

FORCE-BASED ASSESSMENT OF WELD GEOMETRY

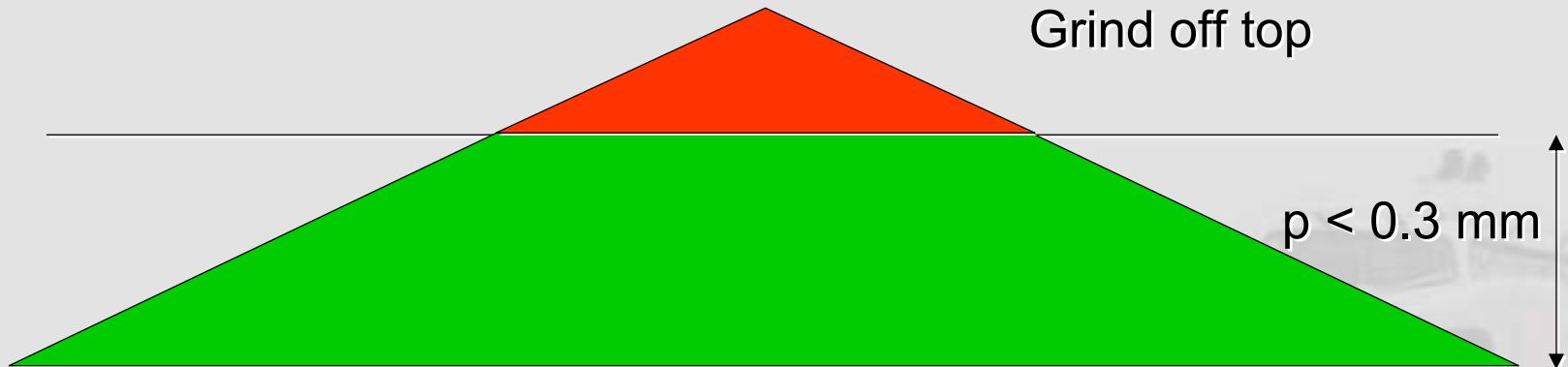
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DAMAGE DUE TO POOR WELD GEOMETRY



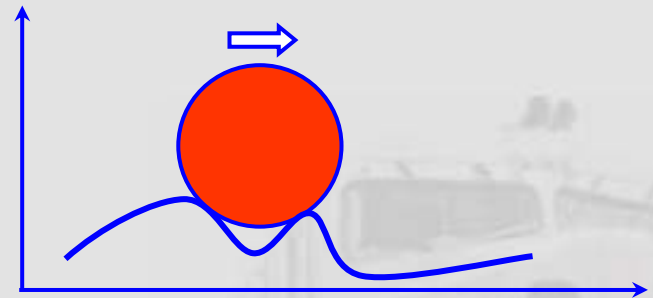
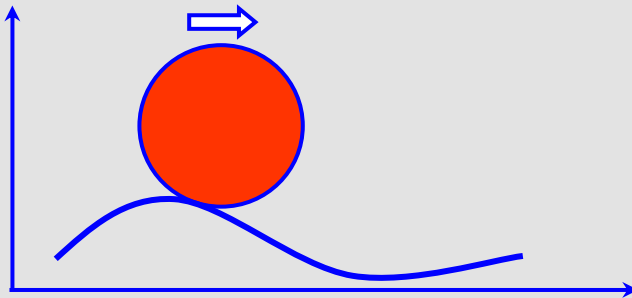
EXISTING WELD GEOMETRY STANDARDS



For example

Versine: $0 < p < 0.3 \text{ mm}$

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)

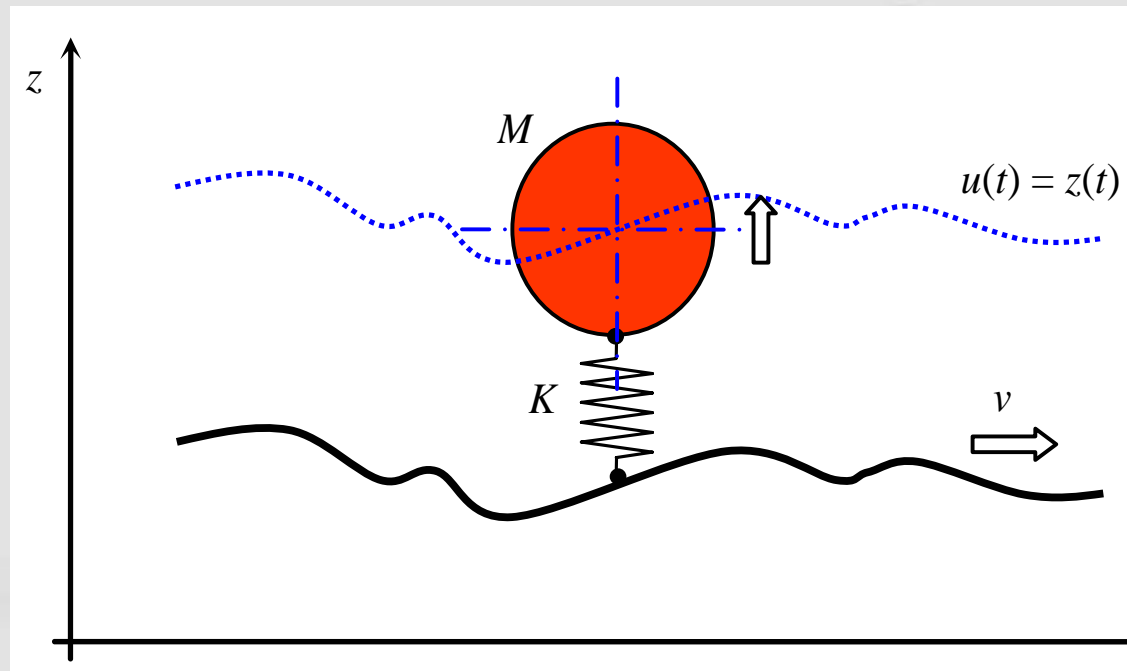
- Speed range: 40-300 km/h
- Frequency range 10-2000 Hz.
- For the development of a practical tool it was decided to consider just one constant mass-stiffness combination.

ACCELERATION APPROACH

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

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

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



VELOCITY APPROACH (1)

Assumption:

Equivalent wheel mass is proportional to wavelength:

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

with:

$$M_e = \frac{1}{L_0} ML = \frac{1}{L_0} M \frac{v}{f} \quad \text{and:} \quad \ddot{z} = \dot{z} \frac{2\pi v}{L}$$

VELOCITY APPROACH (2)

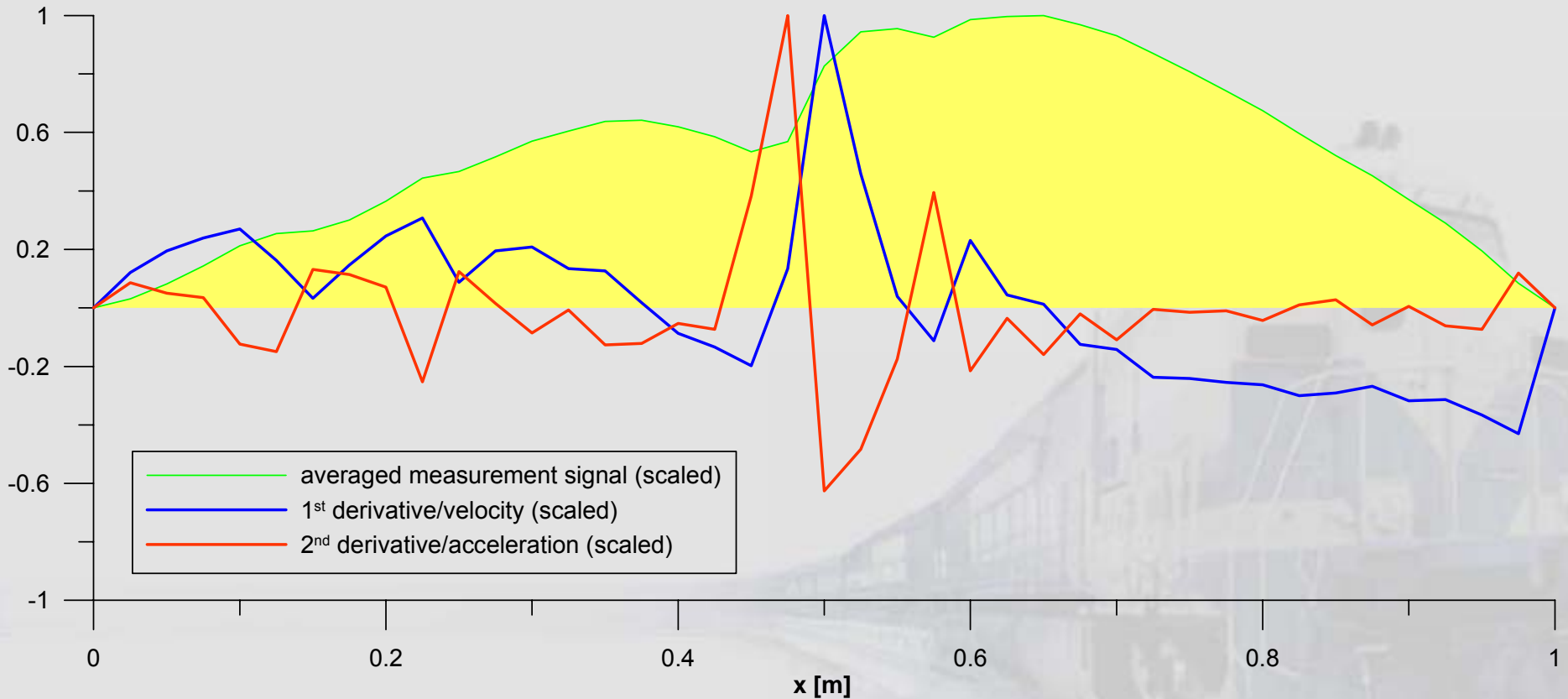
The dynamic contact force as a function of the first time derivative:

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

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



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 |

COMPARISON OLD & NEW STANDARDS

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

New standard:

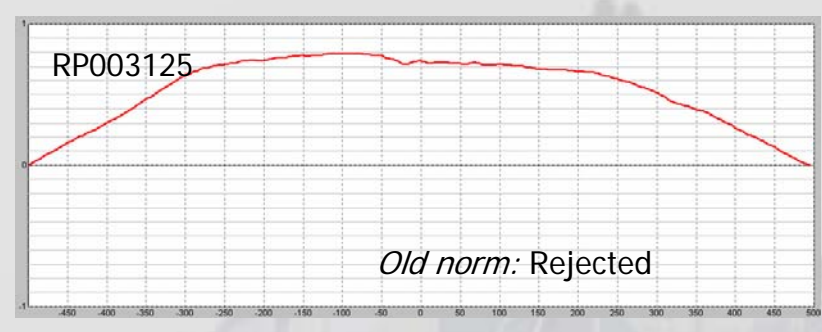
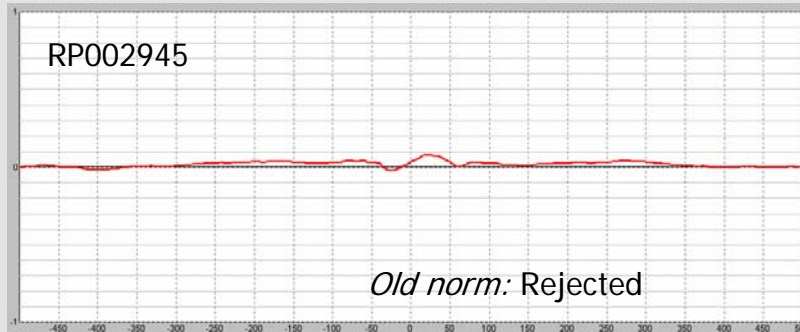
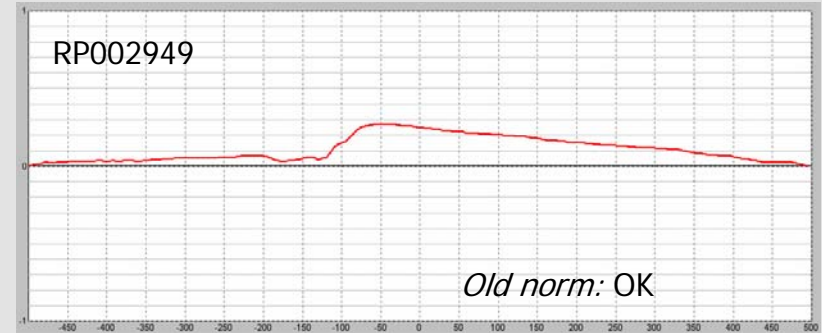
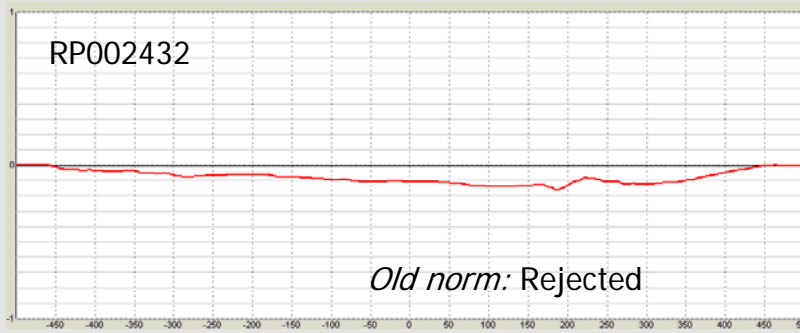
- 40 km/h: 33% (acc. 33%)
- 80 km/h: 53% (acc. 64%)
- 140 km/h: 81% (acc. 93%)
- 200 km/h: 86% (acc. 94%)

QUALITY INDICES (QI)

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

- $QI \leq 1$: 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)

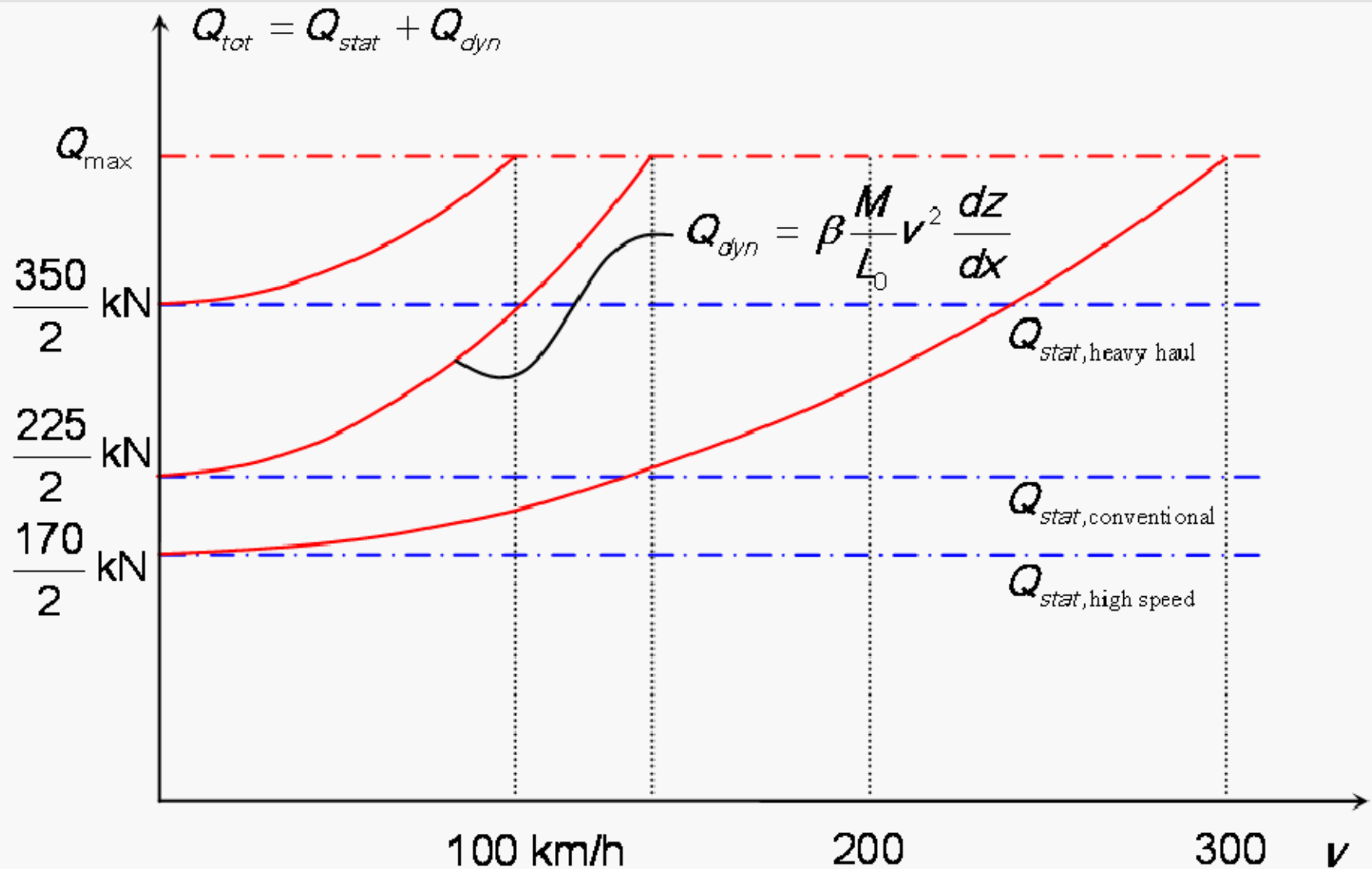
Total wheel load versus velocity:

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

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

Q_{max} is approximately 450/2 kN

EXTENSION TO HEAVY HAUL AND HSL (2)



EXTENSION TO HEAVY HAUL AND HSL (3)

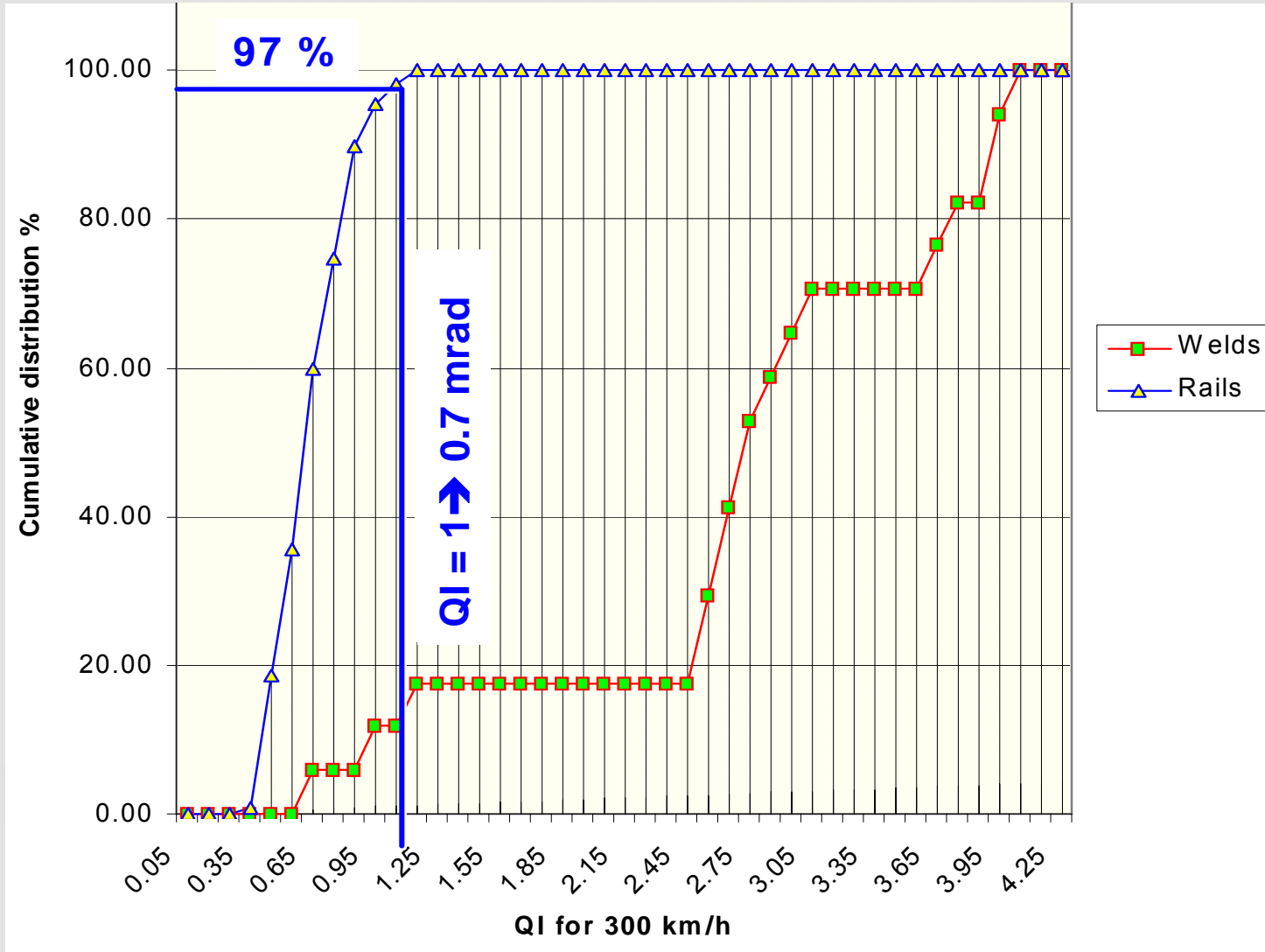
Intervention values for Heavy Haul and HSL lines:

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

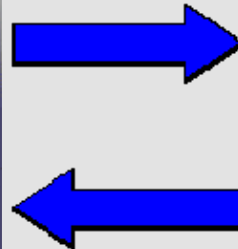


PRACTICAL IMPLEMENTATION (1)

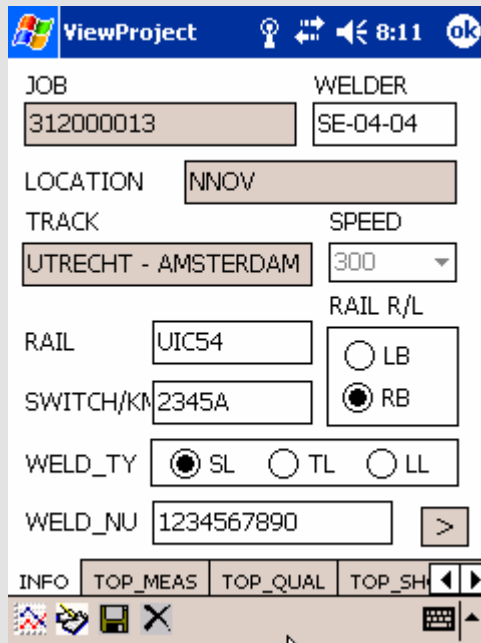
Procedure:

- 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.

PRACTICAL IMPLEMENTATION (2)



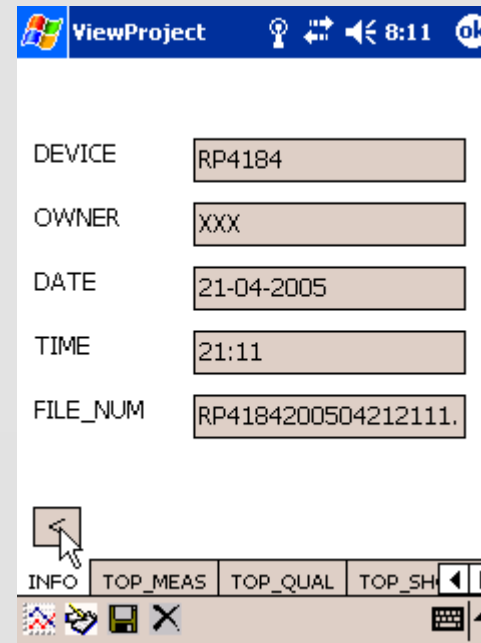
EXAMPLES OF PDA SCREENS (1)



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| | | | |
|-----------|---------------------|----------|---|
| JOB | 312000013 | WELDER | SE-04-04 |
| LOCATION | NNOV | | |
| TRACK | UTRECHT - AMSTERDAM | SPEED | 300 |
| RAIL | UIC54 | RAIL R/L | <input type="radio"/> LB <input checked="" type="radio"/> RB |
| SWITCH/KM | 2345A | WELD_TY | <input checked="" type="radio"/> SL <input type="radio"/> TL <input type="radio"/> LL |
| WELD_NU | 1234567890 | > | |

INFO TOP_MEAS TOP_QUAL TOP_SH

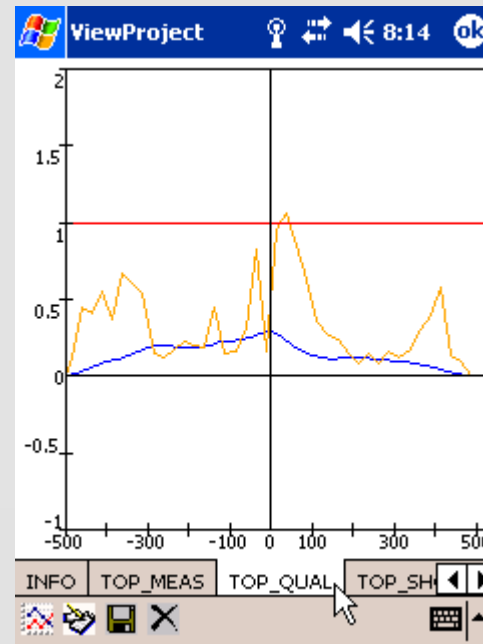
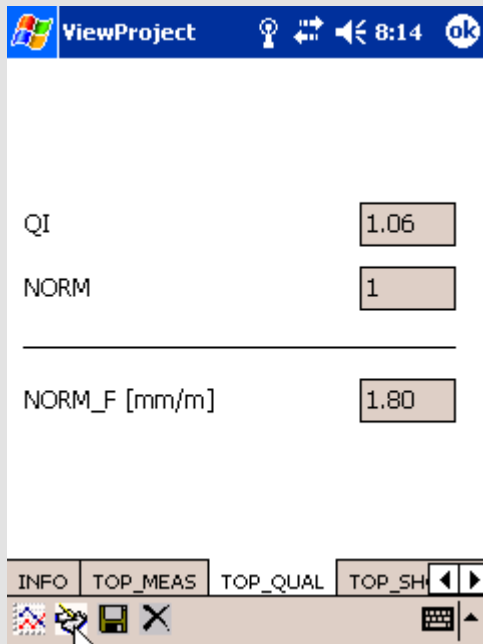


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| | |
|----------|---------------------|
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| OWNER | XXX |
| DATE | 21-04-2005 |
| TIME | 21:11 |
| FILE_NUM | RP4184200504212111. |

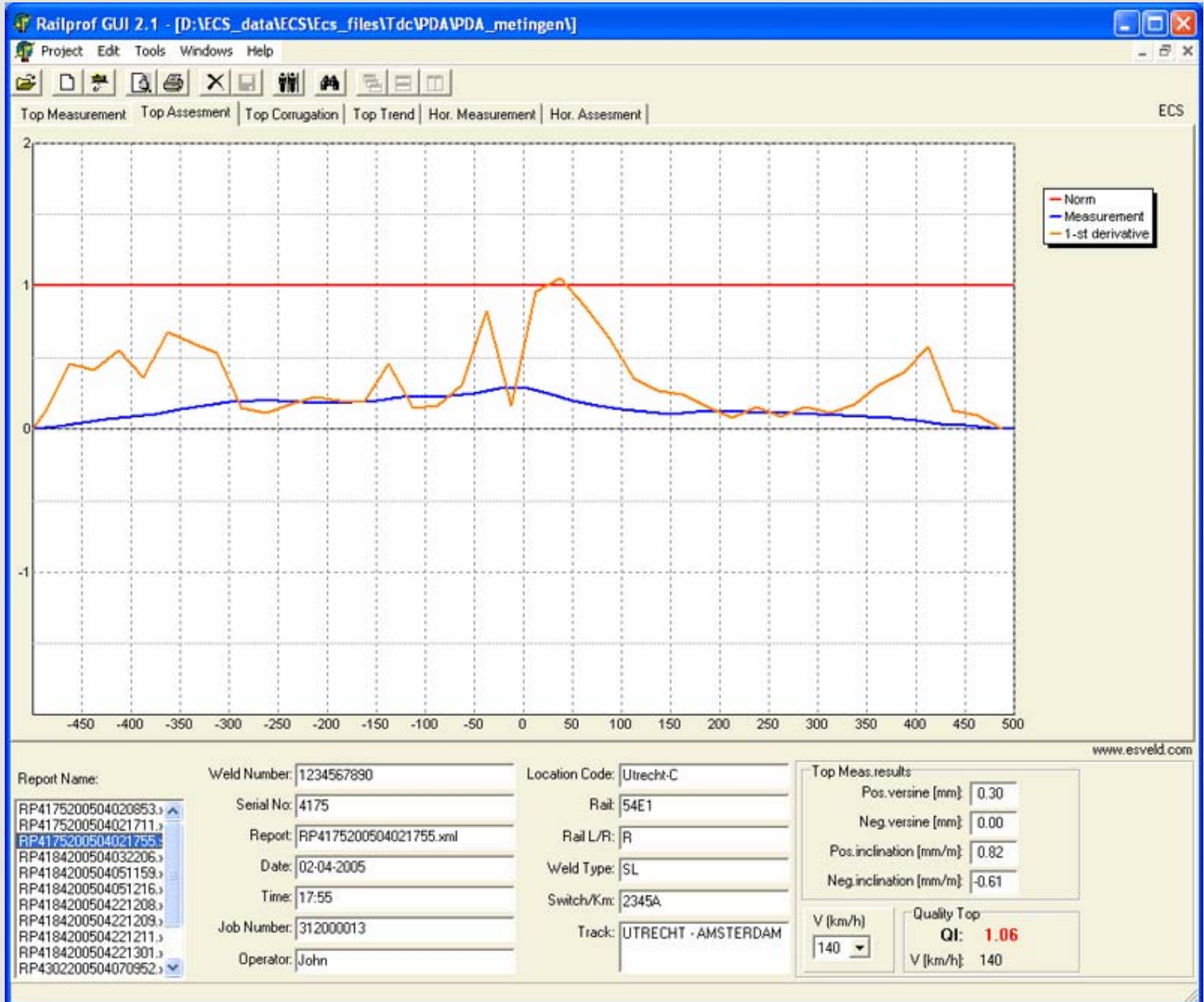
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EXAMPLES OF PDA SCREENS (2)



V = 140 km/h

DESKTOP SOFTWARE



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.