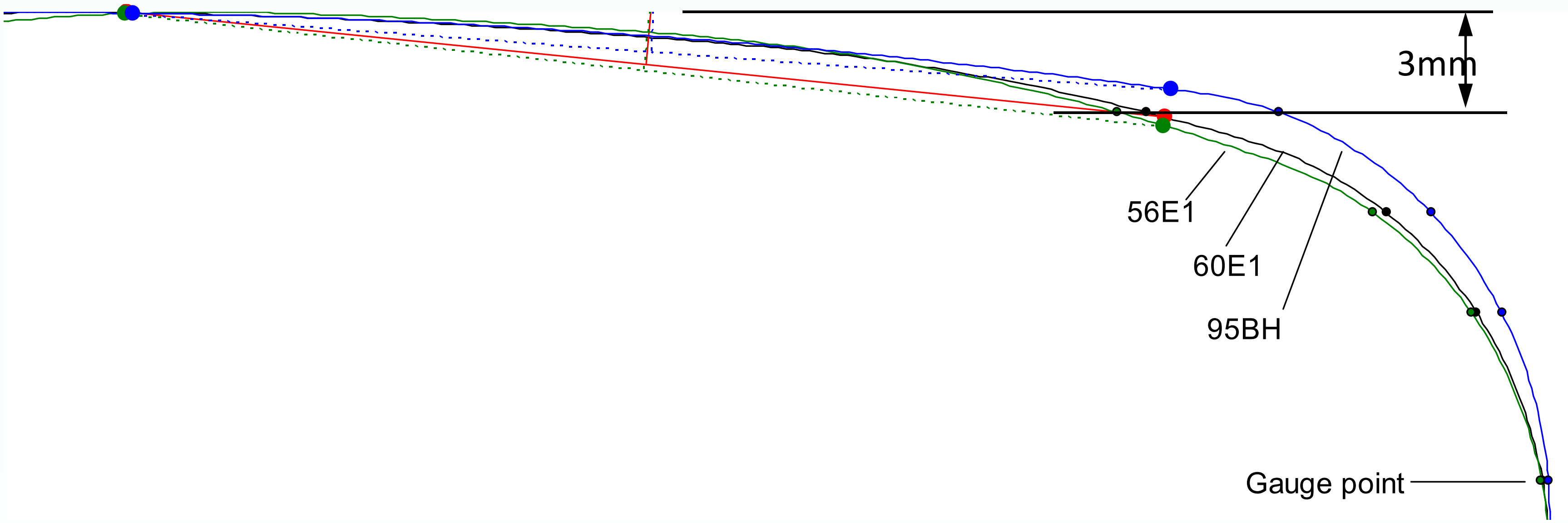
Quick conicity method- 1: Results

- Conicity estimate combined track gauge and versine measurement
- Inverse relationship: lower ‘quick conicity’ measure = higher equivalent conicity



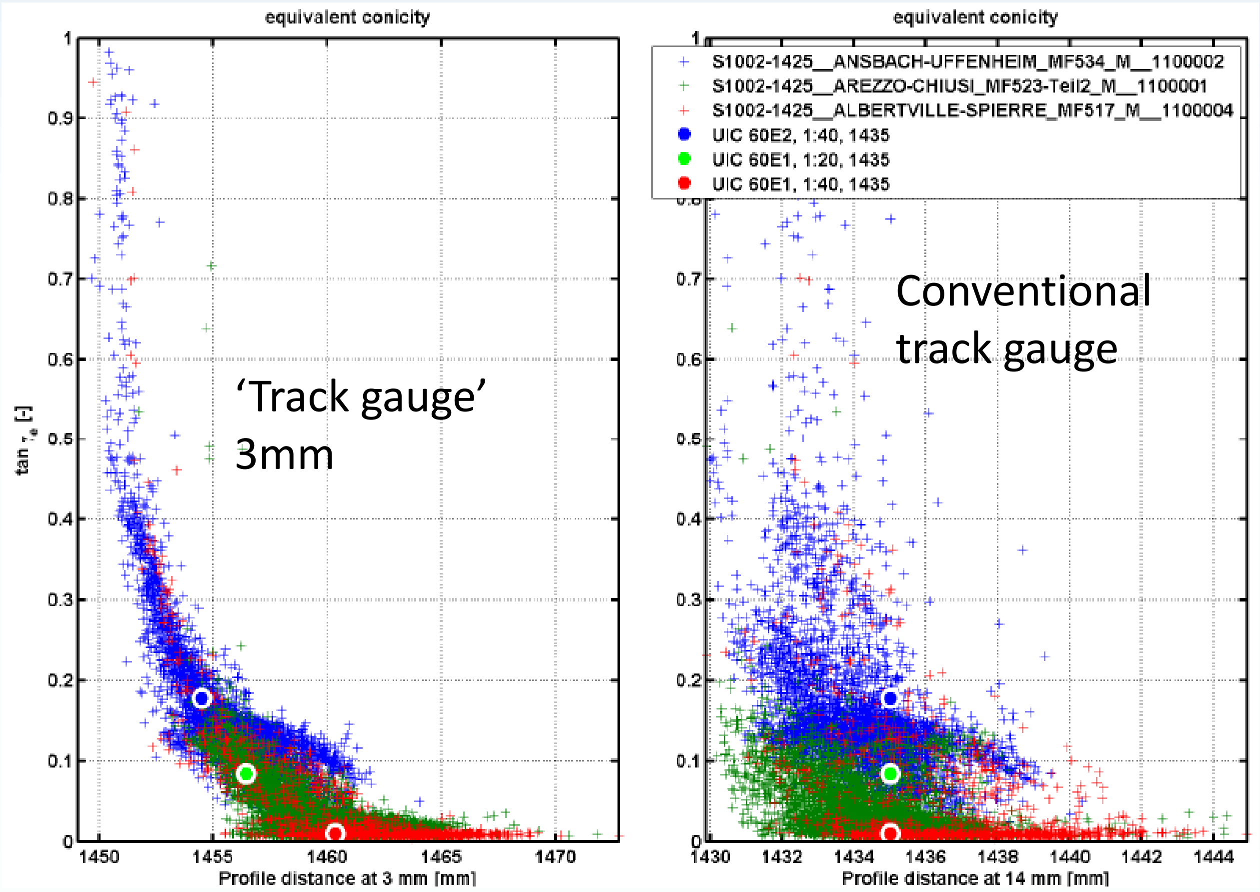
Quick conicity method-2
Alternative track gauge

- Rail profiles with higher gauge corners usually give higher equivalent conicity
  - The gauge corner contacts further into the wheel flange root
  - These rail profiles also have smaller gauge measurements (3mm below the crown)
- At 14mm below the rail crown there is very little difference between the profile shapes



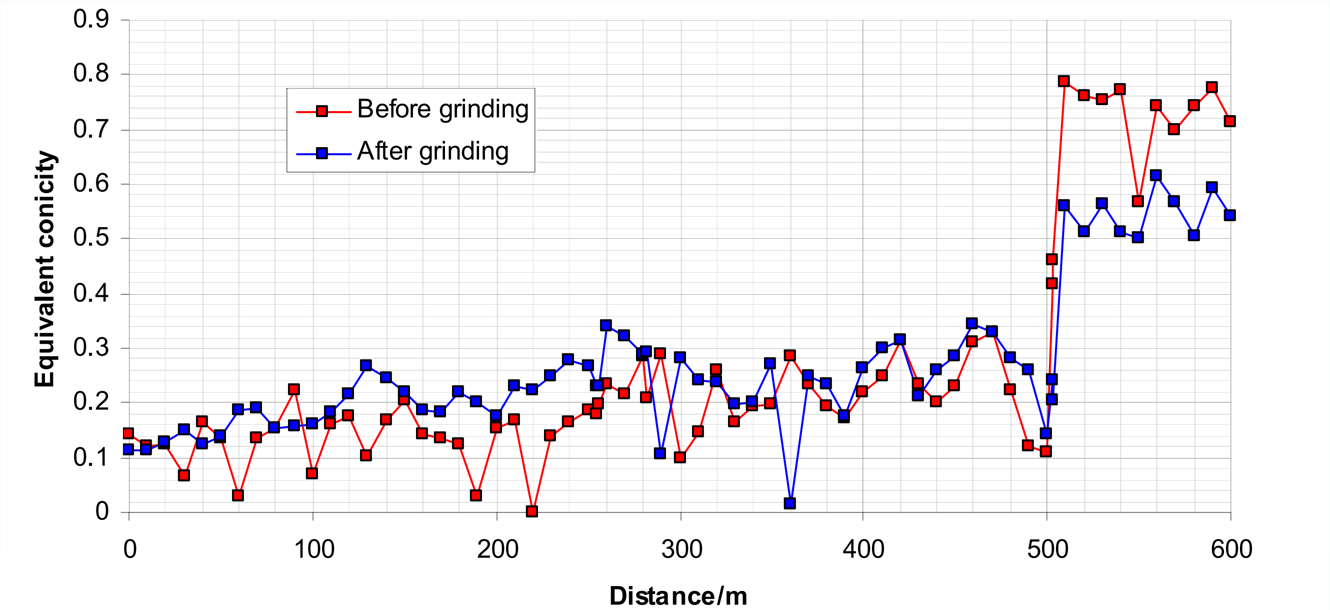
‘Quick’ conicity

- Data from DynoTrain project
  - A ‘Quick conicity’ method for infrastructure?



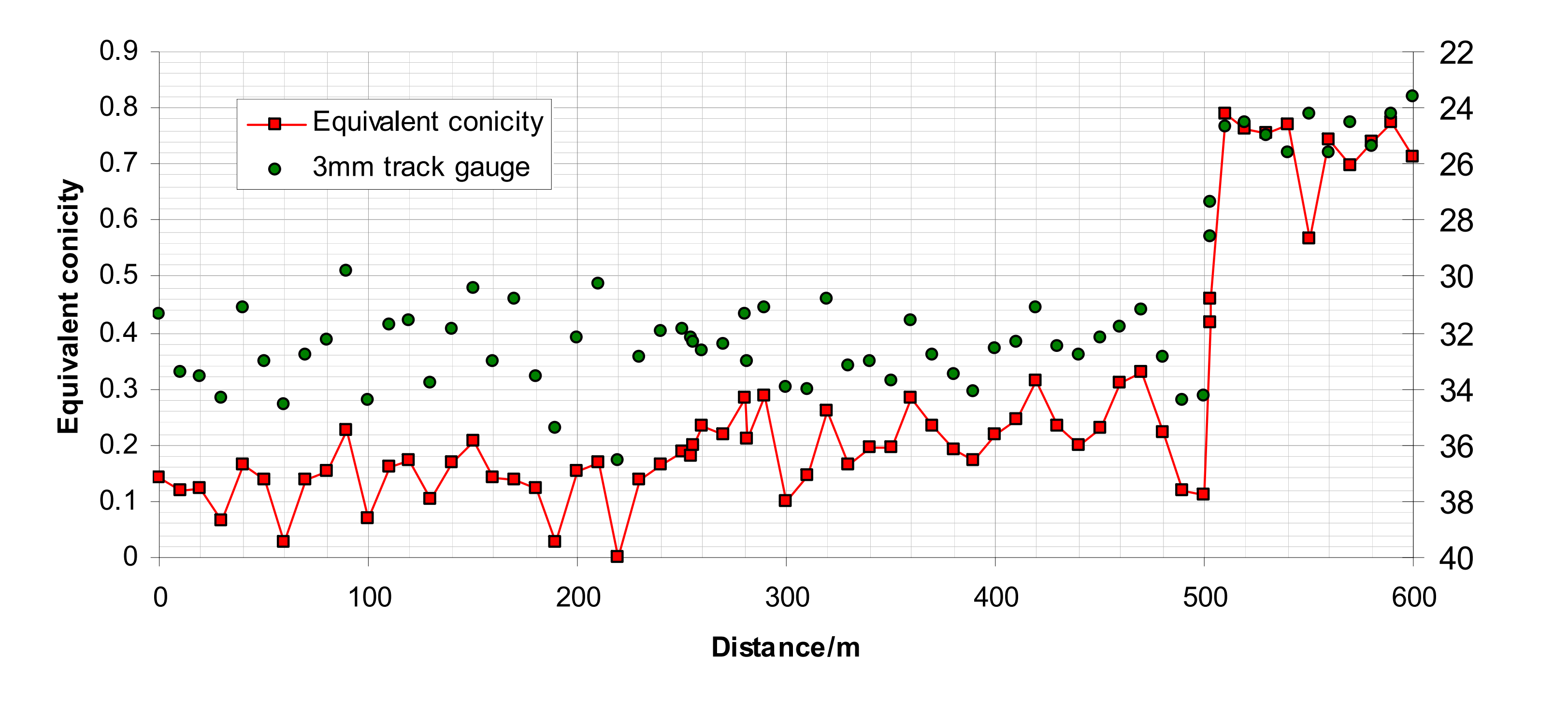
Quick conicity test site #1

- Site on WCML site with instability issues
  - Miniprof measurements of rails
- Showed area of high conicity for worn wheels
  - Rail grinding reduced conicity enough to control conicity



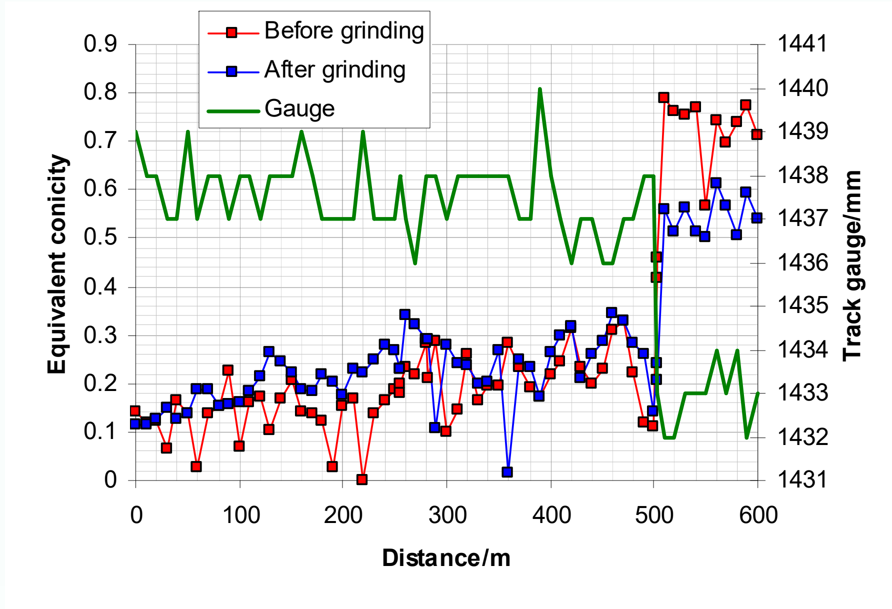
Quick conicity evaluation- #1

- Quick conicity method correctly picks the step change in conicity



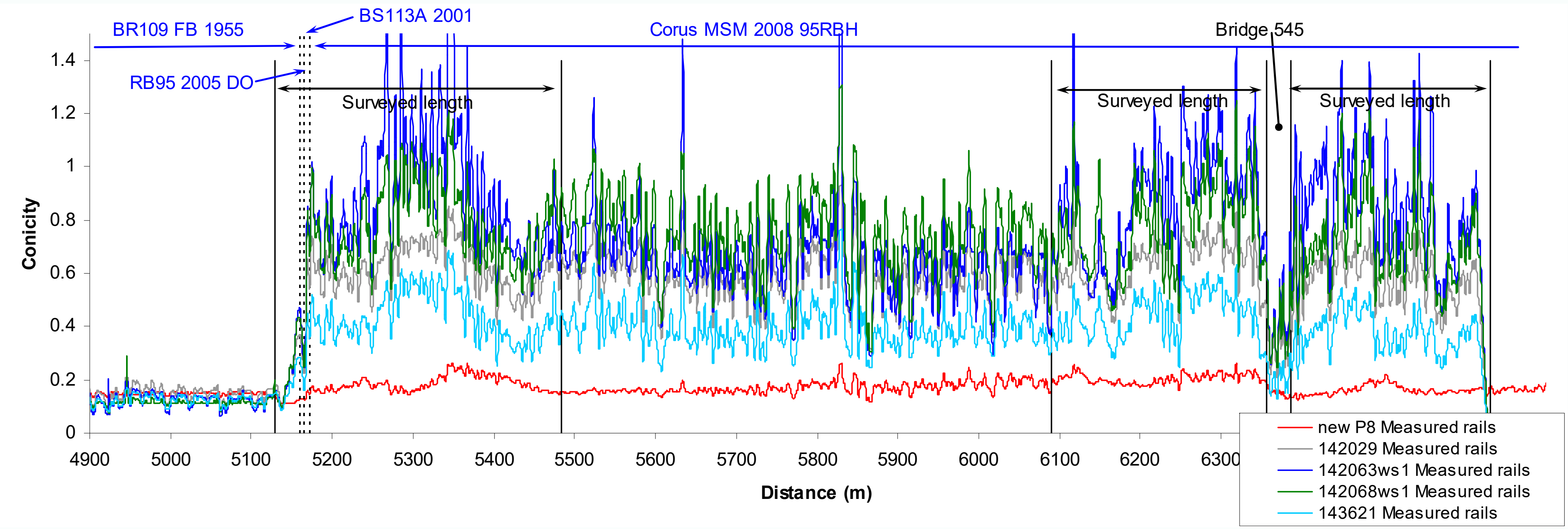
Conicity profiles

- All measurement positions correctly pick the step change in conicity
  - But conicity is dominated by step change in track gauge rather than rail profile

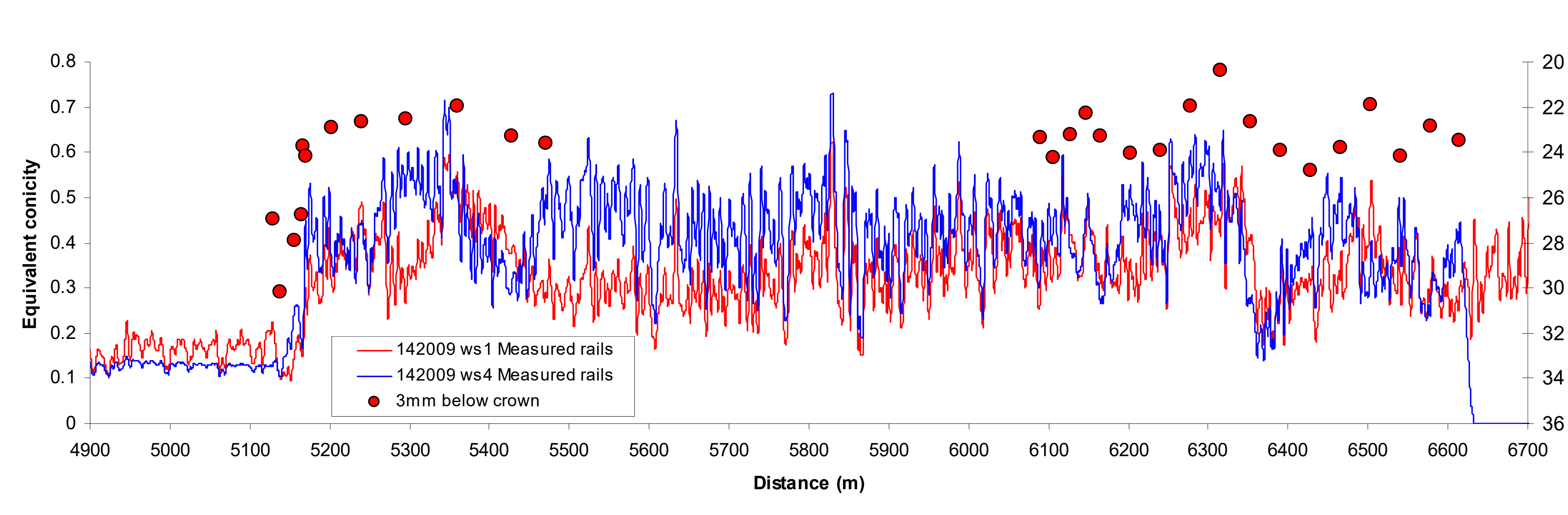


Quick conicity test site #2

- Calculation from measured profiles & gauge showed very high conicities for some wheels



Quick conicity test site #2

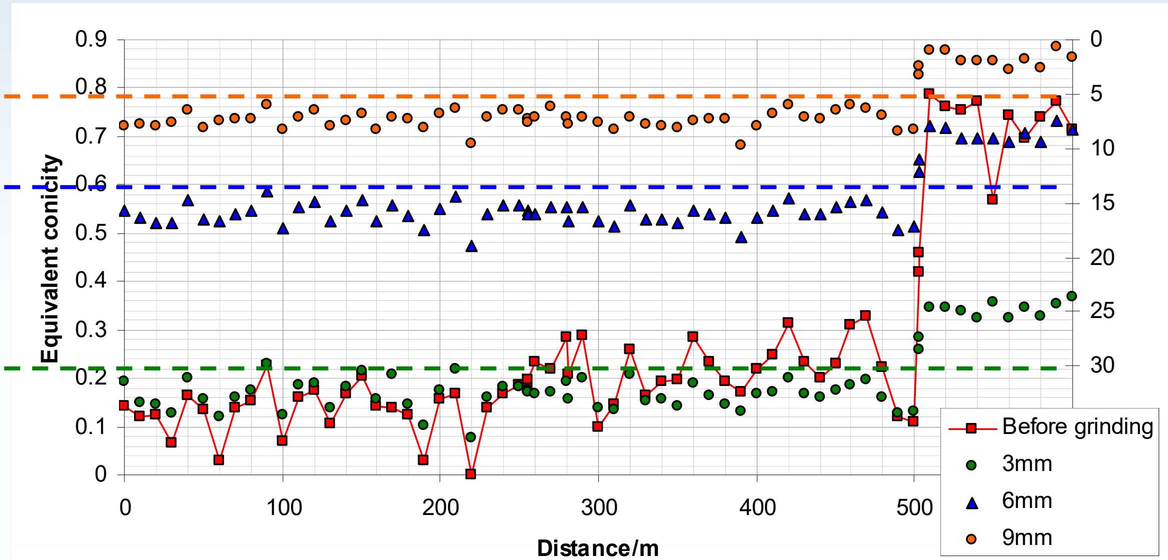


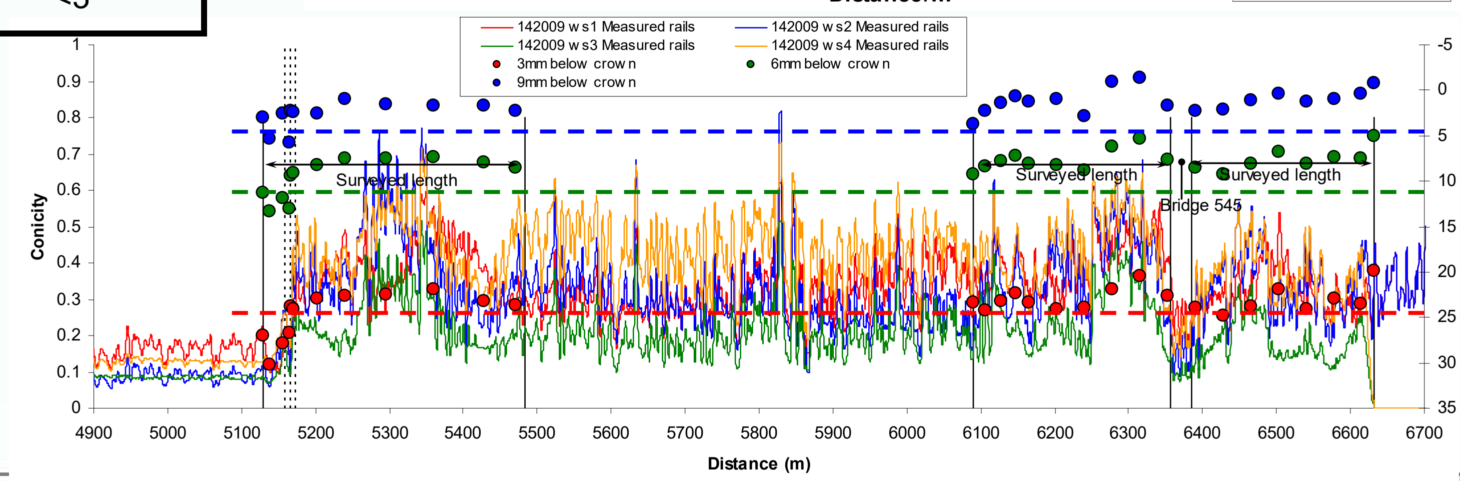
- Quick conicity results follow calculated equivalent conicity well
- High conicity driven by rail profile (new 95BH rail)
  - Rail grinding was the solution

Acceptable 'Quick' conicity limits?

Limits of stability are consistent between the two sites

Gauge measure	Quick conicity limit
3mm	<28
6mm	<12
9mm	<3



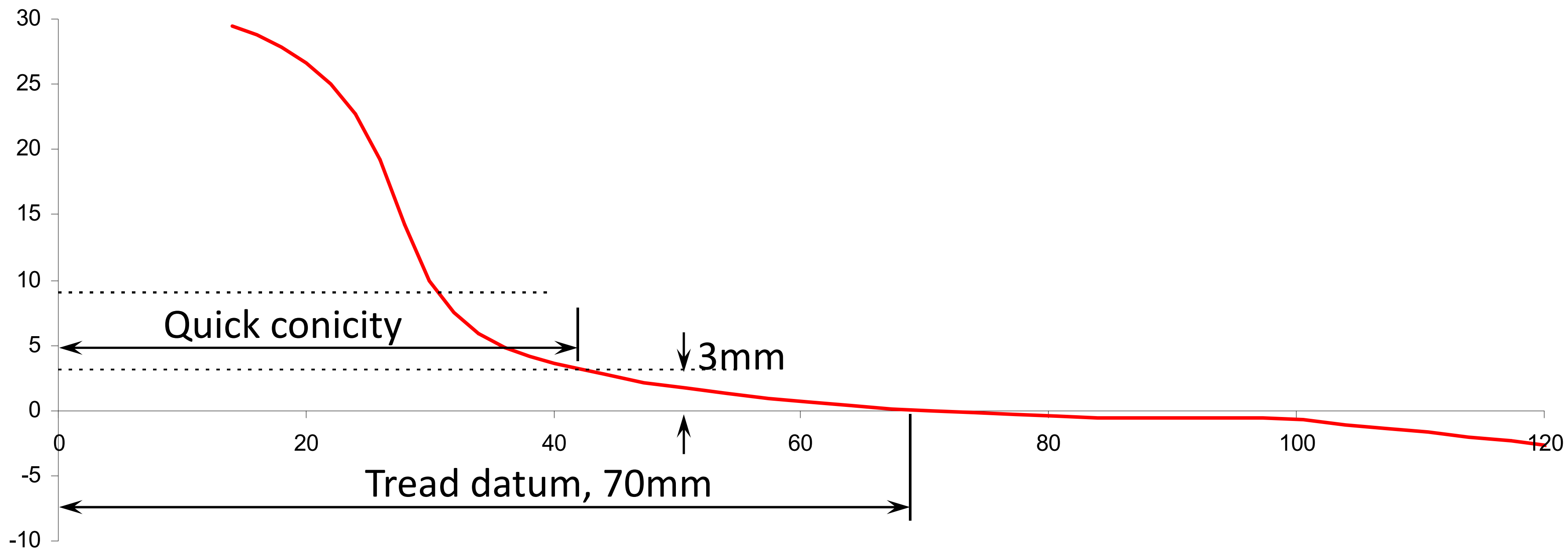


Quick conicity test site #3

- Site shows large variation in equivalent conicity for different wheels:
  - Does the same technique work for wheels?

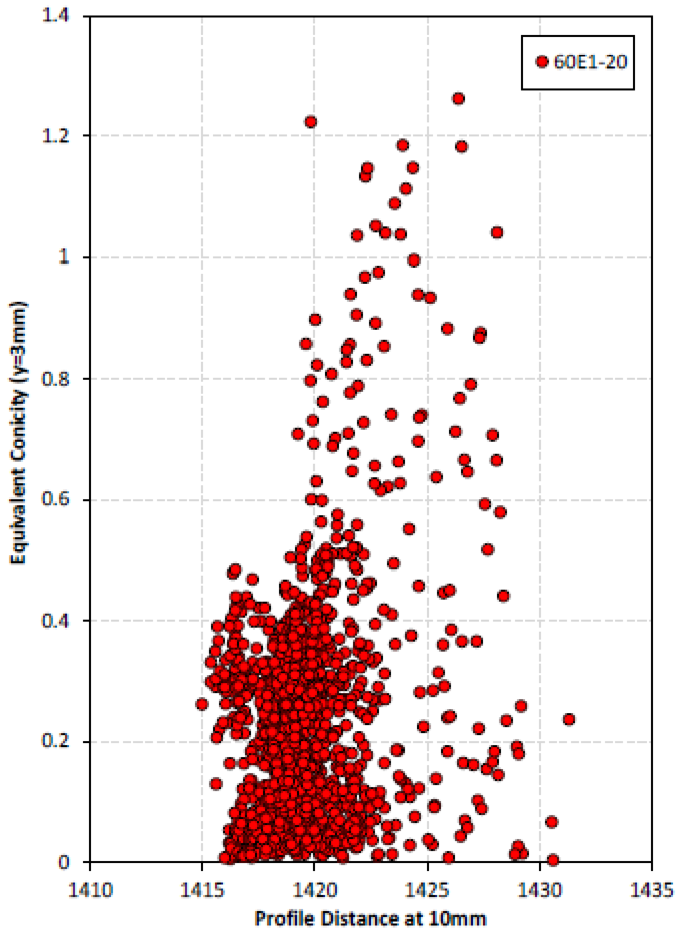
Wheel 'quick' conicity

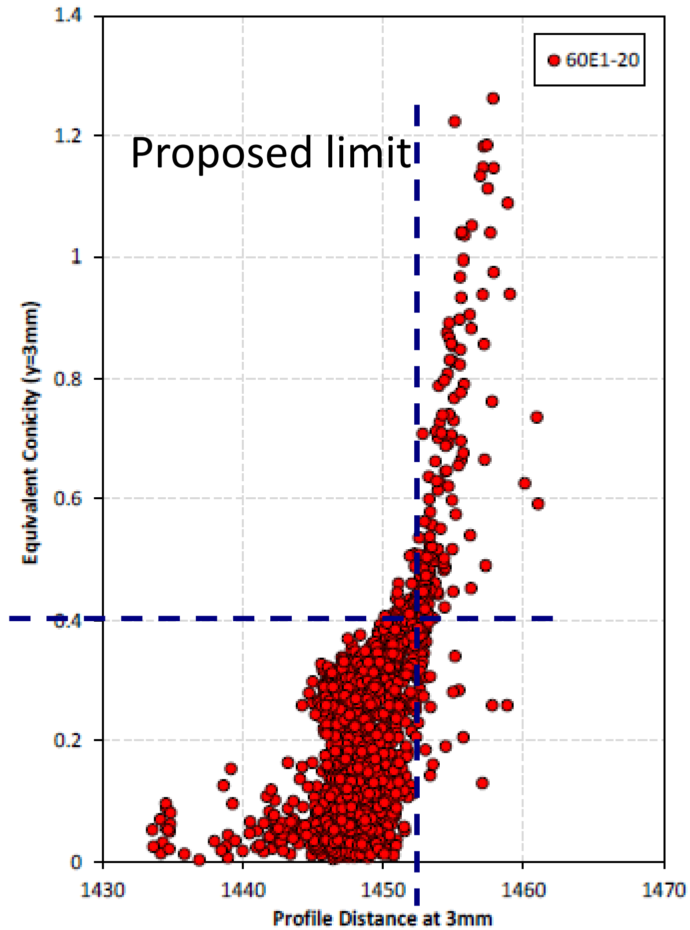
- Thicker flange measurements might be expected to equate to higher conicity
  - Flange root will make contact with rail gauge corner sooner
- Flange thickness needs to be combined with back-to-back dimension



Wheel conicity

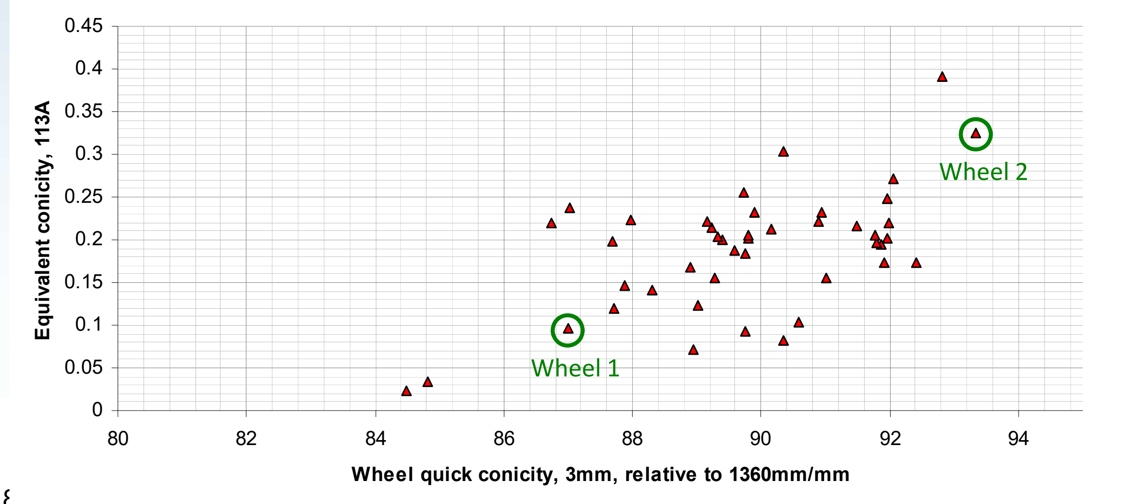
- Data provided by IRR (University of Huddersfield)

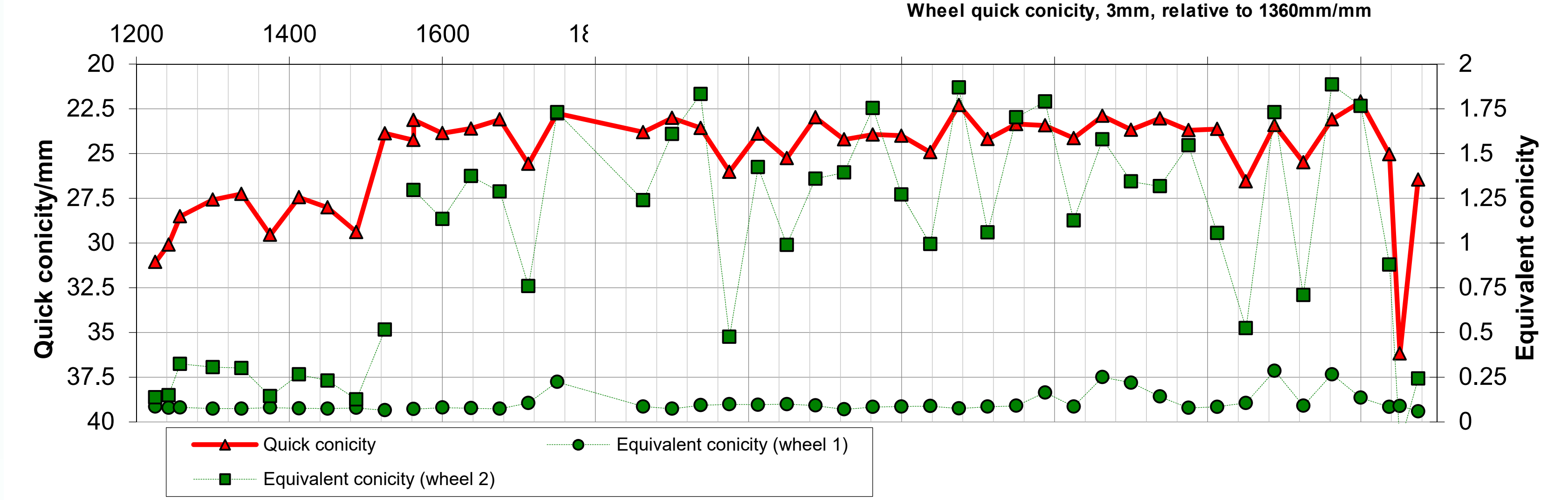




Wheel and rail quick conicity

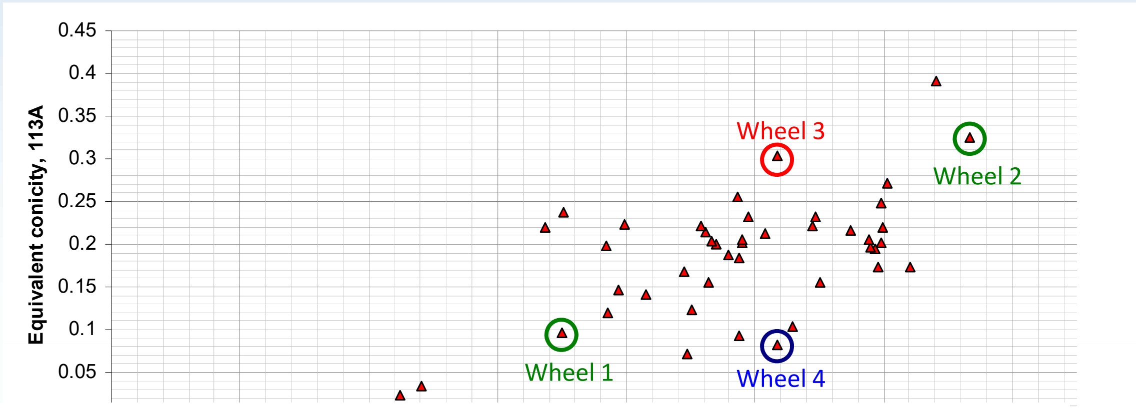
- Choose wheel profiles for ‘low’ and ‘high’ quick conicity

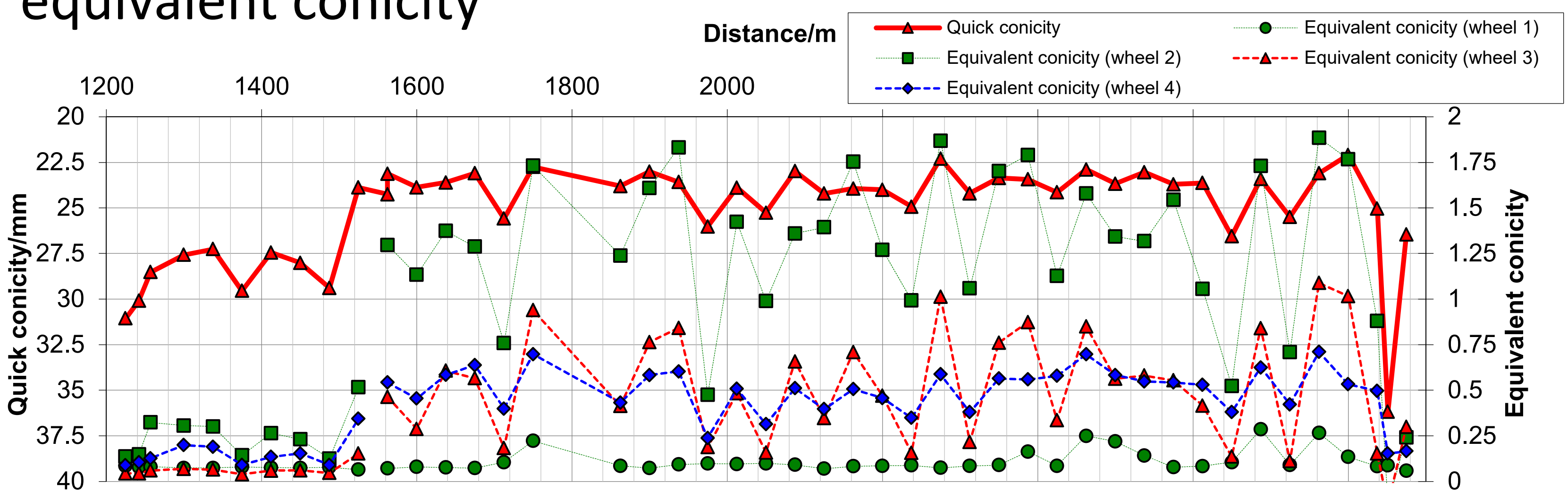




Wheel and rail quick conicity

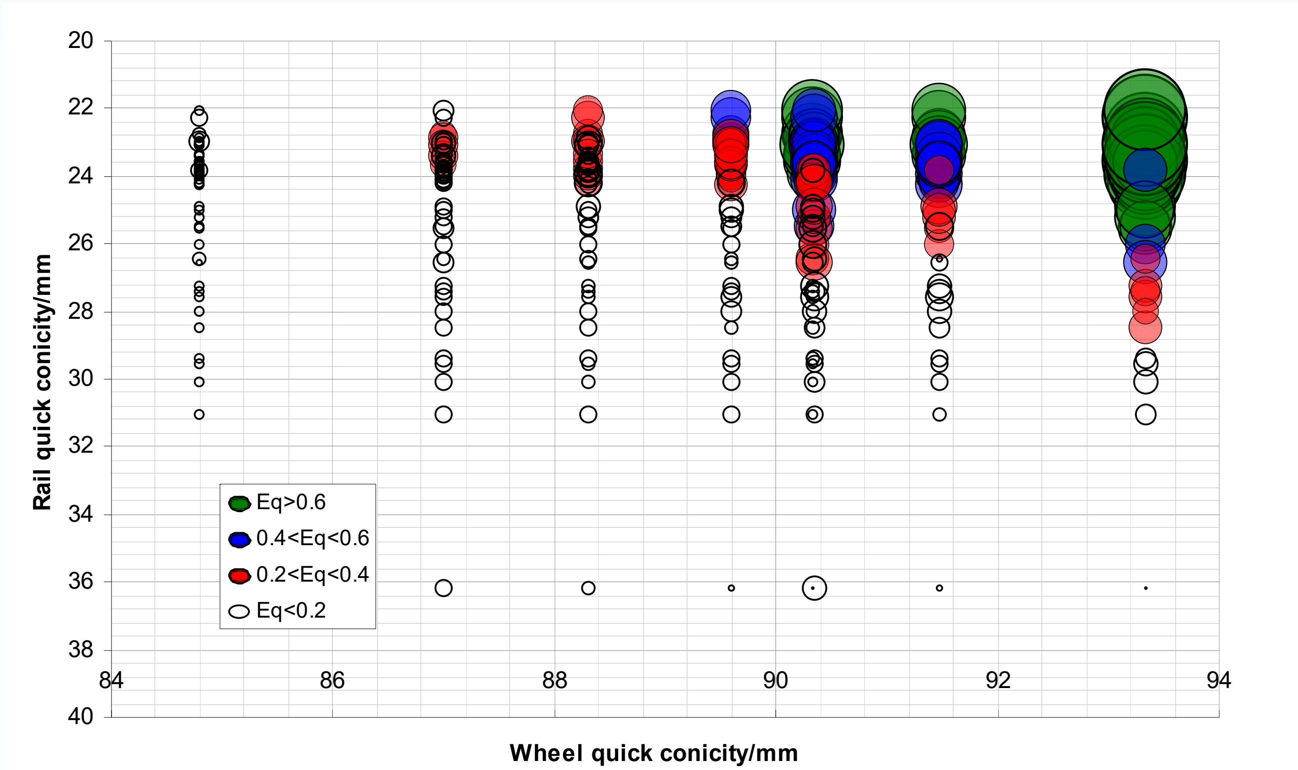
- Some wheels have same 'quick conicity' value but very different equivalent conicity





Combinations of quick conicity wheels and rails

- Contour plots for combinations of quick conicity wheels and rails
  - Good correlation- quick conicity provides a useful way to classify profiles



Conclusions

- An indicator of equivalent conicity can be obtained from a relatively simple measurement:
  - Track gauge 3mm below rail crown
  - Wheel face-to-face 3mm above tread datum
- Can identify rails and wheels which may be contributing to high equivalent conicity
  - Allow infrastructure managers and train operators to better monitor and predict interventions
  - May not eliminate the need for a deeper investigation, but quickly identifies ‘problem’ sites
- Simple addition to existing automated measuring systems
  - Trial currently taking place on infrastructure of an additional track gauge measurement for ‘quick conicity’