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FORCE-BASED ASSESSMENT OF WELD GEOMETRY

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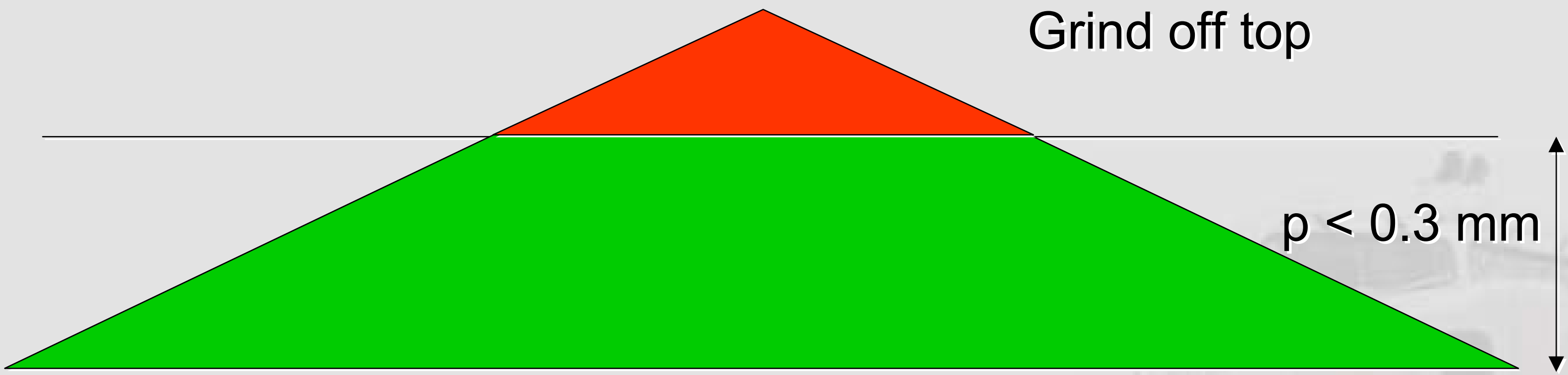
DAMAGE DUE TO POOR WELD GEOMETRY

EXISTING WELD GEOMETRY STANDARDS



For example

Versine: $0 < p < 0.3$ mm

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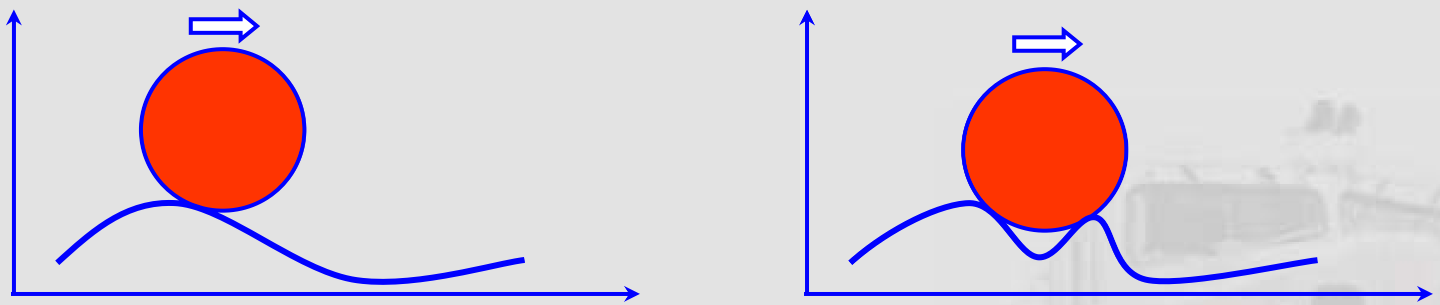
IMPACT LOAD: 1 AND 2-POINT CONTACT



- 2-point contact only relevant for joints. Under normal conditions jump is 10-20 μm and disappears by plastification
- Study concentrated on 1-point contact

MODEL ASSUMPTIONS (1)

- Weld geometry is sampled discretely
- Wavelengths shorter than 25 mm are filtered out
- Maximum wavelength is 2 m (1 m straightedge)
- Wavelength range 10 cm – 2 m

MODEL ASSUMPTIONS (2)

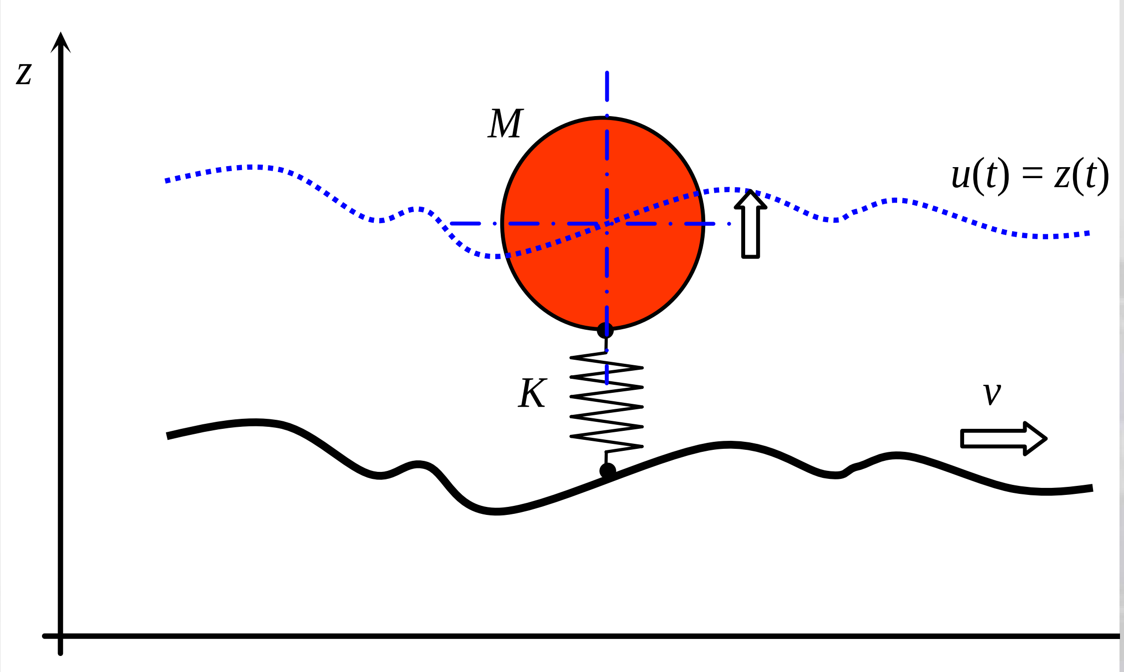
- Speed range: 40-300 km/h
- Frequency range 10-2000 Hz.
- For the development of a practical tool it was decided to consider just one constant mass-stiffness combination.

ACCELERATION APPROACH

- Wheel follows rail irregularities;
- Dynamic part of contact force is governed by:

$$F_{dyn}(t) = M\ddot{z}(t)$$

$$F_{dyn} = \alpha M v^2 \frac{d^2 z}{dx^2}$$



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VELOCITY APPROACH (1)

Assumption:

Equivalent wheel mass is proportional to wavelength:

$$F_{dyn}(t) = M_e \ddot{z}(t)$$

with:

$$M_e = \frac{1}{L_0} ML = \frac{1}{L_0} M \frac{v}{f}$$

and: $\ddot{z} = \dot{z} \frac{2\pi v}{L}$

VELOCITY APPROACH (2)

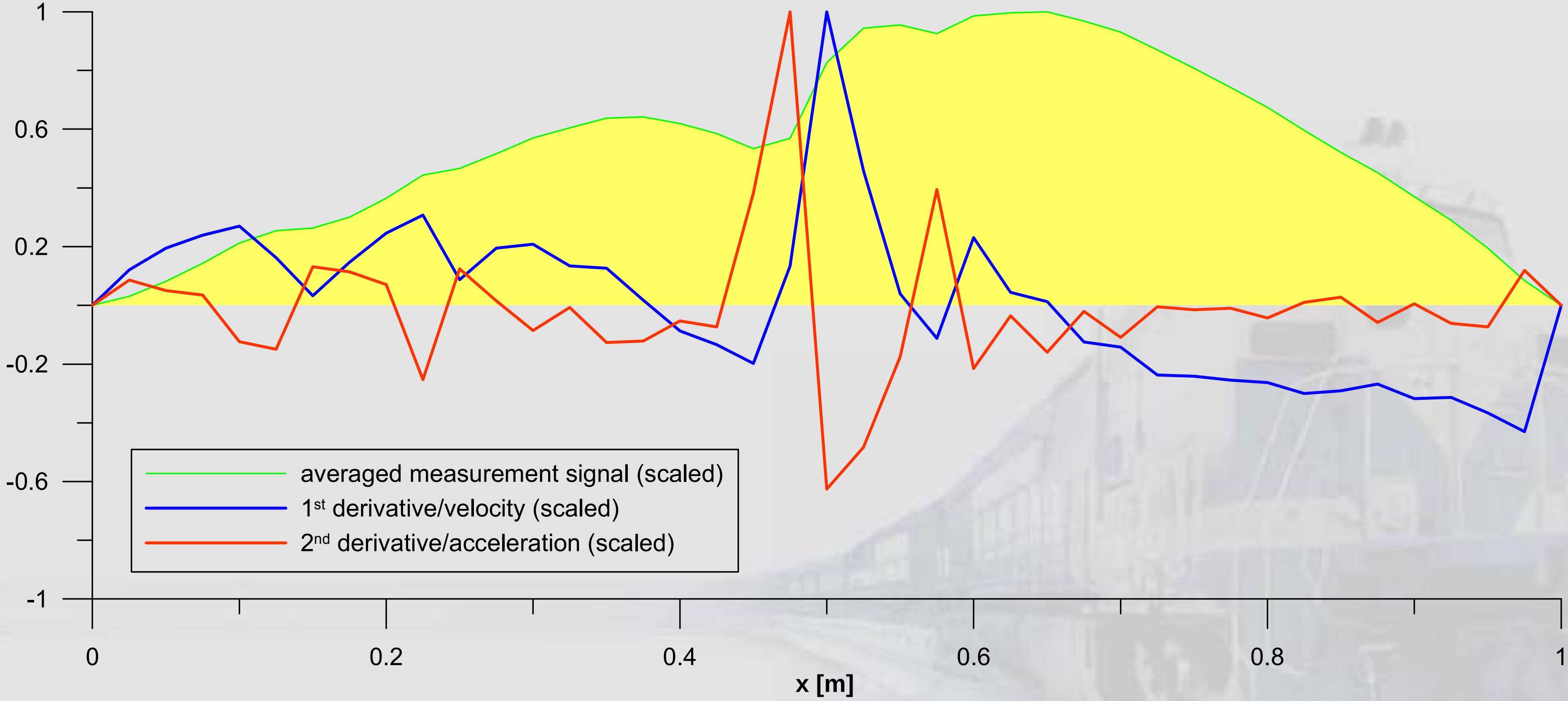
The dynamic contact force as a function of the first time derivative:

$$F_{dyn} = M \frac{2\pi v}{L_0} \dot{z}$$

The dynamic contact force in terms of the spatial derivative, including calibration factor β:

$$F_{dyn} = \beta \frac{M}{L_0} v^2 \frac{dz}{dx}$$

ACCELERATION VERSUS VELOCITY



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EVALUATION BASED ON VELOCITY

Force intervention values (relative) and inclinations

Velocity	Force	Inclination
40 km/h	5 kN	3.2 mrad
80 km/h	15 kN	2.4 mrad
140 km/h	35 kN	1.8 mrad
200 km/h	65 kN	0.9 mrad

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COMPARISON OLD & NEW STANDARDS

Old standard ($0 < p < 0.3$ mm): 76% rejected

New standard:

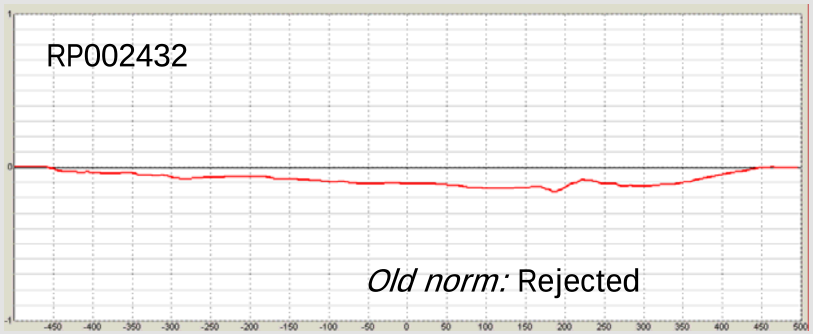
- 40 km/h: 33% (acc. 33%)
- 80 km/h: 53% (acc. 64%)
- 140 km/h: 81% (acc. 93%)
- 200 km/h: 86% (acc. 94%)

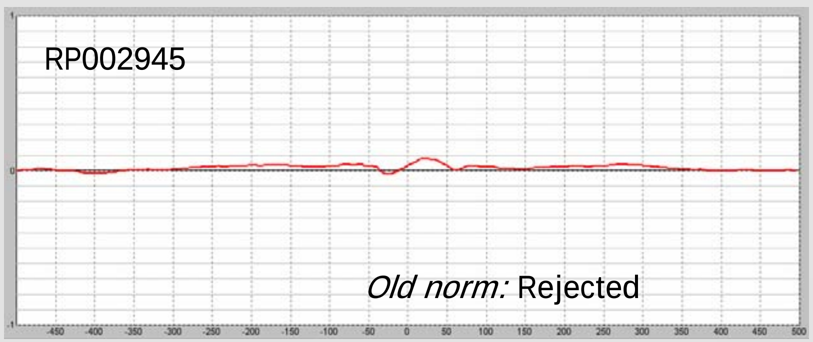
QUALITY INDICES (QI)

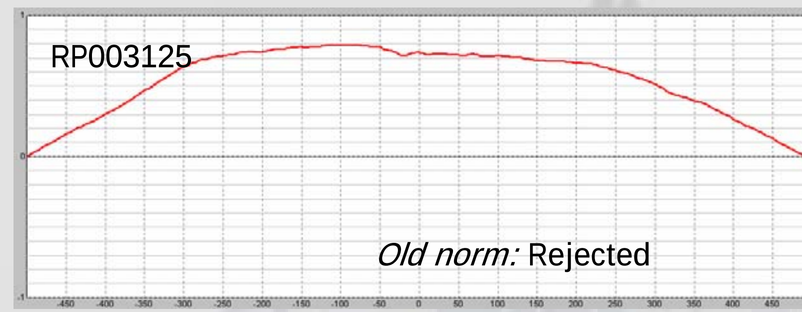
$$QI = \frac{\left|F_{max,\, actual}\right|}{F_{norm}} \leq 1 \quad \Rightarrow \quad OK$$

- $QI \leq 1$: Accepted
- $QI > 1$: Rejected

ASSESSMENT OLD AND NEW







NORM BASED ON ACCELERATIONS						NORM BASED ON VELOCITIES			
[km/h]	*norm 40*	*norm 80*	*norm 140*	*norm 200*		*norm 40*	*norm 80*	*norm 140*	*norm 200*
[kN]	30	80	150	300		5	15	35	65
	SCORE PER NORM: (<1: OK)					SCORE PER NORM: (<1: OK)			
RP002432	1.3	1.7	3.3	3.3		0.5	0.7	0.9	1
RP002945	1.3	1.7	3.3	3.3		0.6	0.8	1	1.1
RP002949	1.1	1.7	2.5	2.5		1.1	1.7	2	2.5
RP003125	0.6	0.9	1.4	1.4		1.1	1.4	2	2

EXTENSION TO HEAVY HAUL AND HSL (1)

Total wheel load versus velocity:

$$Q_{tot} = Q_{stat} + \beta \frac{M}{L_0} v^2 \frac{dz}{dx} \Rightarrow$$

$$\frac{dz}{dx} < \Delta Q \frac{1}{\beta} \frac{L_0}{M} \frac{1}{v^2}$$

Q_{max} is approximately 450/2 kN

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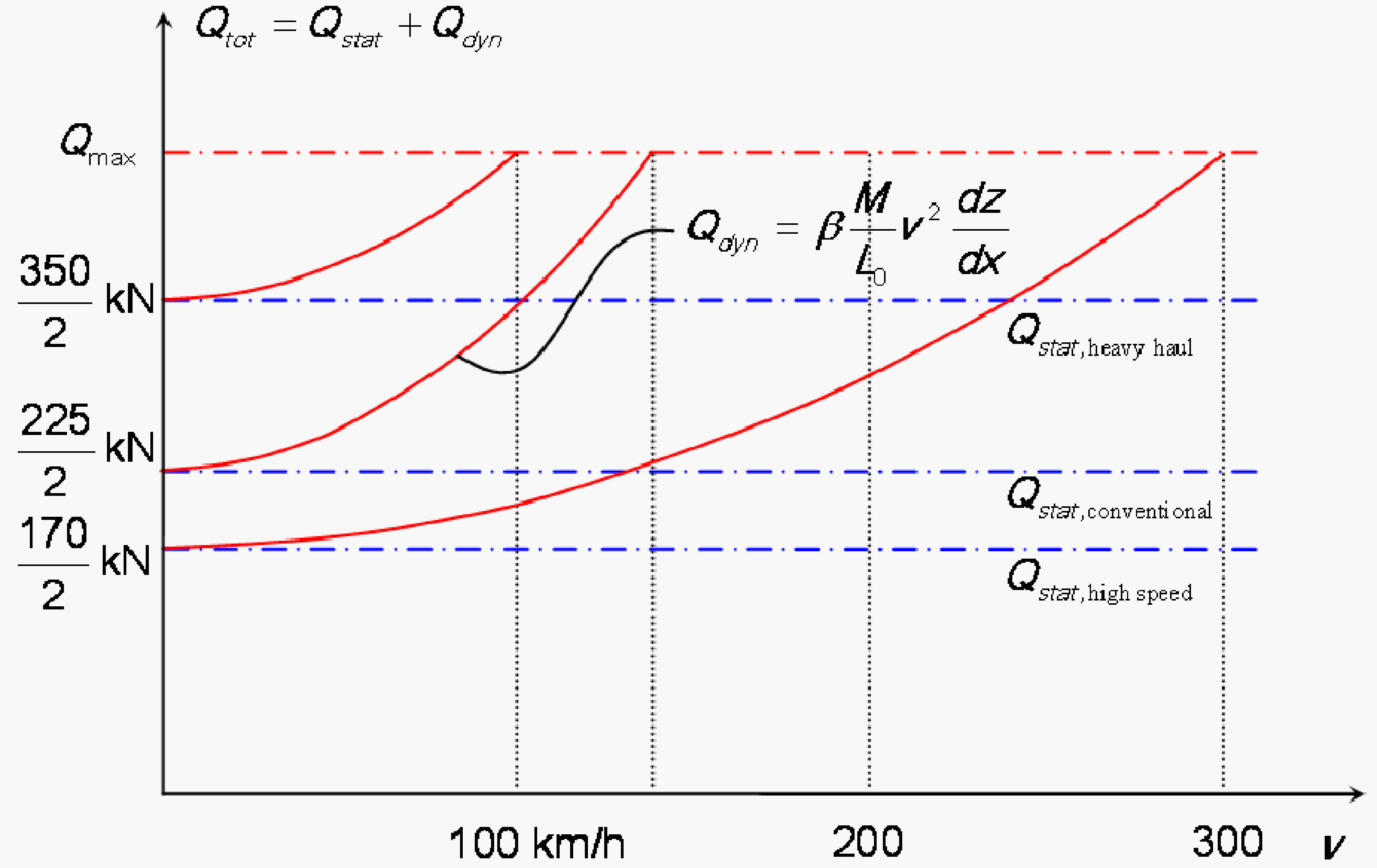
EXTENSION TO HEAVY HAUL AND HSL (2)



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EXTENSION TO HEAVY HAUL AND HSL (3)

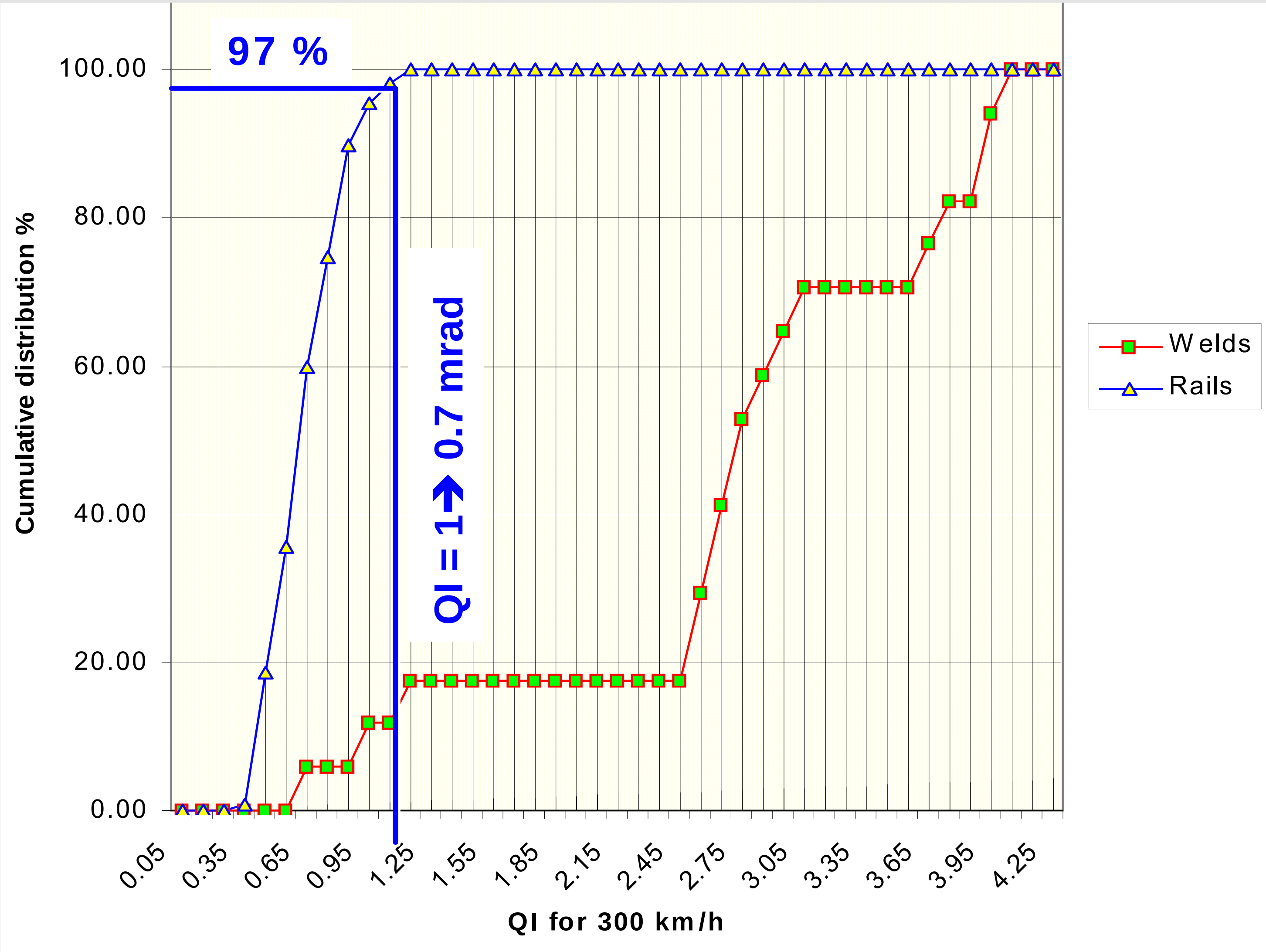
Intervention values for Heavy Haul and HSL lines:

	[kN] ΔQ	v [m/s]	$\frac{dz}{dx} \cdot \frac{\beta M}{L_0}$	**Norm value [mrad]**
Conventional	225/2	40	0.070	**1.8**
Heavy Haul	100/2	30	0.056	**1.4**
High-Speed	280/2	85	0.019	**0.5**

EXTENSION TO HEAVY HAUL AND HSL (4)

- The value of 0.5 mrad as max. inclination for HSL was changed to 0.7 mrad based on 100 measurements of new HSL rails;
- 97 % of rails is better than 0.7 mrad → QI = 1;
- Standard can only be achieved by applying grinding train (Plasser GWM).

RAIL & WELD GEOMETRY HSL



PRACTICAL IMPLEMENTATION (1)

Procedure:

- Sample weld geometry with digital straightedge
- Filter measured signal
- Determine 1st derivative (inclination)
- Normalize with intervention value for line speed
- Calculate QI.
- QI < 1: OK, otherwise: grinding.

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PRACTICAL IMPLEMENTATION (2)

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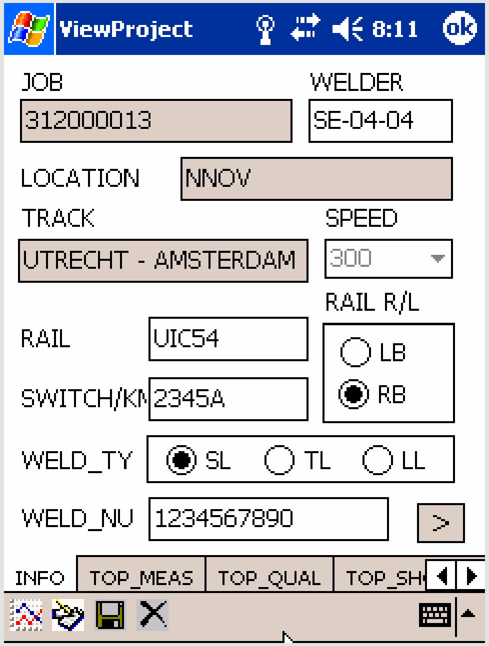
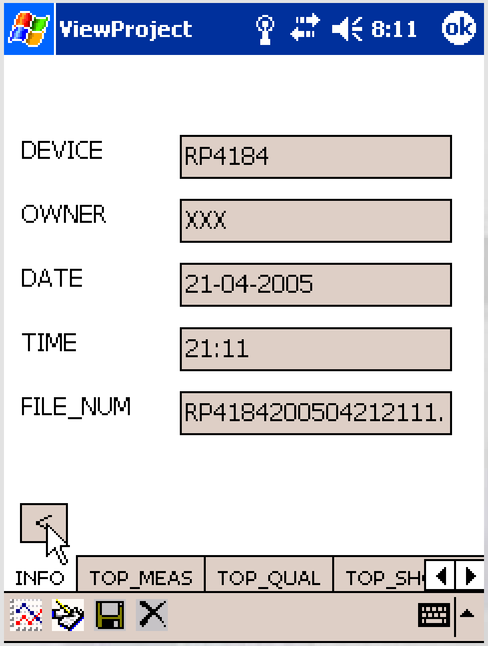
EXAMPLES OF PDA SCREENS (1)





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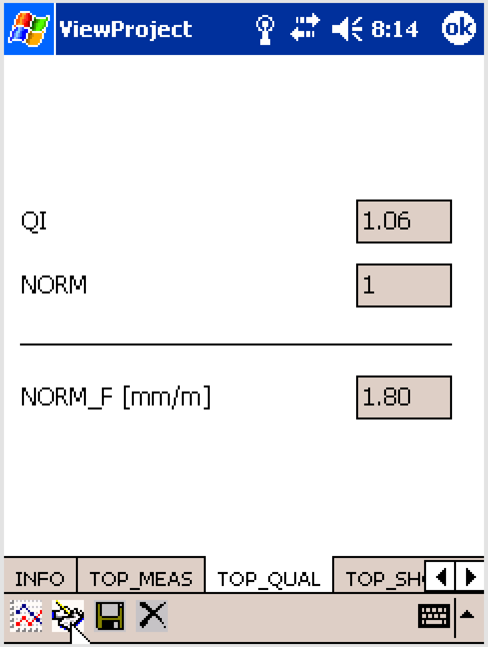
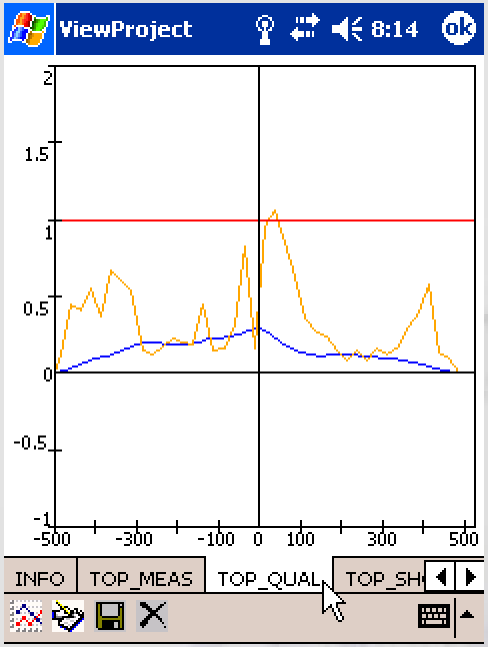
EXAMPLES OF PDA SCREENS (2)





V = 140 km/h

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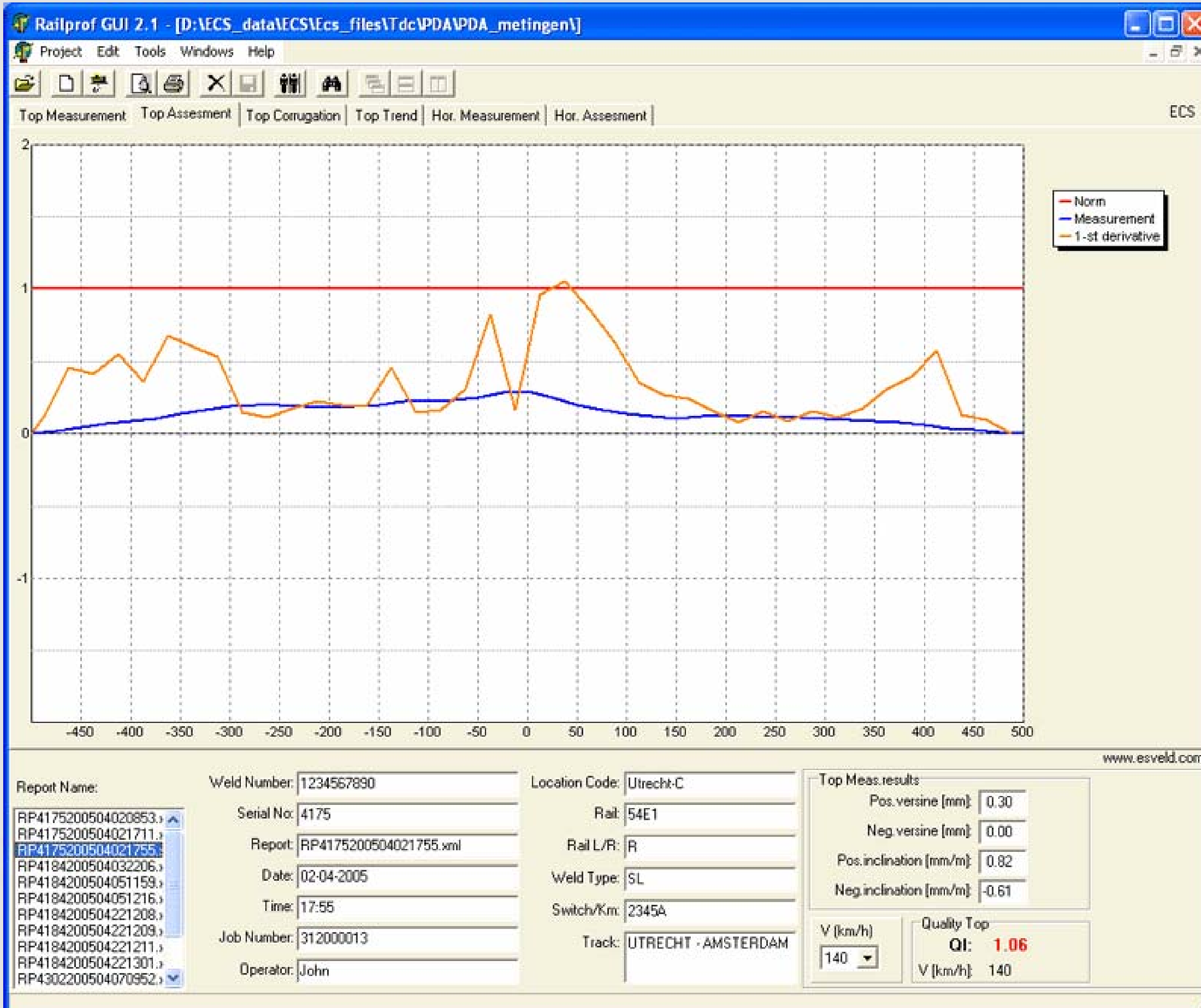
DESKTOP SOFTWARE



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CONCLUSIONS

1. The theory developed on the basis of the first derivative is powerful and practical;
2. New, high quality rails have a first derivative < 0.7 mrad;
3. Mechanical grinding (GWM) is inevitable to achieve such an accuracy for weld geometry;
4. Steel straightedges are absolutely inadequate;
5. Instead accurate electronic straightedges (RAILPROF), producing versine and 1st derivative, are required;
6. The presented concept is very well applicable to heavy haul tracks.