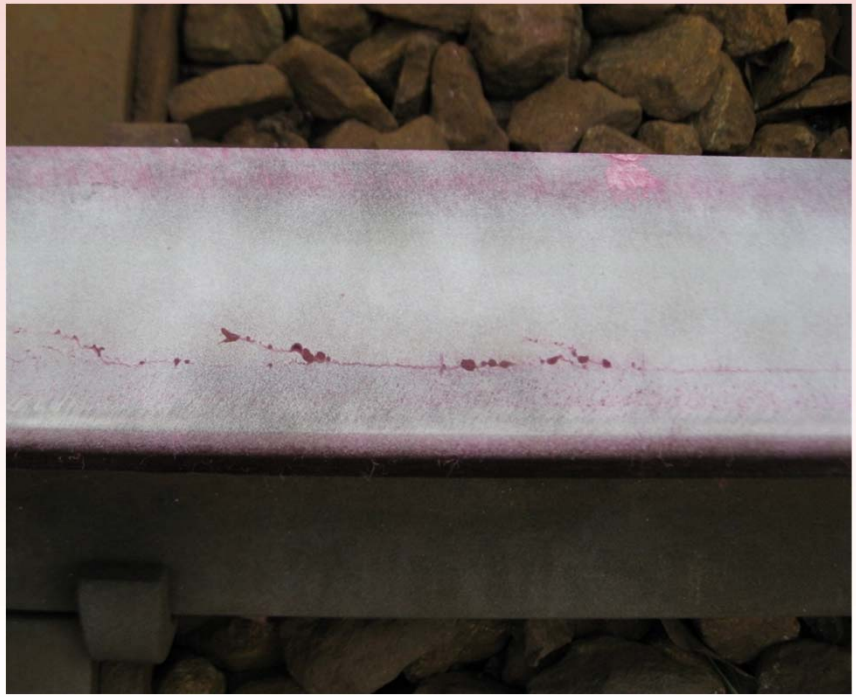
Validation of Rail Crack Measurement Devices on NS



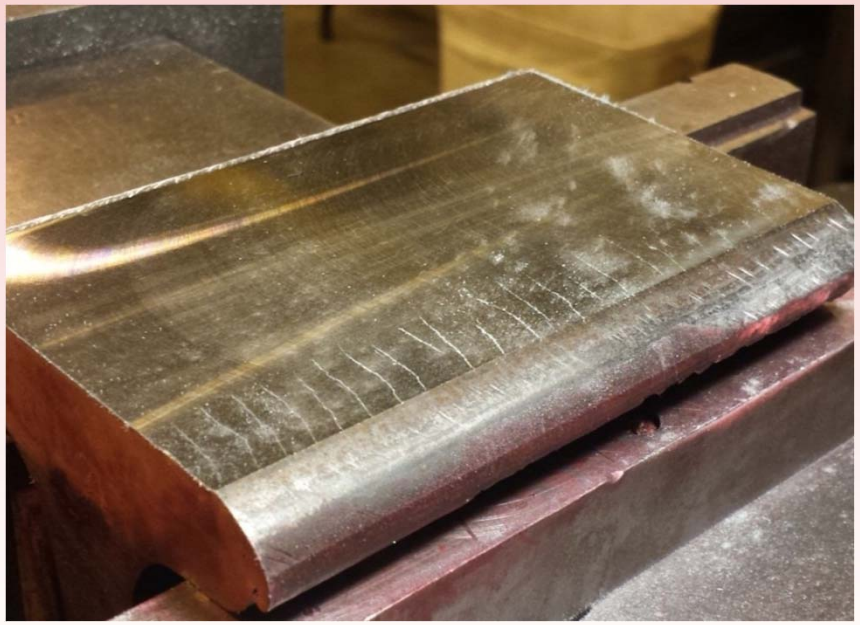
Brad Kerchof

NS Research & Tests

May 21, 2015

Outline

- What we know about rail cracks
- Crack measurement technology from 4 suppliers
  - Rohmann
  - MRX
  - Sperry Rail Service
  - ARM / IE / Rohmann
- Validation work in 2013 – 2015
- Conclusions
- Questions



What we know about rail cracks (part 1)

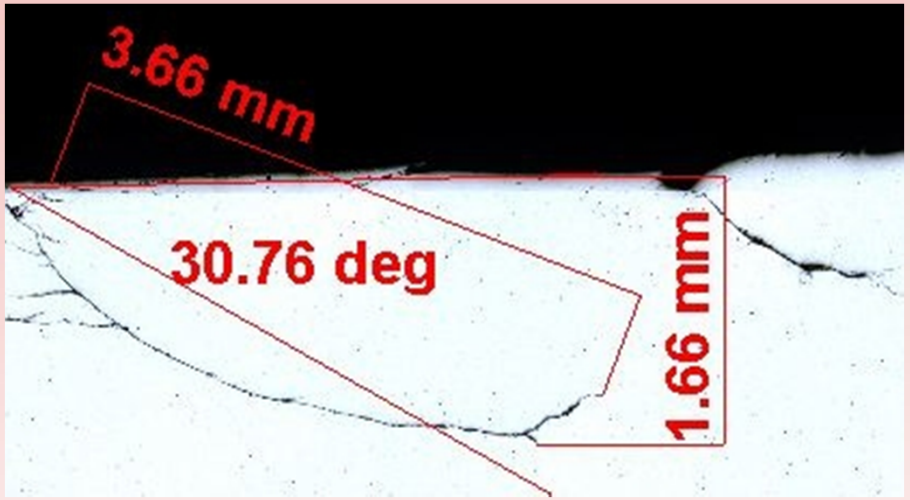
- Cracks are caused by lateral and longitudinal creep forces that exceed the strength of the rail steel.
- Cracks are much more common on curves, where lateral and longitudinal creep forces are higher.
- Cracks weaken the running surface of the rail. They can create spalls or develop into transverse defects.

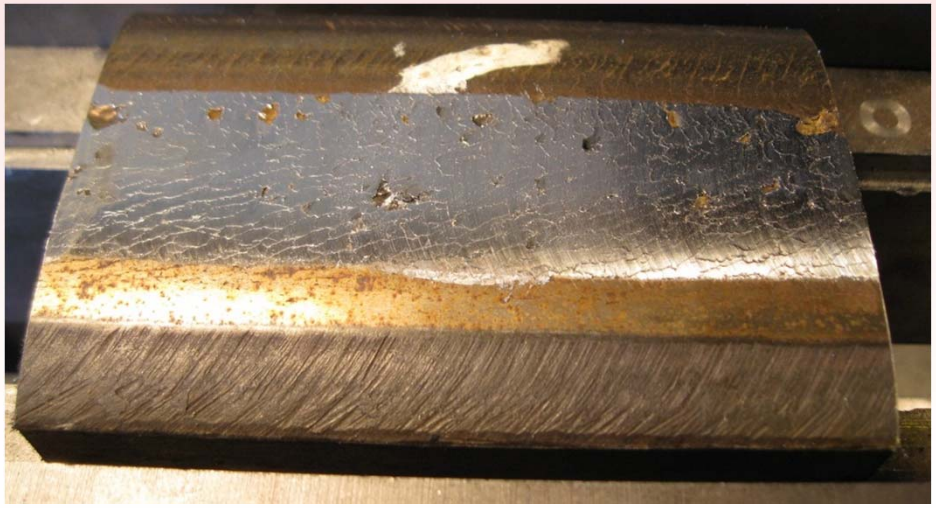
What we know about rail cracks (part 2)

- Suppliers are developing equipment that measures cracks.
- If cracks are open to the surface, their length can be measured non-destructively.
- Crack depth and angle cannot be measured non-destructively.
- Cracks can be removed by grinding (though currently, crack removal is not the primary objective of grinding; restoring the desired rail profile and removing corrugations and spalls are the primary objectives).

What would we like to know about cracks

1. What is the best way to characterize cracks – depth? Or are length, angle and density also important?
2. What are crack growth rates?
3. When is a crack likely to initiate a TD?
4. At what stage of crack development is grinding advised?
5. Should all cracks be removed during each grinding cycle?

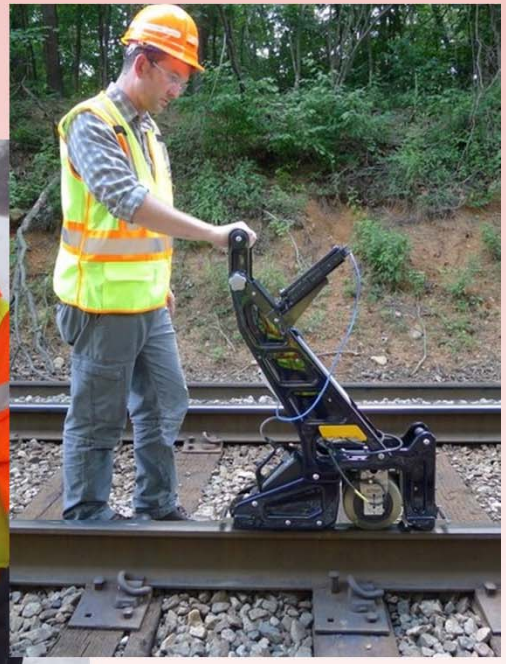




Crack measurement devices from 4 suppliers

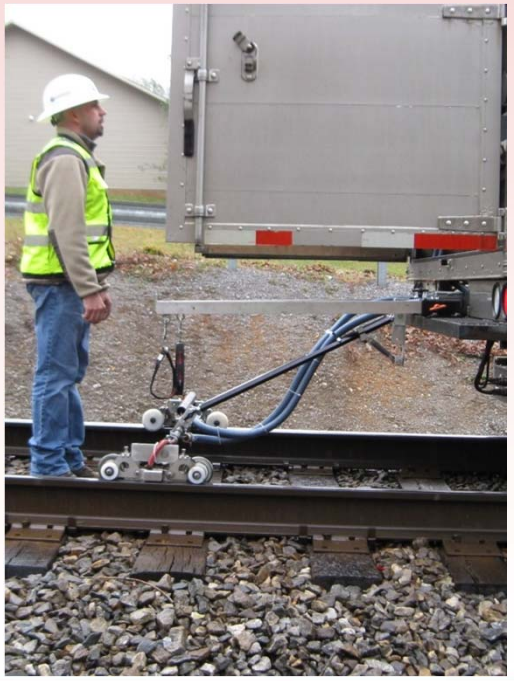
1. Rohmann

2. MRX



3. Sperry

4. ARM–IE-Rohmann

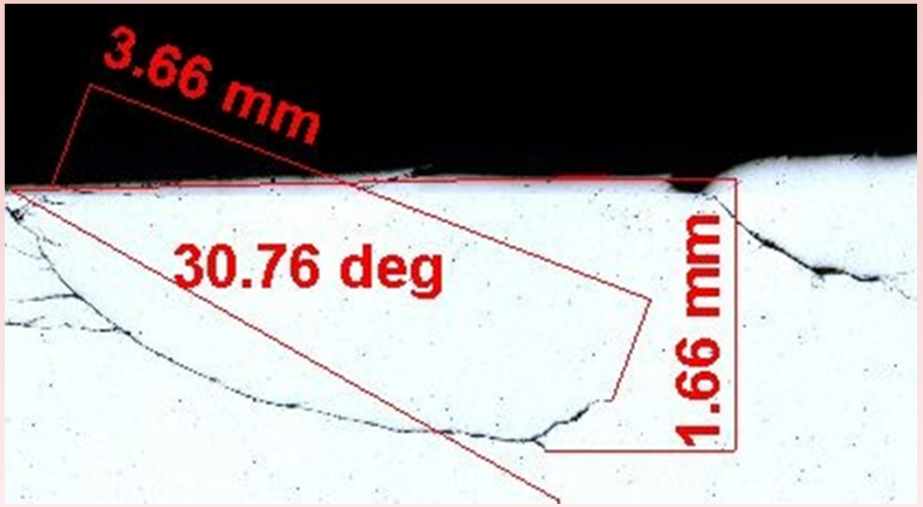


1. Rohmann eddy current device – “Draisine”

Rohmann is a Germany company that manufactures non-destructive testing equipment

How does an eddy current device measure cracks?

It correlates eddy current signal strength to crack length.

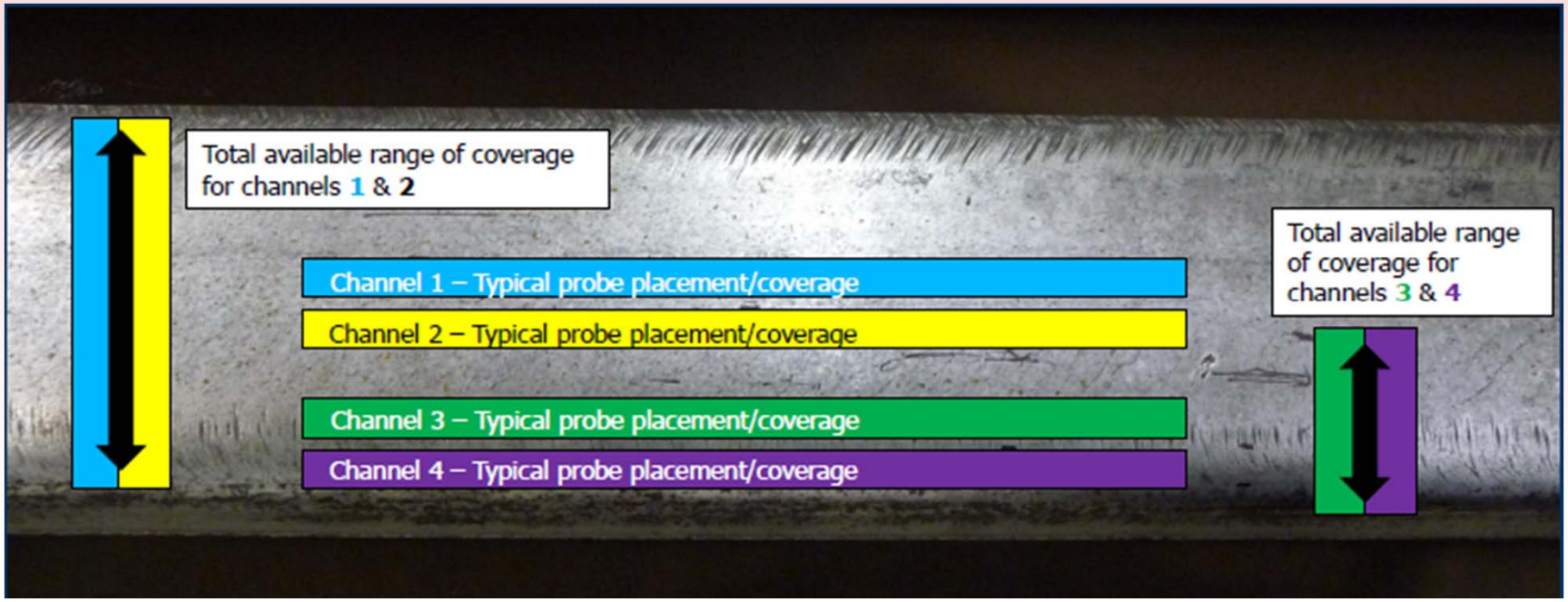


To determine crack depth, a crack angle must be assumed; depth is then calculated using crack length & angle.

Assumed angle - 25˚

Draisine probe coverage

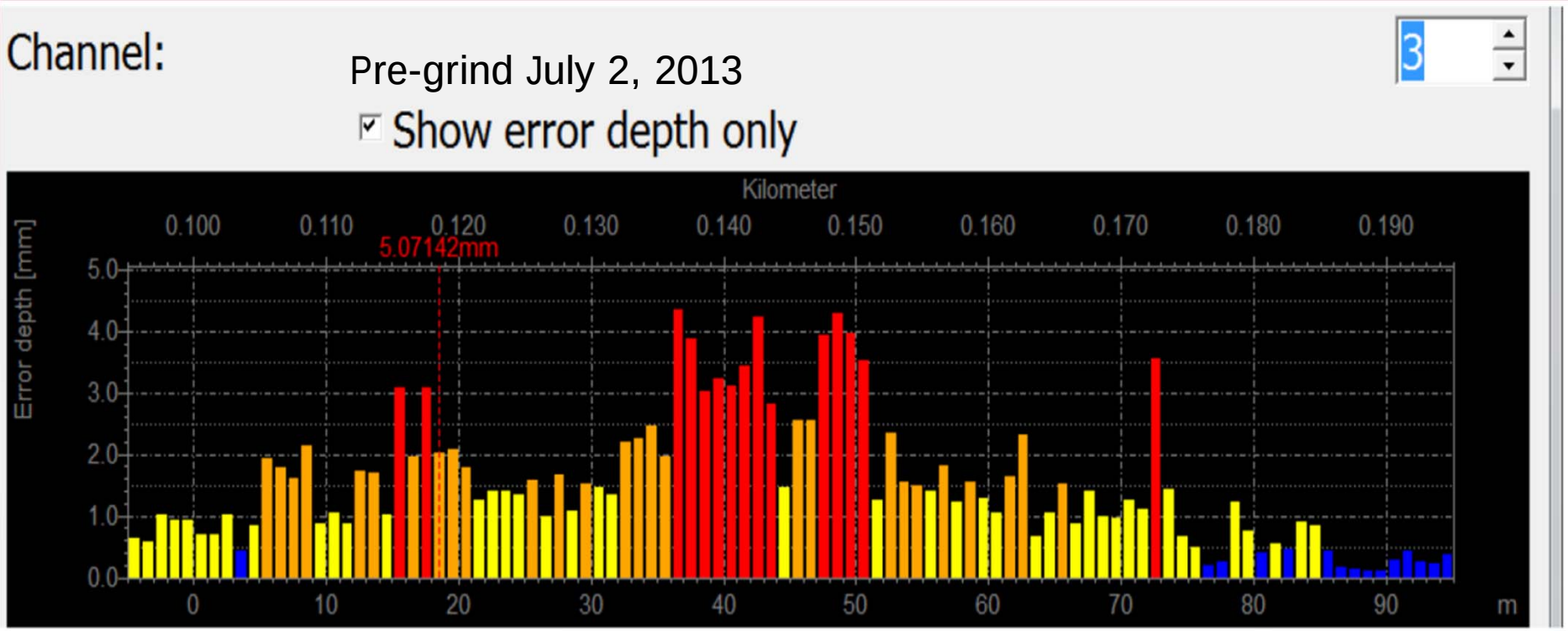
- Four probes
- Measurement width of each probe is 6 mm (so only 24 mm of 75 mm head width is covered)
- Probes can be moved



Draisine data presentation

Processed data is presented in a bar graph

- X axis - each bar represents 1 meter of rail length
- Y axis – bar height and color indicate the deepest crack in that meter; maximum depth reported is 5 mm



2. MRX electromagnetic induction device

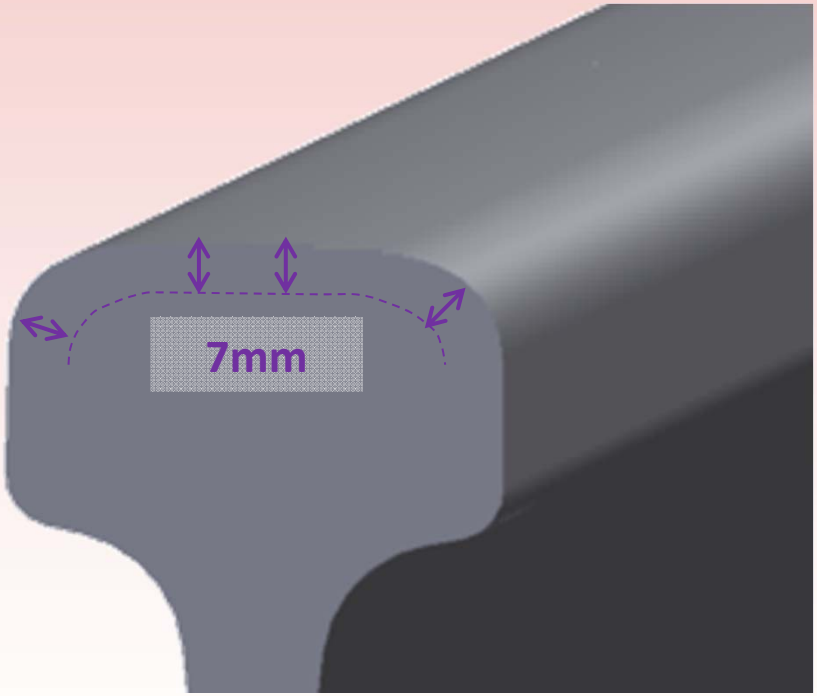
MRX Technologies is based in the UK.

Formal name – Rail Surface Crack Measurement System (but we call it the MRX)

How does the MRX measure cracks?

- The MRX magnetizes the rail head, which introduces lines of magnetic flux
- The flux is measured by the sensors
- If cracks are present, the flux strength changes, and that change is measured by the sensors
- The MRX was calibrated by comparing changes in flux strength with actual crack depths in rail samples examined in the UK

MRX sensor coverage

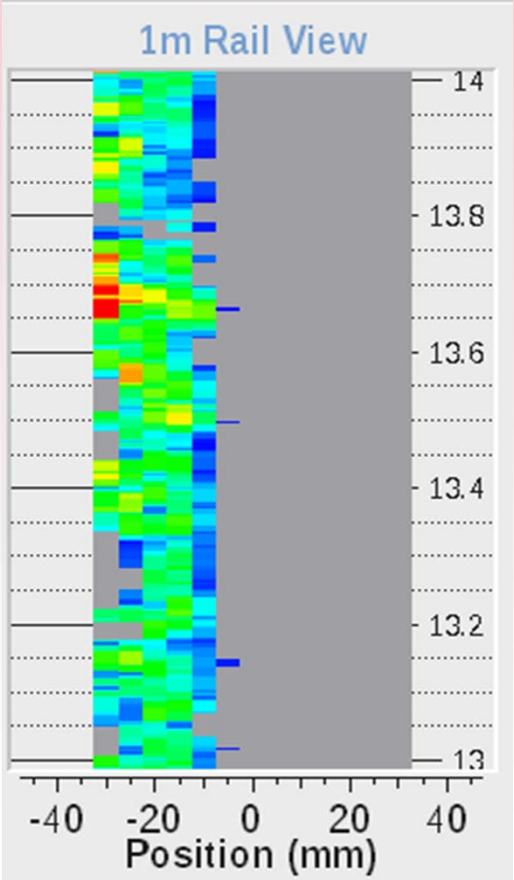


The MRX

- covers the entire rail head, and
- reports crack depth in the top 7 mm of the rail.

MRX data presentation

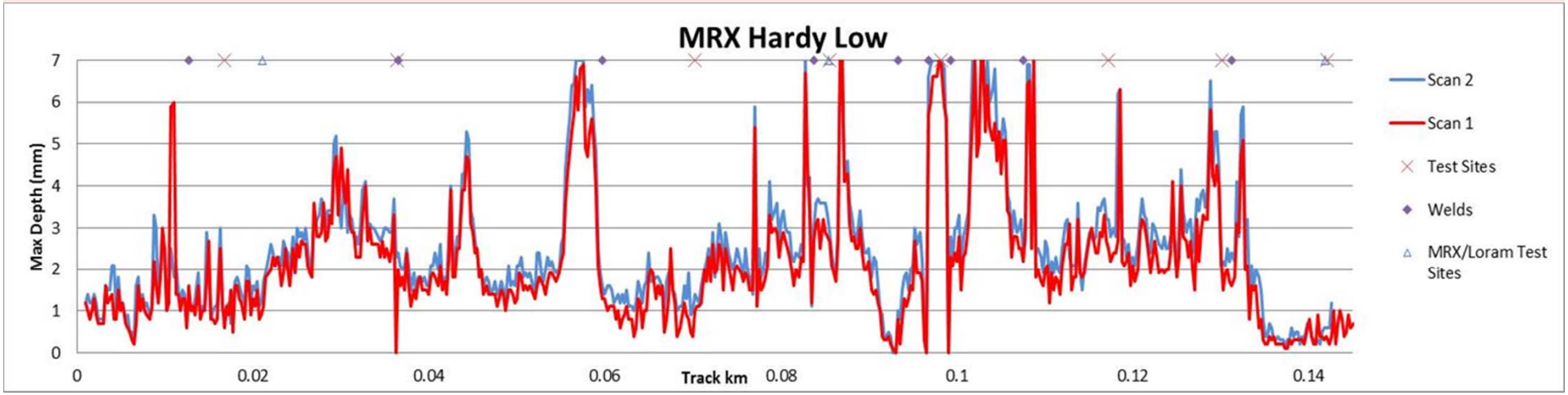
Shallow Damage  ***Deep Damage***



- Vertical - 1 meter of rail
- Horizontal – full rail head width
- Pixels 25 mm x 5 mm, display defect position on the rail head
- Pixel color indicates signal intensity

MRX data presentation

- Graph reports deepest crack for each meter of track; the entire width of the head is evaluated
- In this example, the length of track is 0.14 kilometers (about 450 ft) and the maximum crack depth reported is 7 mm (0.280”)



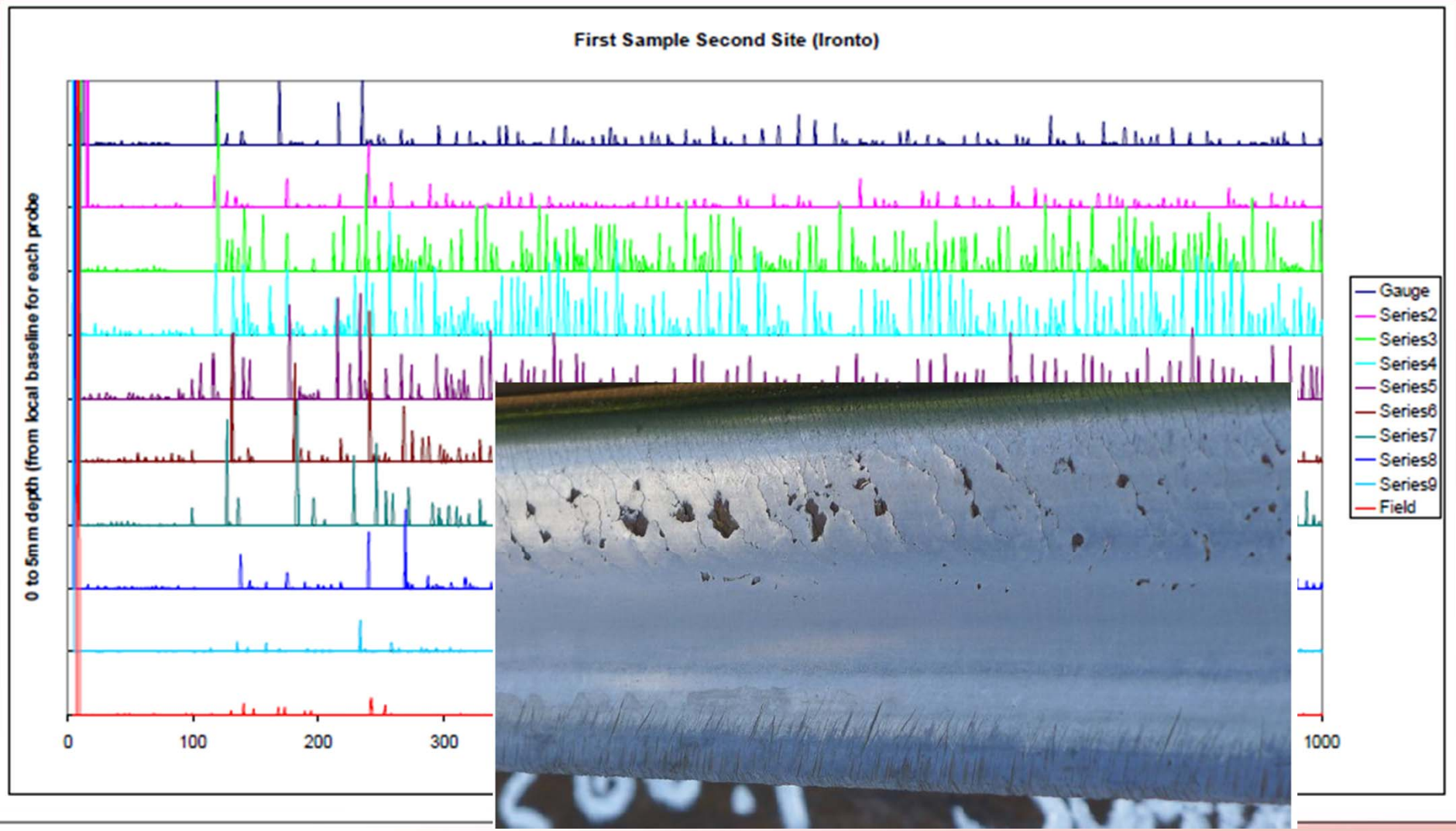
3. Sperry eddy current device

The eddy current roller search unit contains ten probes, each of which has a measurement width of 1/4” (2-1/2” of rail head is inspected)

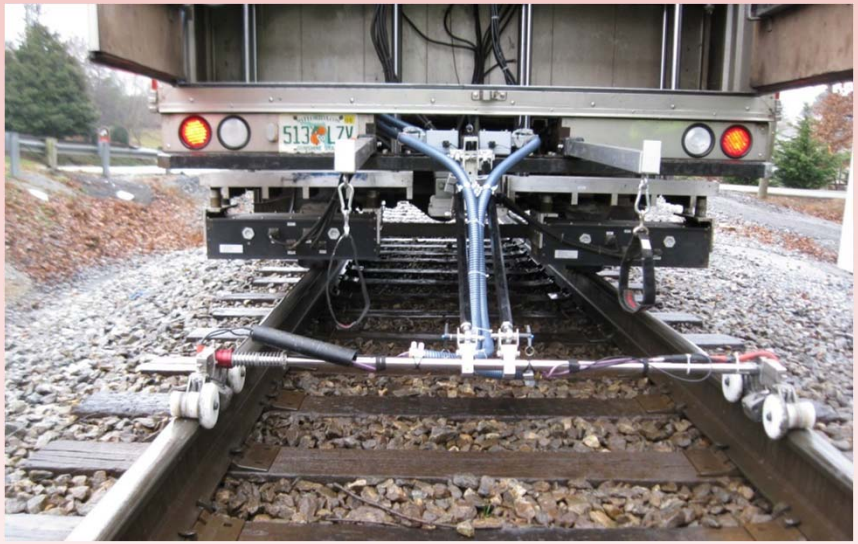
Crack measurement process similar to other eddy current devices:

- crack length is measured
- crack angle is assumed
- crack depth is calculated

Sperry data presentation



4. ARM, IE & Rohmann eddy current buggy



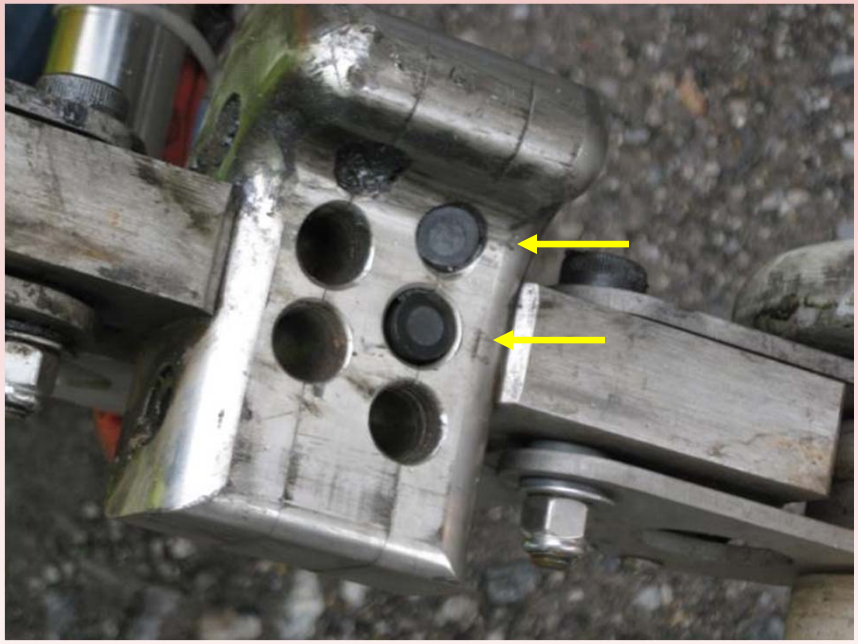
- Advanced Rail Management provided the truck
- International Engineering provided the buggy
- Rohmann provided eddy current technology and data collection

Buggy collects crack data from both rails at up to 20 mph.

IE / Rohmann probe assembly

Gage-side view of eddy current probe assembly. The steel block can hold up to six probes, positioned one on the gage face, one at gage corner, and four over the head of the rail.

IE / Rohmann probe measurement area

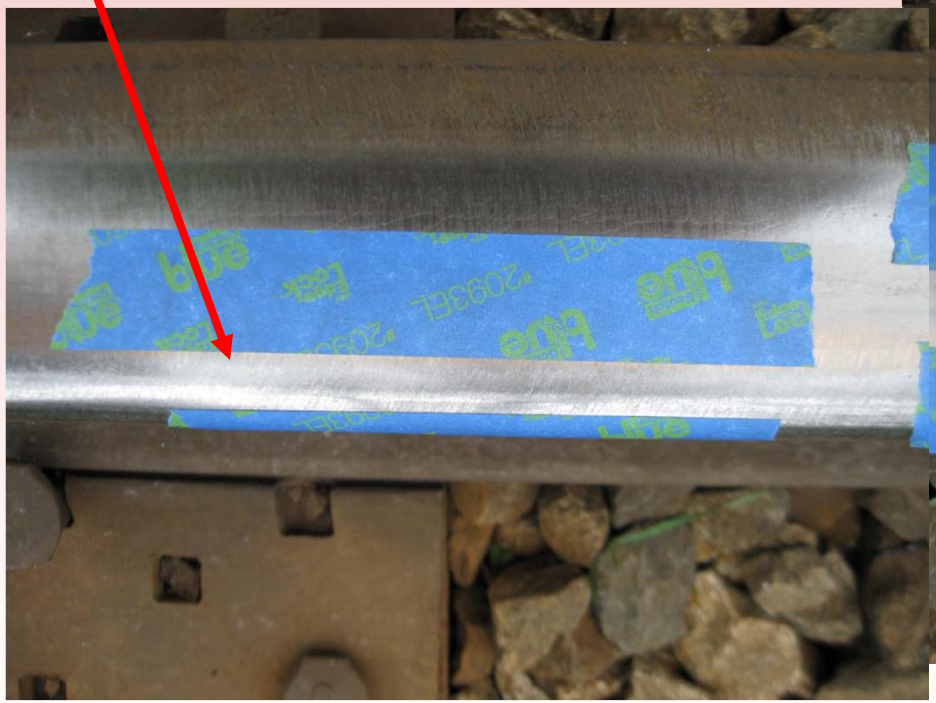


Underside of block showing probes inserted in holes 2 and 4 (hole 1, in the upper left, is filled with curve grease).

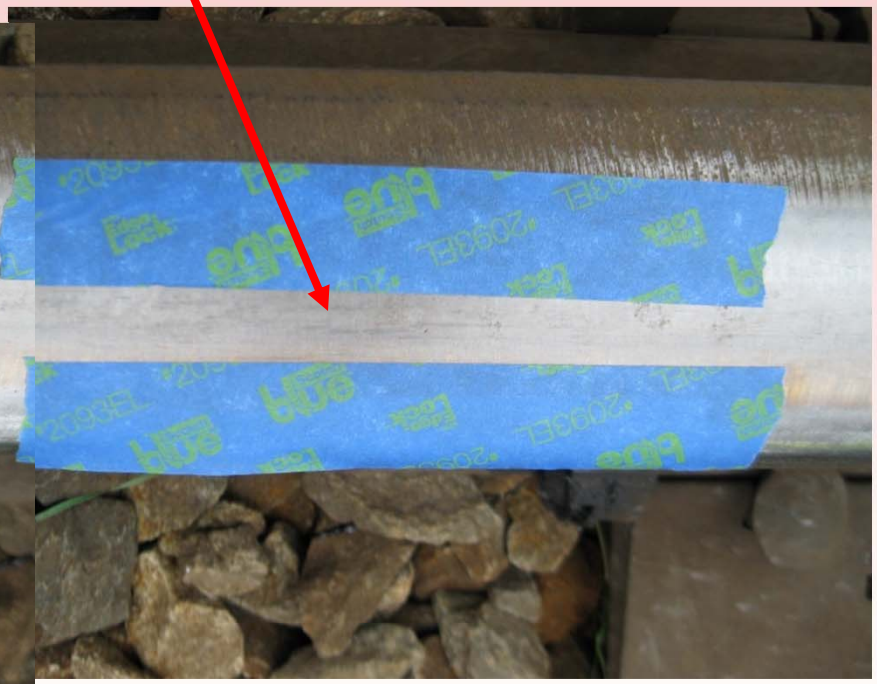
Probe 2 and 4 rail contact bands; probe measurement width is 11 mm

IE / Rohmann probe measurement area

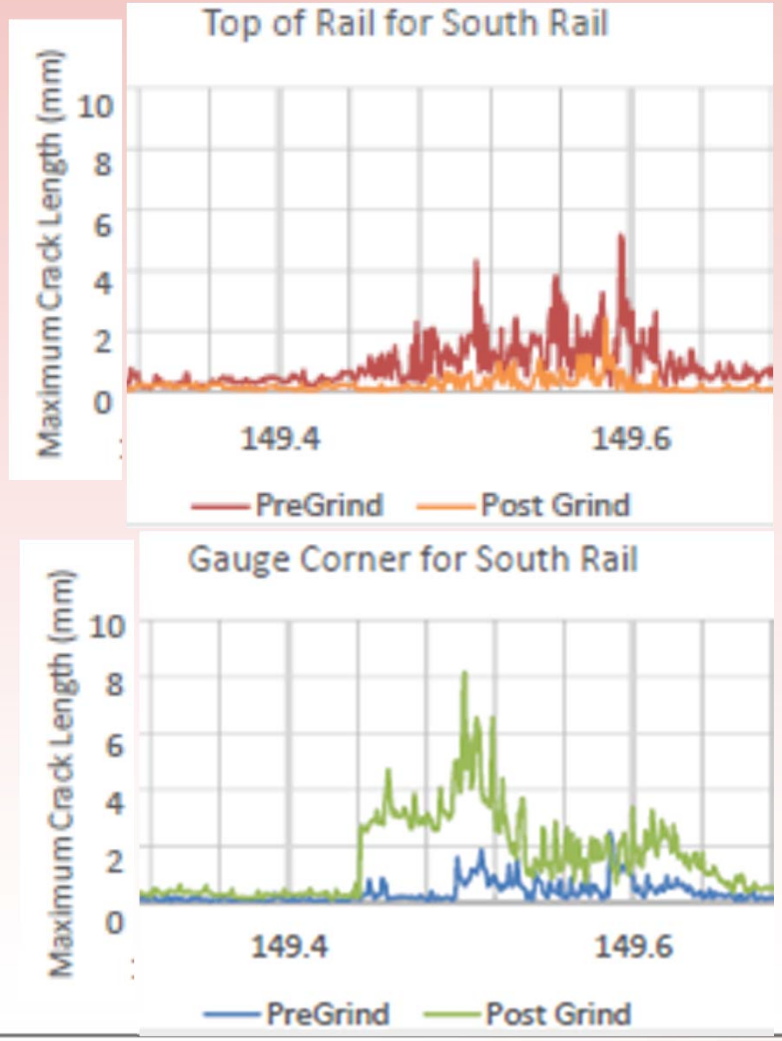
Gage corner probe contact



Head probe contact band

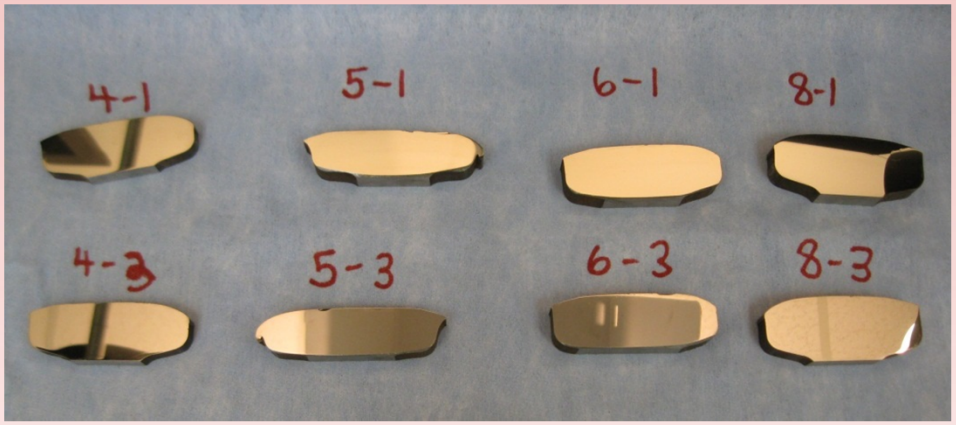


Rohmann data presentation

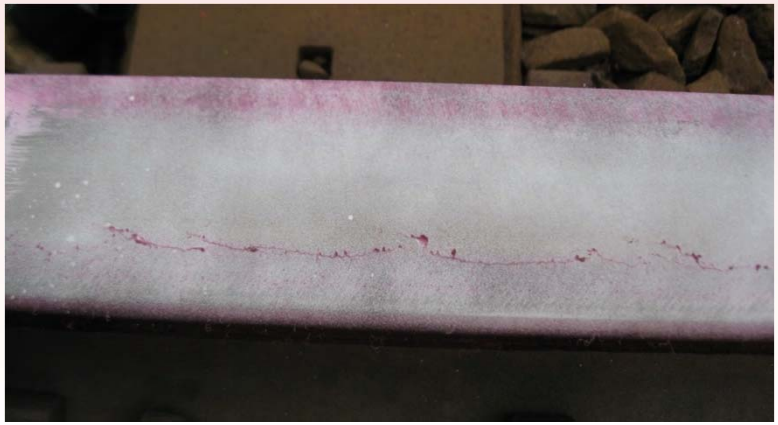


- Cracks are described by their length
- Data from top probe shows a reduction in crack length from pre-grind to post-grind
- Data from gage corner probe is questionable: pre-grind cracks show to be longer than post-grind cracks

Crack measurement validation – 3 methods



Cross-section measurement

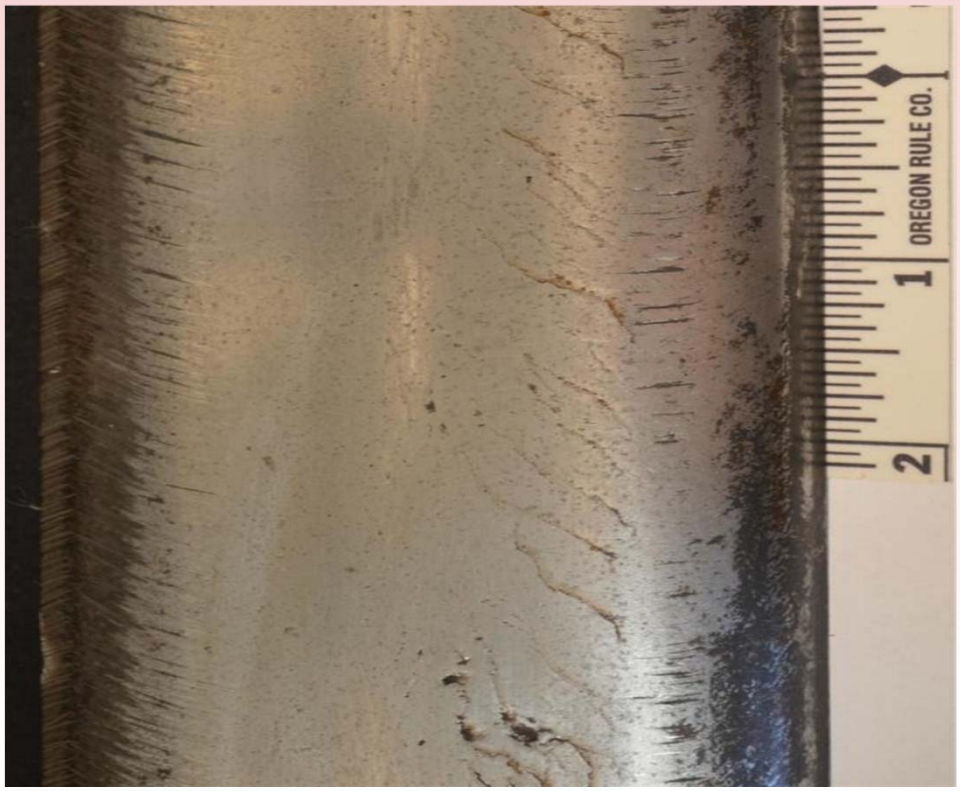


Dye Penetrant (does not confirm depth)

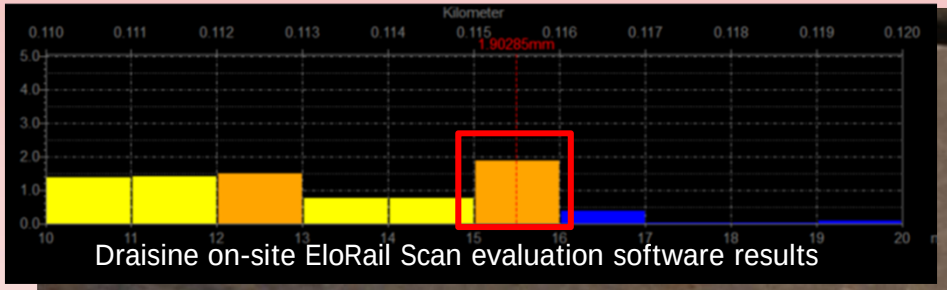
Rail head removal by milling

Cross section, high rail

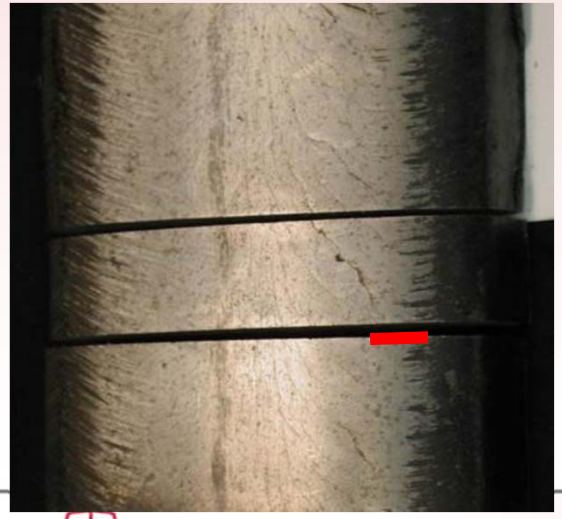
Standard rail, high side of 1˚ curve

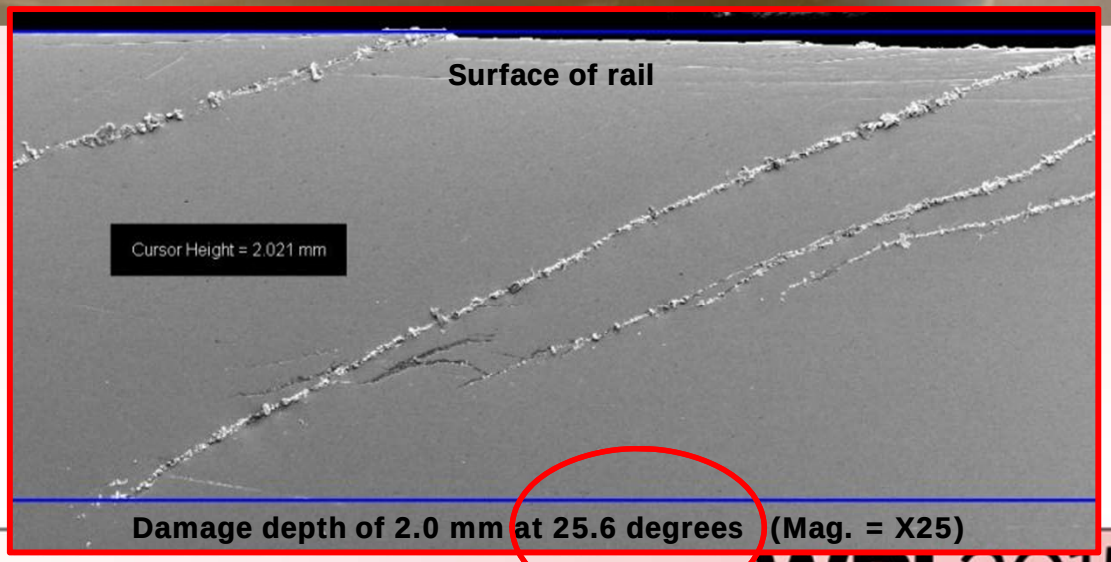


Actual crack depth - 2.0 mm (crack angle 25˚)
Draisine crack depth - 1.9 mm



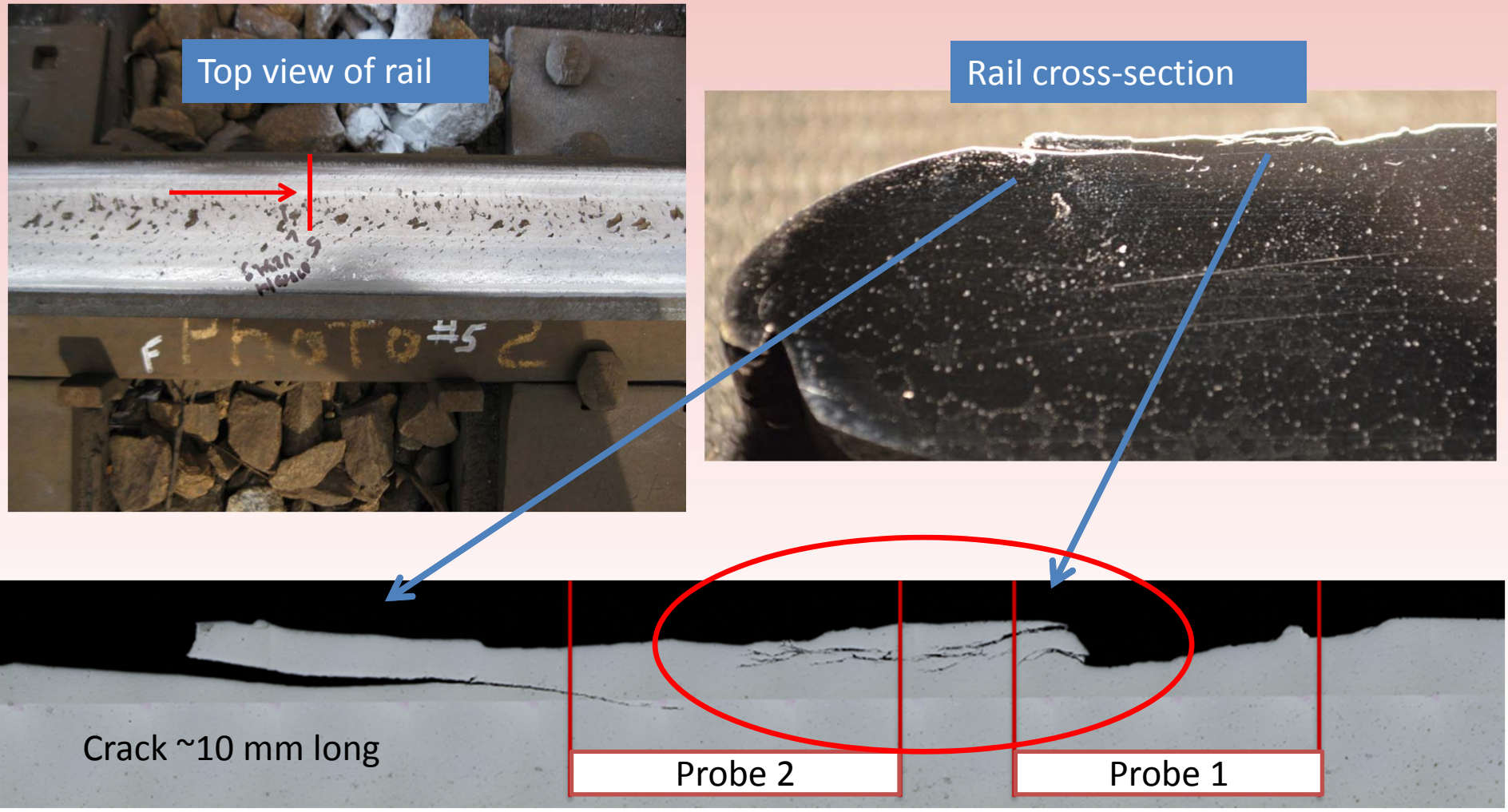
Draisine on-site EloRail Scan evaluation software results





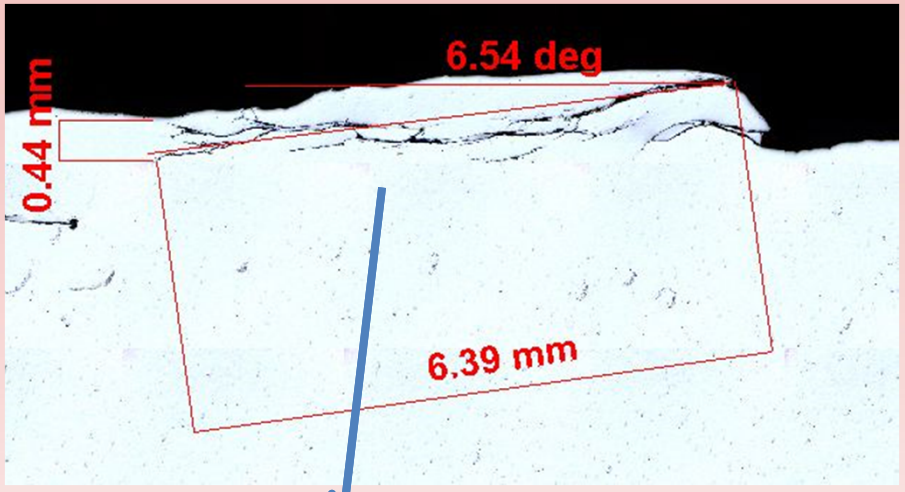
Damage depth of 2.0 mm at 25.6 degrees (Mag. = X25)

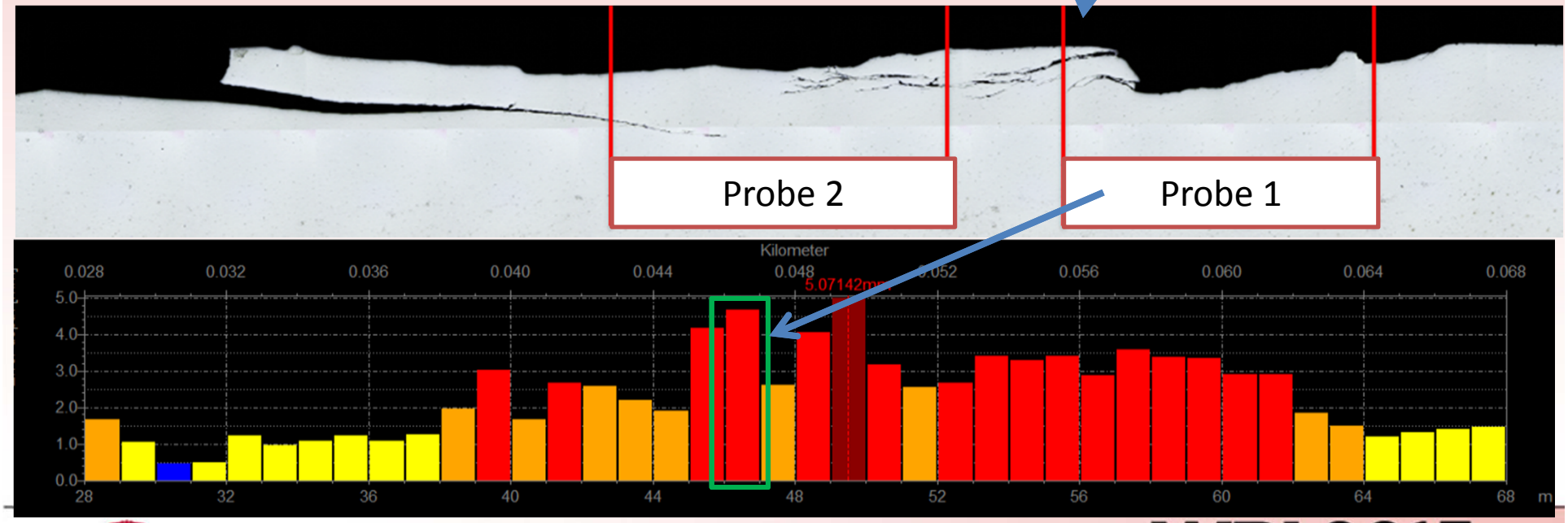
Cross section, low rail



Cross section, low rail

- Crack under probe 1 - actual depth 0.5 mm
- Draisine reported a depth close to 5 mm





Milling, low rail

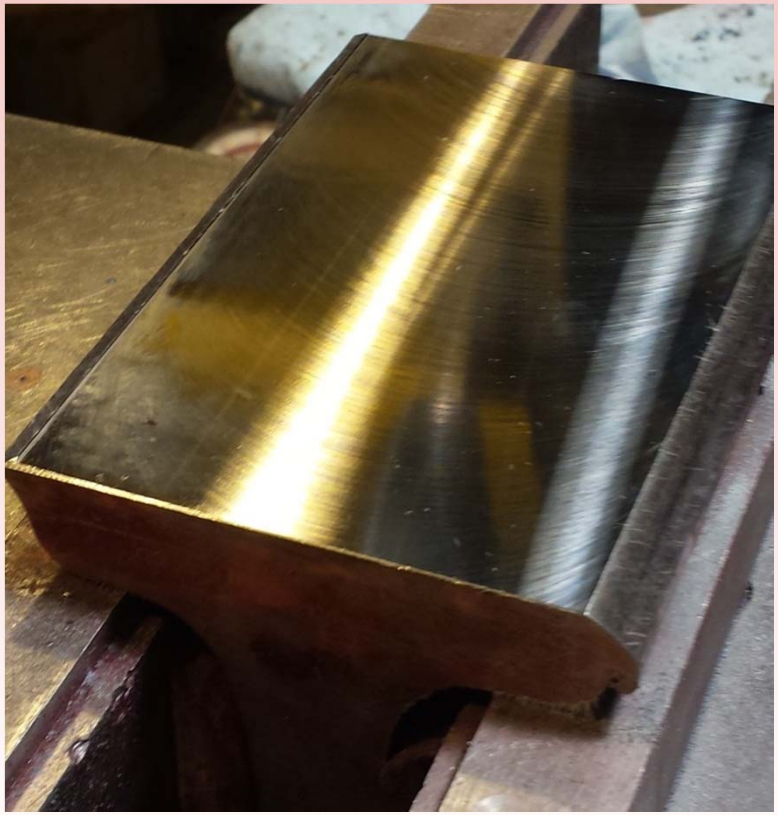
1st pass, depth 0.5 mm (gage near)

9th pass, depth 2.7 mm

Strategy: Repeated passes with a vertical milling machine until all cracks disappear.

Milling, low rail

11th pass, depth 3.5 mm

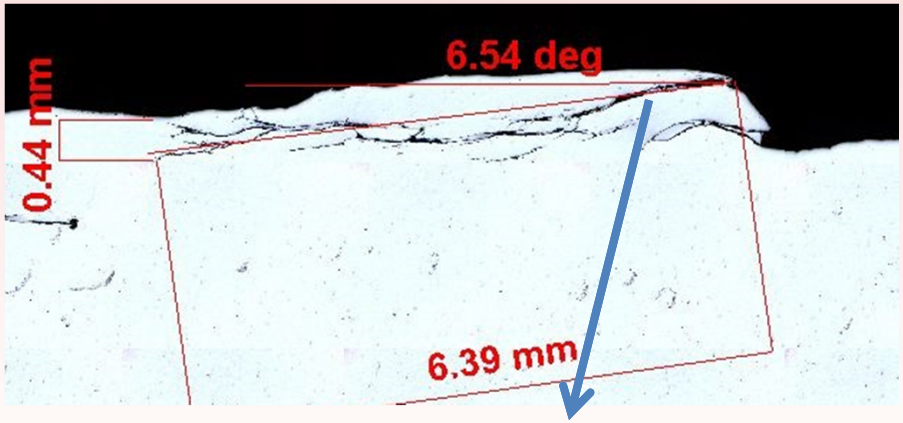


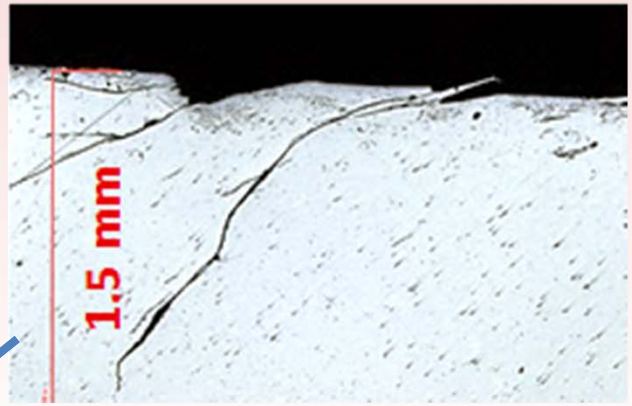
12th pass, no cracks at depth of 3.75 mm

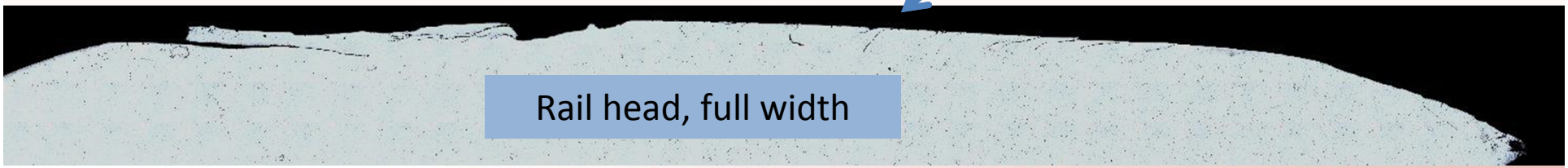
Crack depth results, low rail

Maximum depths

- Milling – 3.75 mm
- Cross section - 1.5 mm
- Draisine – 4.5 mm
- MRX – 7.0 mm

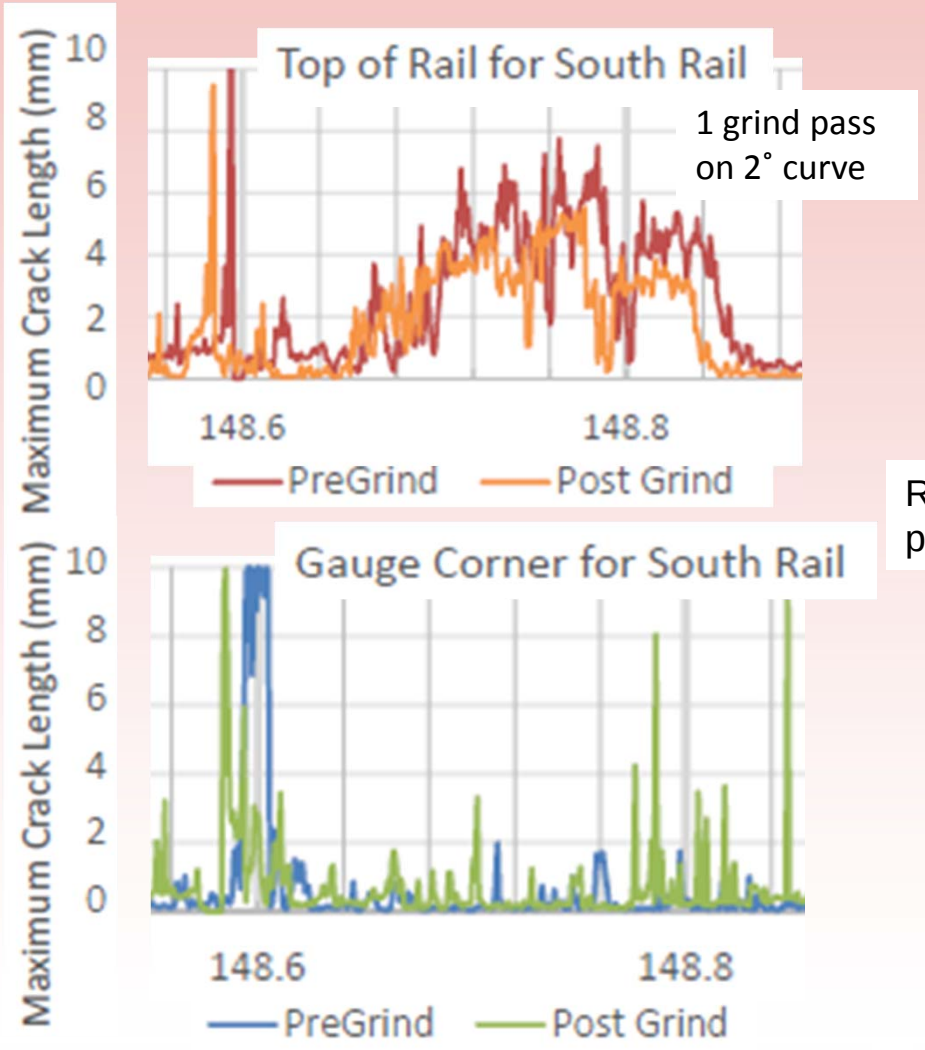




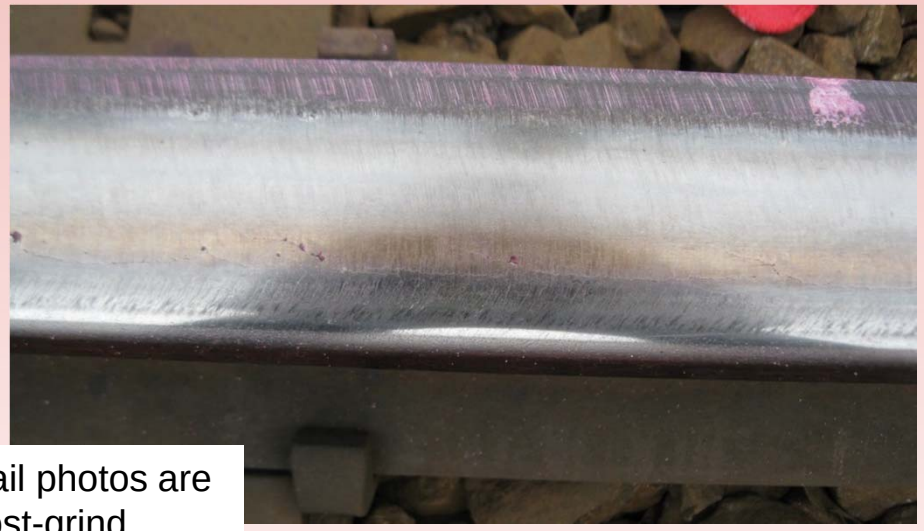


Rail head, full width

Dye penetrant, high rail - Rohmann

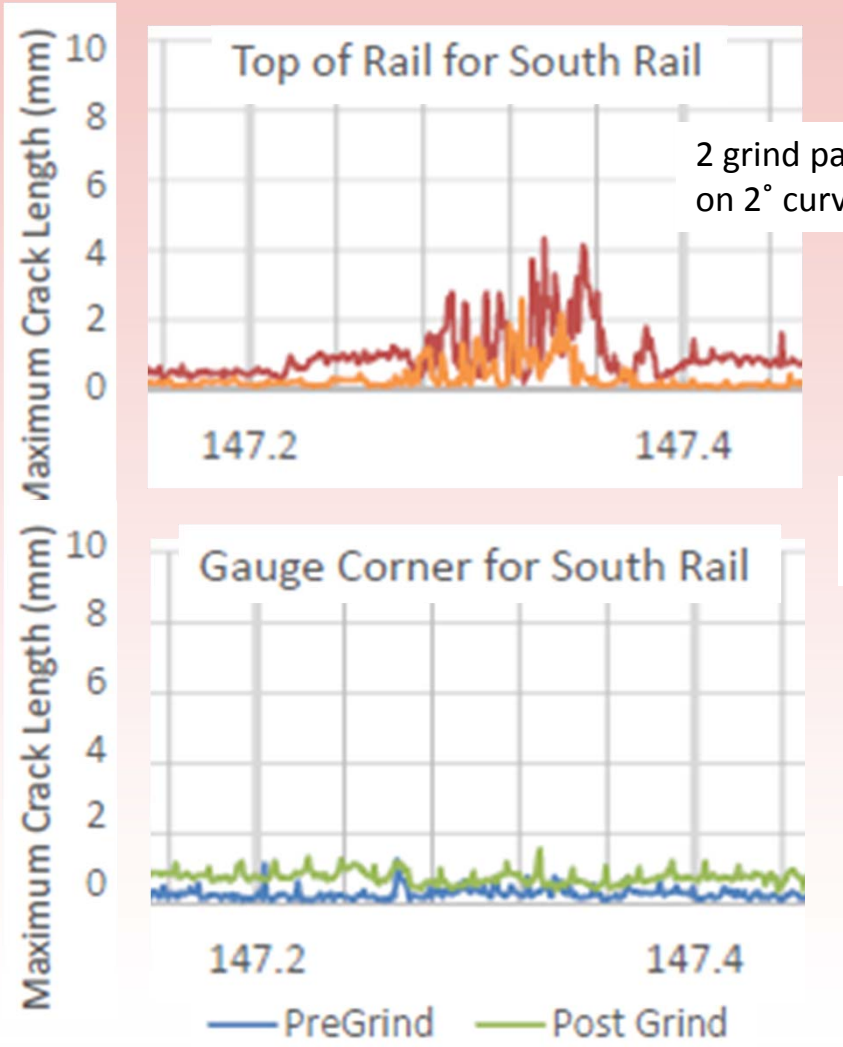


1 grind pass on 2˚ curve



Rail photos are post-grind

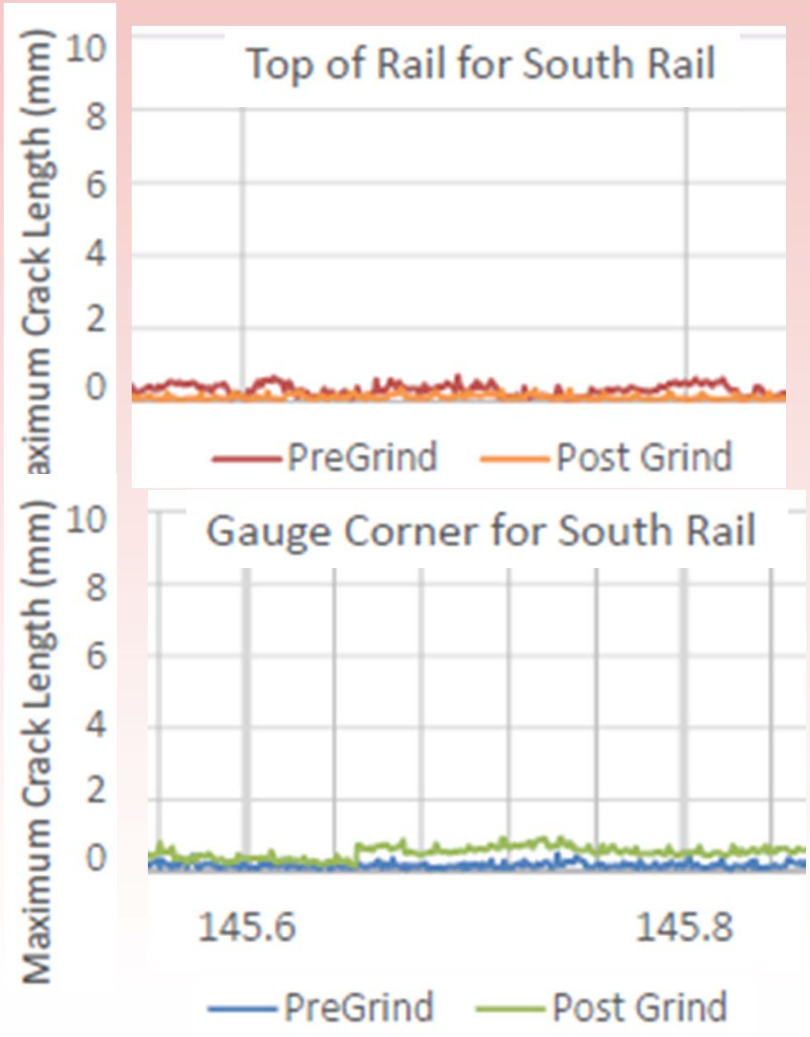
Dye penetrant, low rail - Rohmann



2 grind passes on 2˚ curve

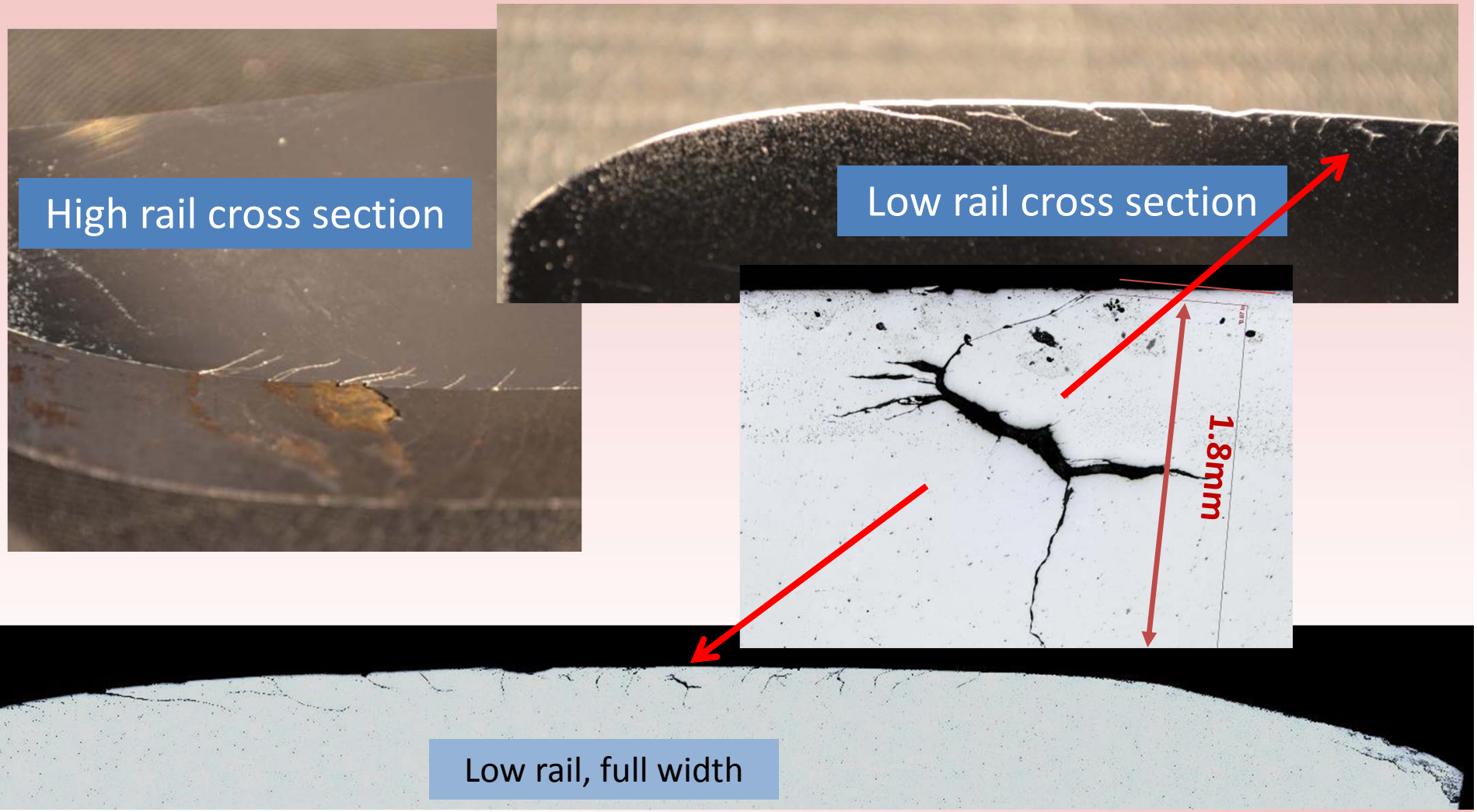
Rail photos are post-grind

Dye penetrant, tangent - Rohmann



Rail photos are post-grind

Crack orientation - high vs. low rails



Conclusions

- Eddy current systems can measure crack length. They can determine crack depth only if the crack angle is known.
- Crack angles vary greatly.
- Both eddy current and electro-magnetic devices tend to over-estimate the depth, sometimes significantly.
- Crack measurement devices can distinguish between rail with cracks and without cracks.

Q 1: Is this technology useful?

Given that these devices cannot measure crack depth reliably, can we still derive value from what they can tell us about our rail?

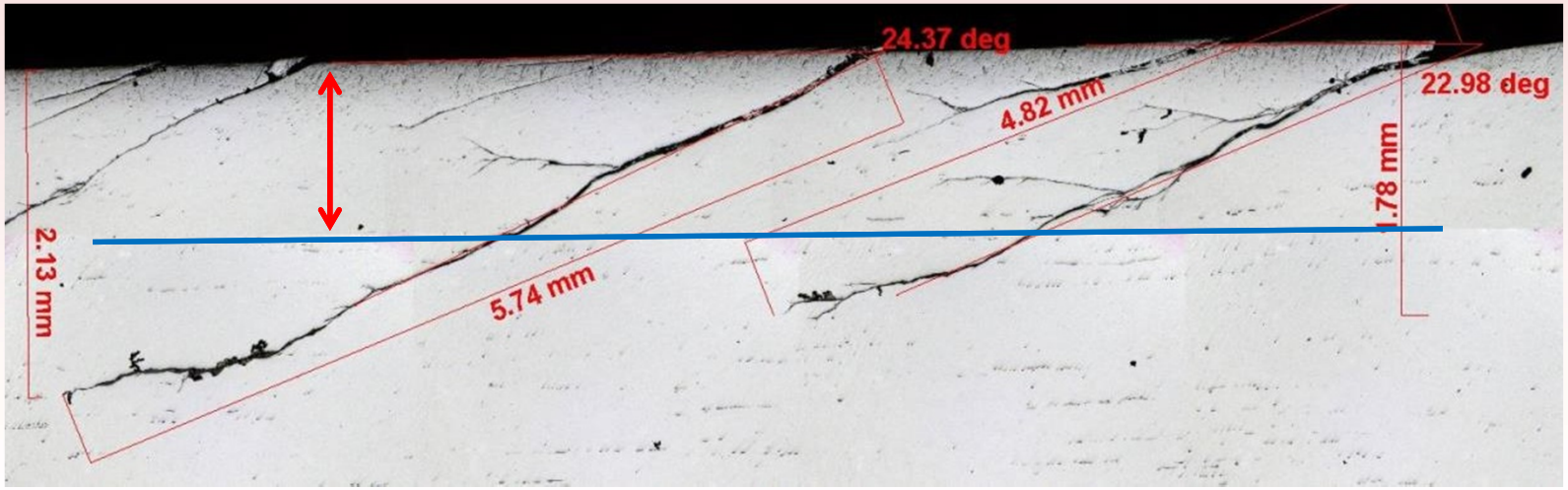
Crack measurement devices can:

- distinguish between rail with and without cracks, and
- provide a qualitative assessment of RCF; a strong electro-magnetic response typically indicates long cracks and a heavily damaged rail surface.

Example: A crack measurement device, placed on a pre-grind inspection vehicle, should inform the operator whether the RCF is light, medium or heavy. He can specify a number of grinding passes.

Q 2: How important is complete crack removal?

What is the consequence to the crack growth rate, RCF development and defect formation if the grinder removes only 1 mm of metal (5 passes by a big grinder). In this rail, cracks 2 - 3 mm in length would remain!

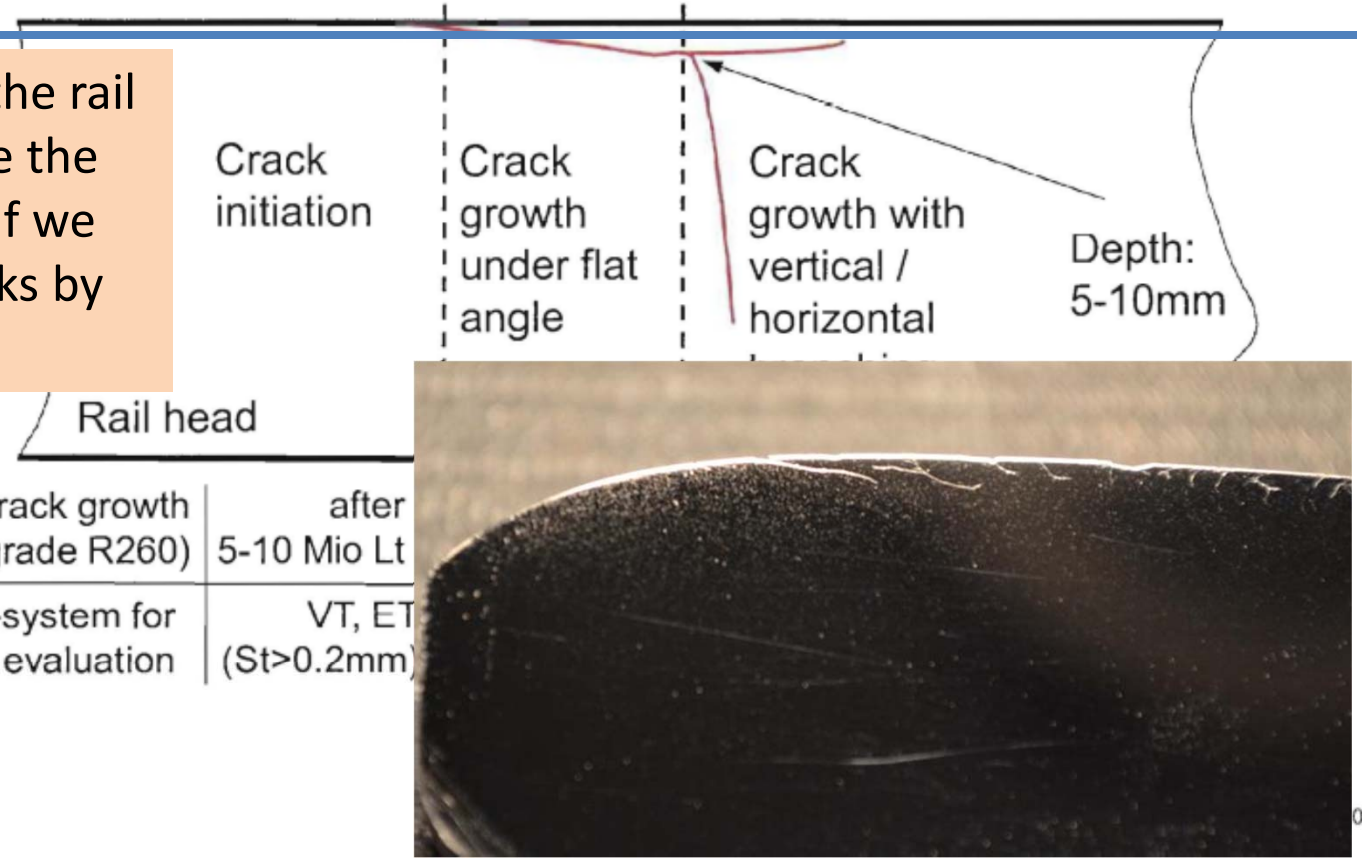


Crack growth divides into three stages

DB NETZE

Head Checks – Path of crack and speed of crack growth

Do we strengthen the rail surface, and reduce the crack growth rate, if we shortened the cracks by grinding?



Rate of crack growth (steel grade R260)	after 5-10 Mio Lt
ZfP-system for evaluation	VT, ET (St>0.2mm)

DB Netz AG, 30.03.2010

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Answers?