Electromagnetic measurement of rail surface cracking

Eric E. Magel

National Research Council, Canada

(Latest) Contributors

- Bob Harris – Loram
- Dave Sheperd and Kristie Drawe - BNSF
- Brad Kerchof - NS

- Eric Eberius (Rohmann)
- Stephanie Klecha – MRX (UK)
- Scott Saunders, Ron Davis, Simon Broomhead - Sperry Rail (UK/Canada/USA)

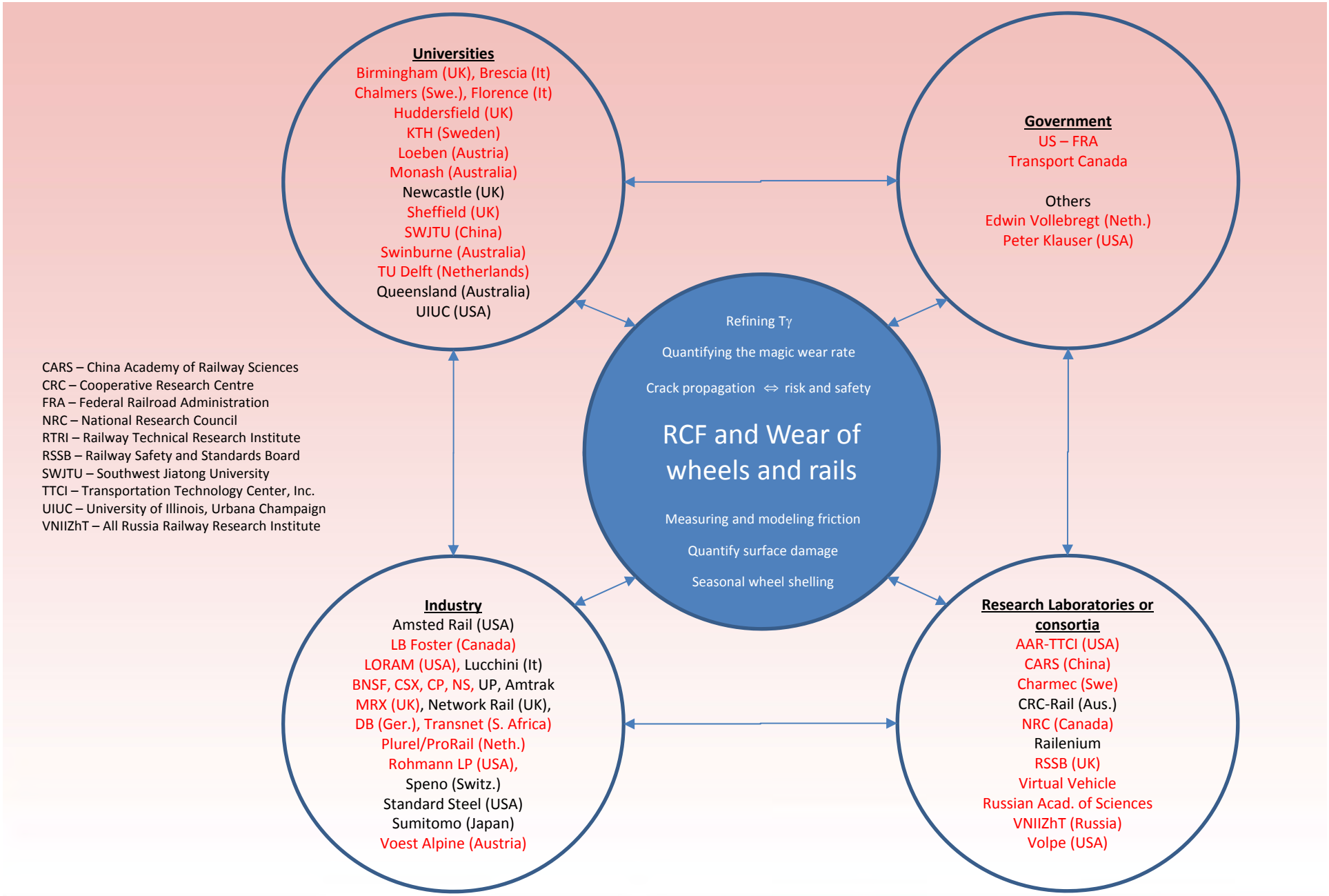
- Ali Tajaddini – FRA R&D
- CaRRL – CDN Railway Research Laboratory

Outline

- Motivation
- Measuring results
- Where next?

An International Collaborative Research Initiative

on rolling contact fatigue and wear of rails and wheels



CARS – China Academy of Railway Sciences
CRC – Cooperative Research Centre
FRA – Federal Railroad Administration
NRC – National Research Council
RTRI – Railway Technical Research Institute
RSSB – Railway Safety and Standards Board
SWJTU – Southwest Jiatong University
TTCI – Transportation Technology Center, Inc.
UIUC – University of Illinois, Urbana Champaign
VNIIZhT – All Russia Railway Research Institute

Current Tasks, leaders

Klaus Six / Edwin Vollebregt
ICRI-FrictionModeling

Roger Lewis
ICRI-Wear Mapping

Eric Magel
ICRI-MagicWearRate
ICRI-QuantifySurfaceDamage
ICRI-WebExBriefs
ICRI-DefinitionScope

International Collaborative Research Initiative (ICRI) on RCF and Wear of Rails and Wheels

Adam Bevan
ICRI- WheelSteel
ICRI-RailSteel

ICRI-SubSurface

Roger Enblom / Adam Bevan
ICRI-WheelDamage

ICRI-ResidualCracks

ICRI-Safety

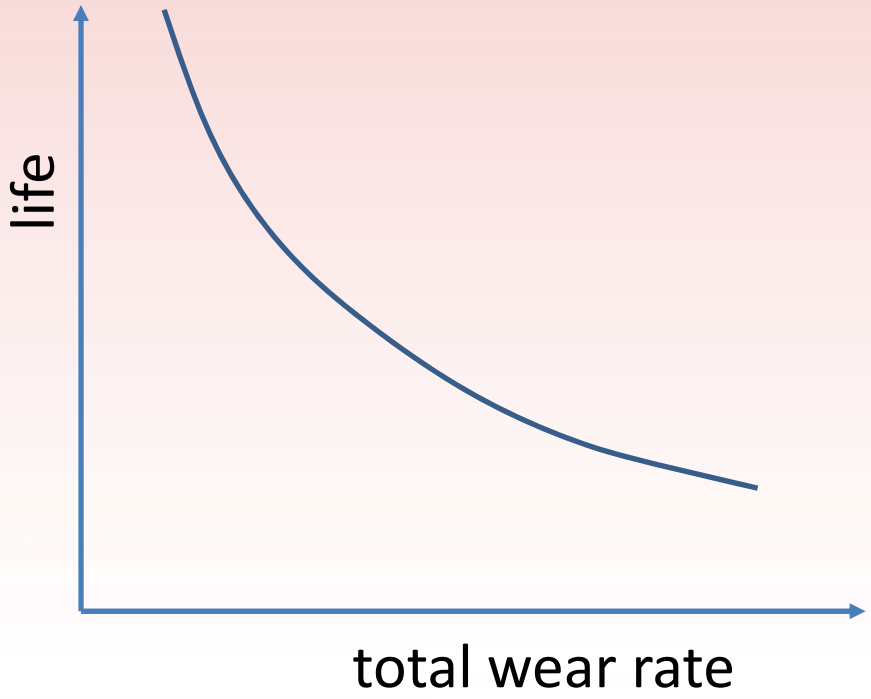
Quantify the Magic Wear Rate

Robert Frohling, Martin Hiensch, John Tunna, Darrien Welsby, Bob Harris, Ryan McWillliams, Tom O'Brien, Eric Eberius, Andrea Ghidini, Chang Chongyi

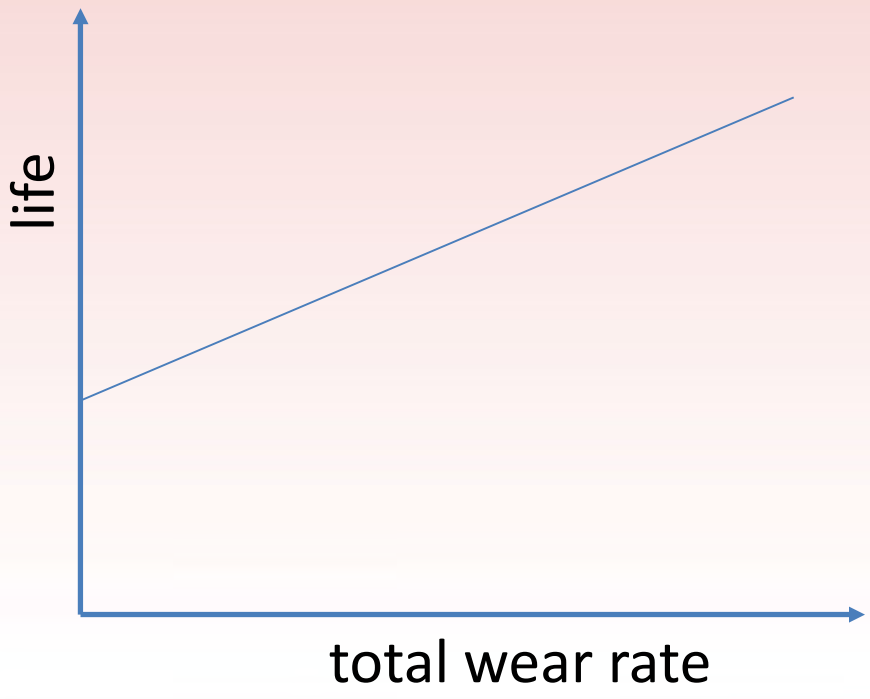
Eric Magel

Description

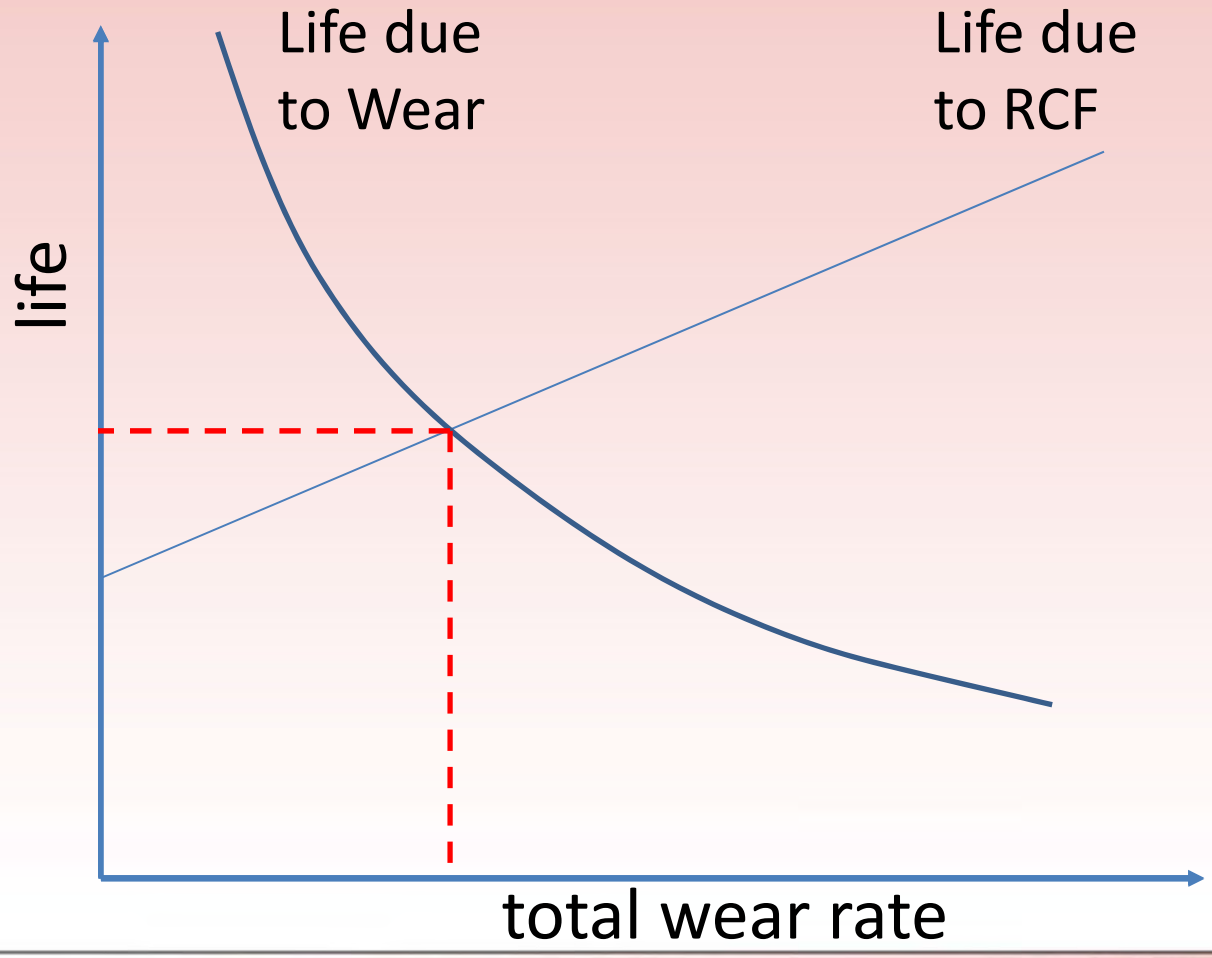
Life due to Wear



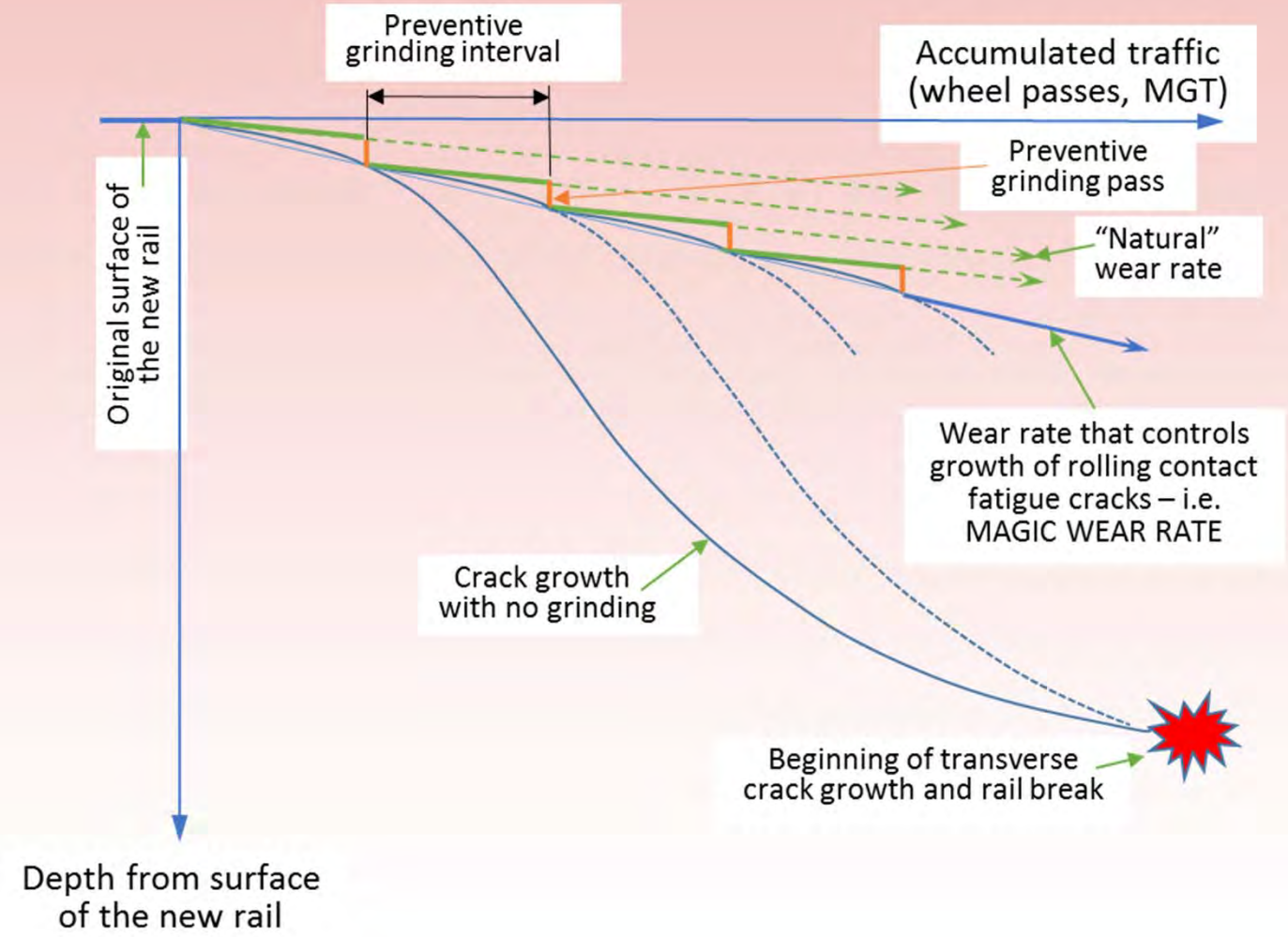
Life due to RCF



Magic Wear Rate

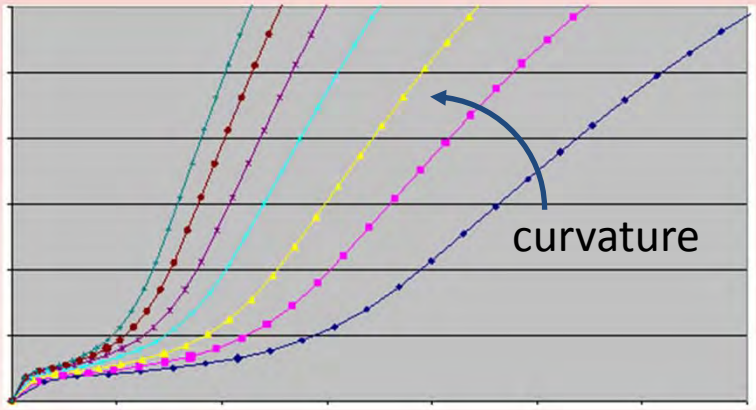


Crack Initiation and Growth



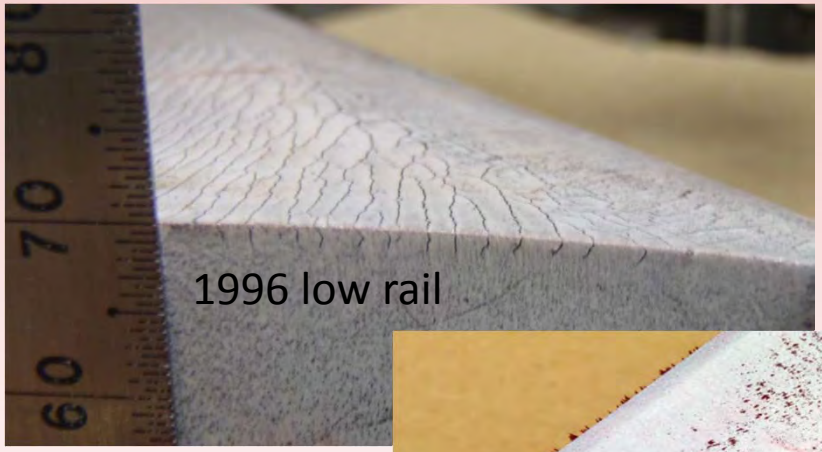
A family of crack growth curves

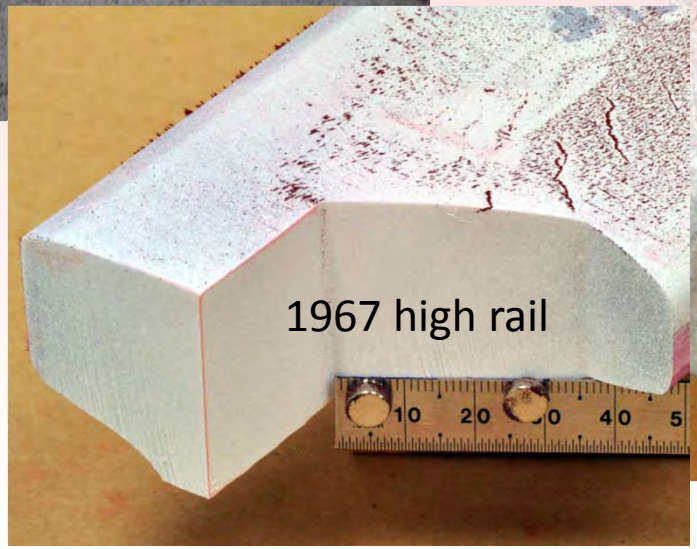
- probably for different
  - rail steels
  - curvature
  - traffic types (e.g. passenger, transit, freight)
  - environmental conditions
  - friction regimes

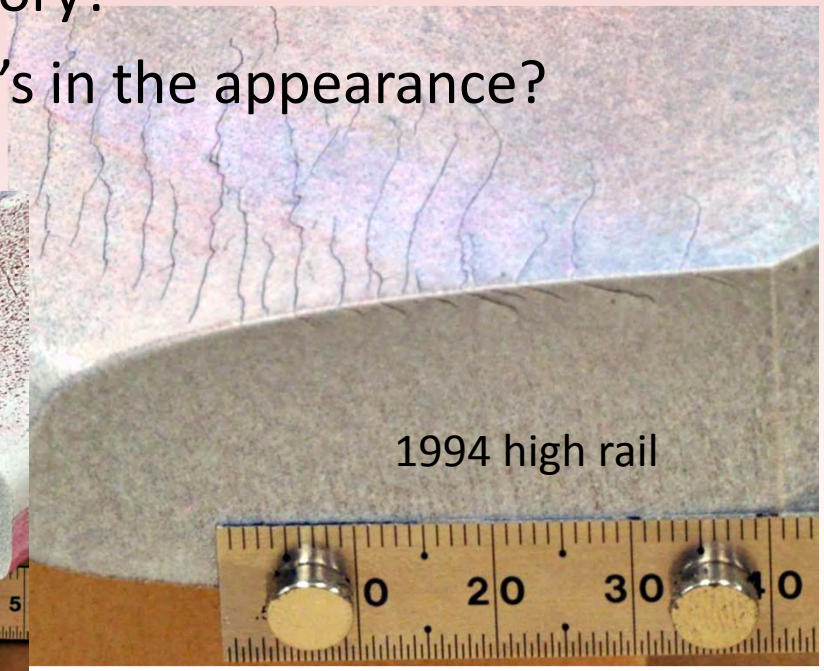


Atlas of Rail Surface Fatigue

- Currently: interpreted by grind inspector, based on experience
- different from territory to territory?
- what's in the appearance?







The measuring systems

MRX

Sperry

Rohmann

Three Previous Validation Studies

1. CSX Rail Samples - June 2013
   - CSX track in the Bluefield Mountains, TN
   - Documented Draisine/RSCM measurements
   - 30 rail samples taken at varying levels of fatigue
   - rail samples sent to MRX in Australia
2. CSX Pre/Post Grinding - February 2014
   - CSX track in Kentucky, 3 days of grinding
   - 7 test sites, pre/post grind documentation & measurements
3. NS Hardy Samples - February 2014
   - Previous NS & Loram test sites at NS Hardy curve
   - 8 rail samples

Validation Study #4

BNSF Staples subdivision

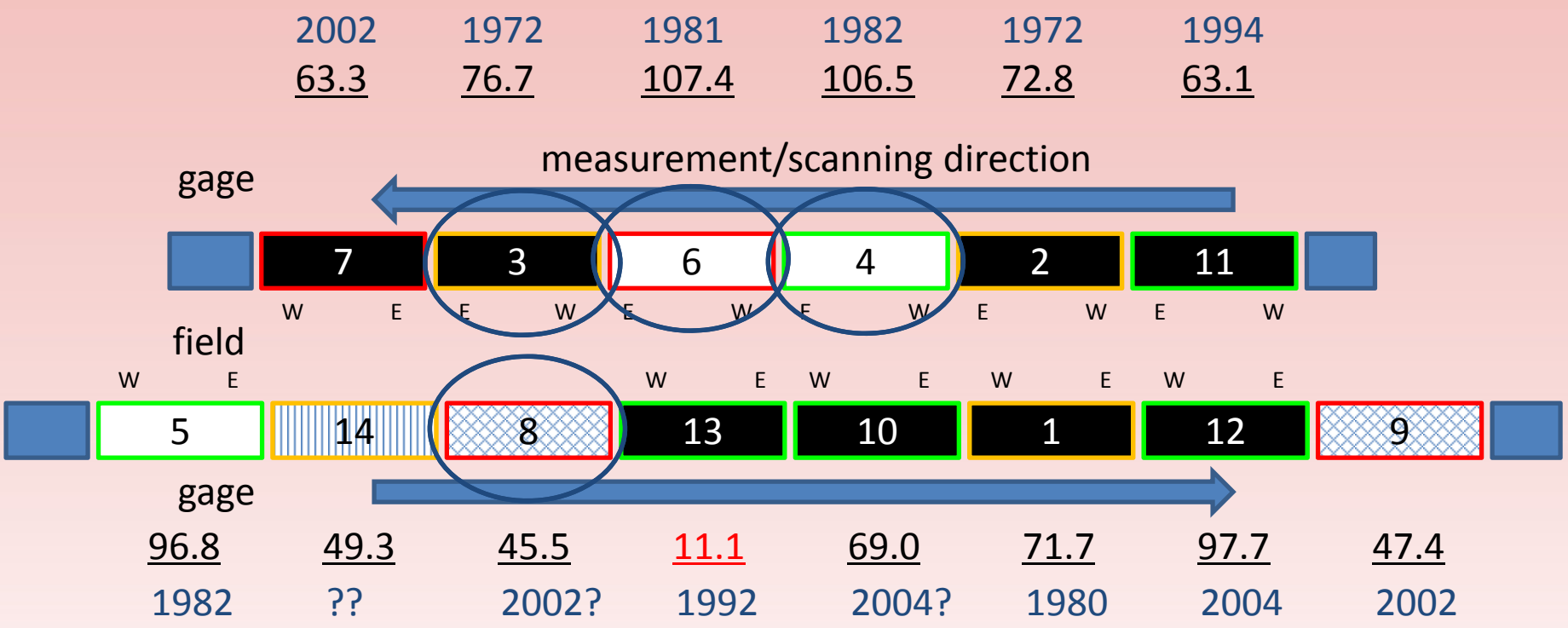
16 rail samples

14 samples in 2 strings

Broken rail assembly
(samples 15 and 16)

#14 – NS Sample

#9 – Crossing



visible surface cracking

light

moderate

heavy

sample length (cm)

year of manufacture

run-in rail

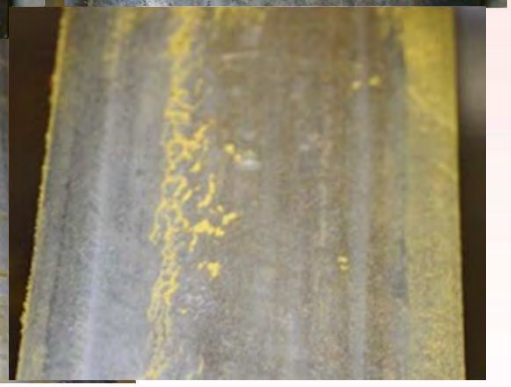
low

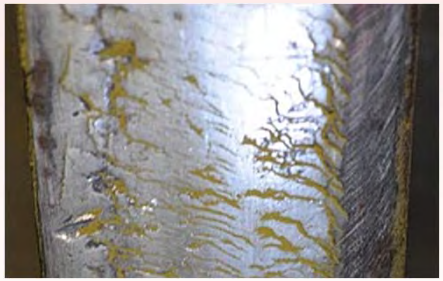
high

crossing

NS sample

4 samples selected for milling

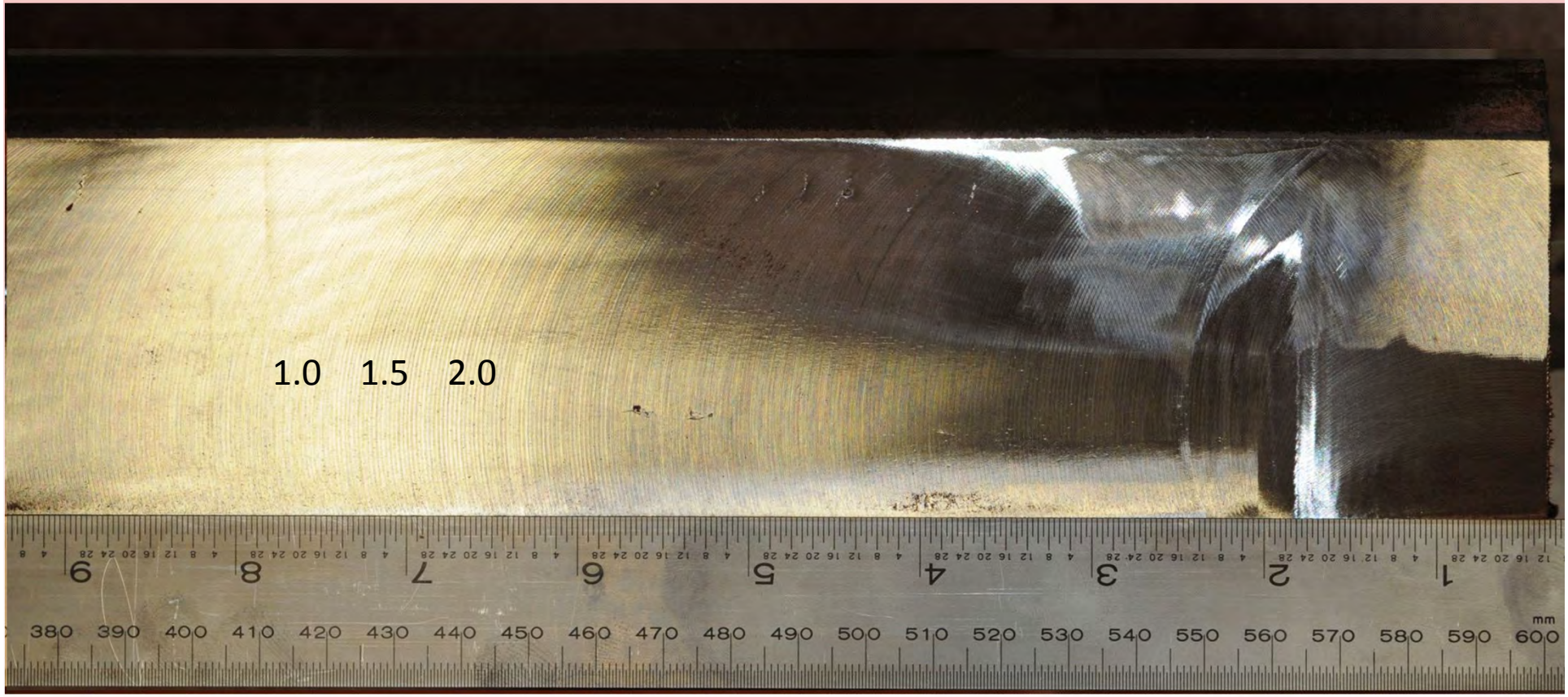




Sample 4 – left end

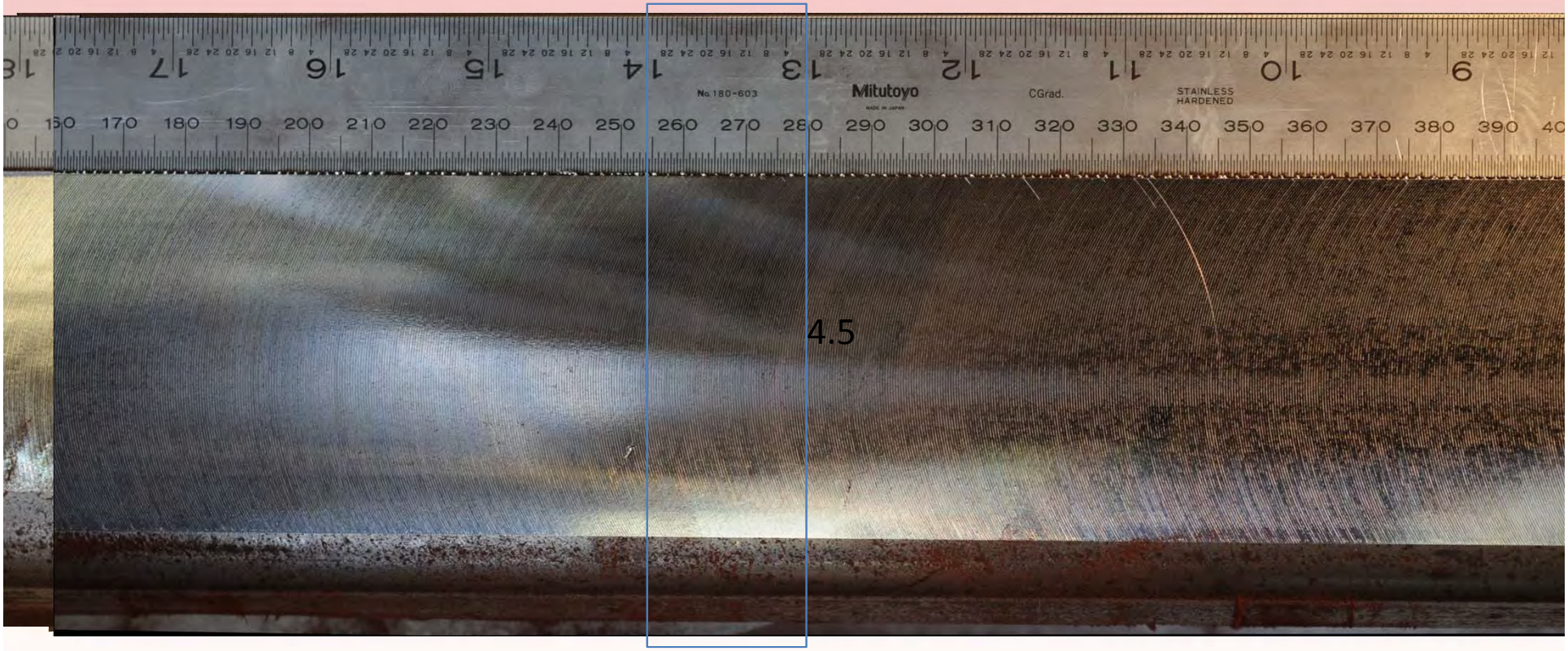
field side

Sample 4 – right end

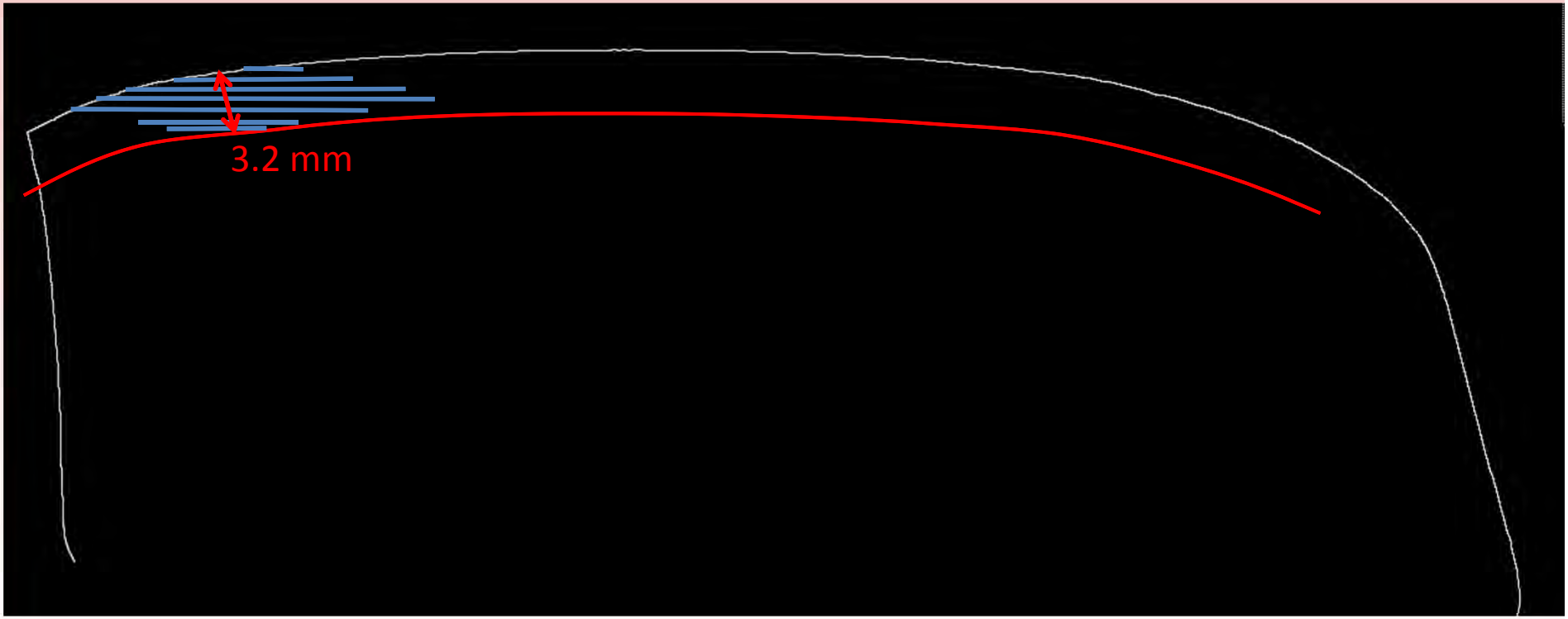


field side

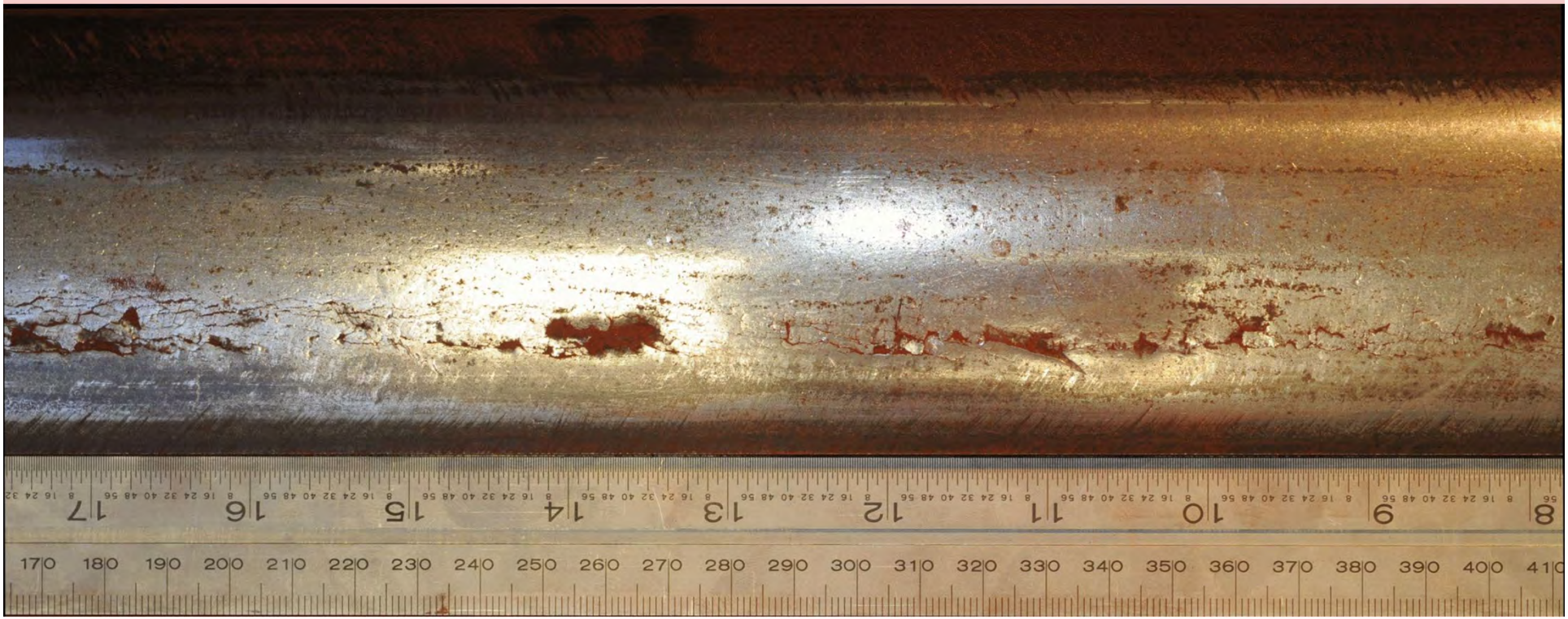
Sample 3



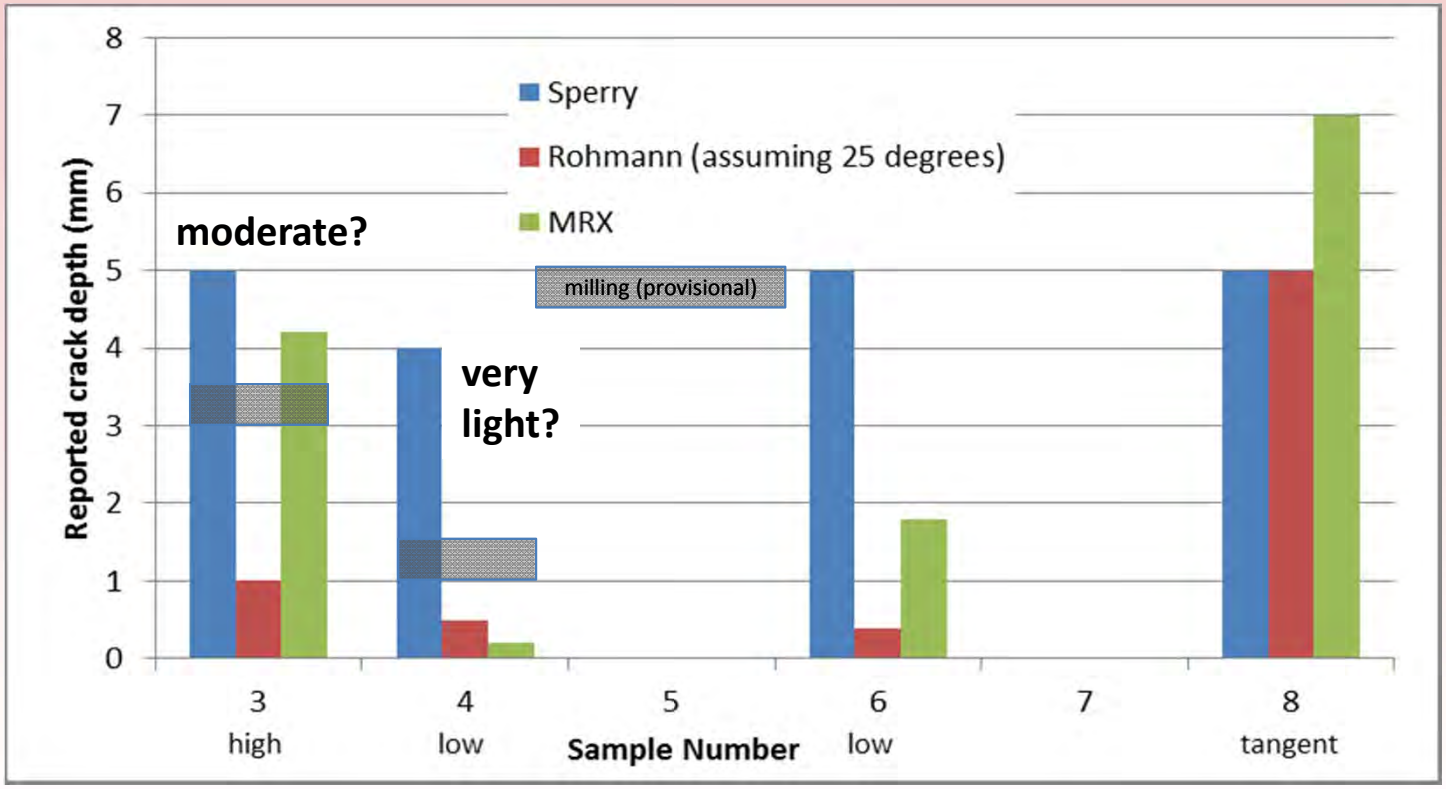
Sample 3: Crack depth



Sample 6



Walking Stick Measurements
BNSF Staples Subdivision



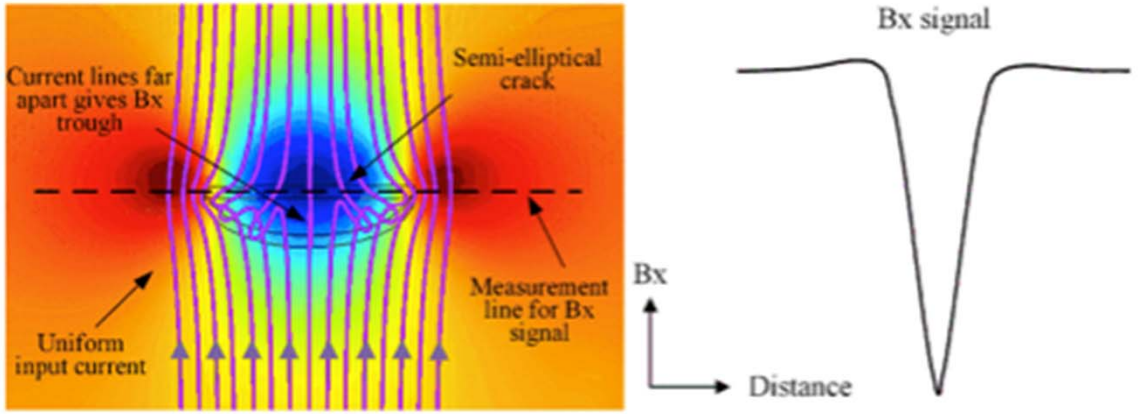
Quantification of RCF cracks using ACFM technology – modelling and experimental verification

Professor Claire Davis – University of Warwick, UK
Jialong Shen, Frank Zhou (UoW) and
Gemma Nicholson, Hamed Rowshandel (UoB)

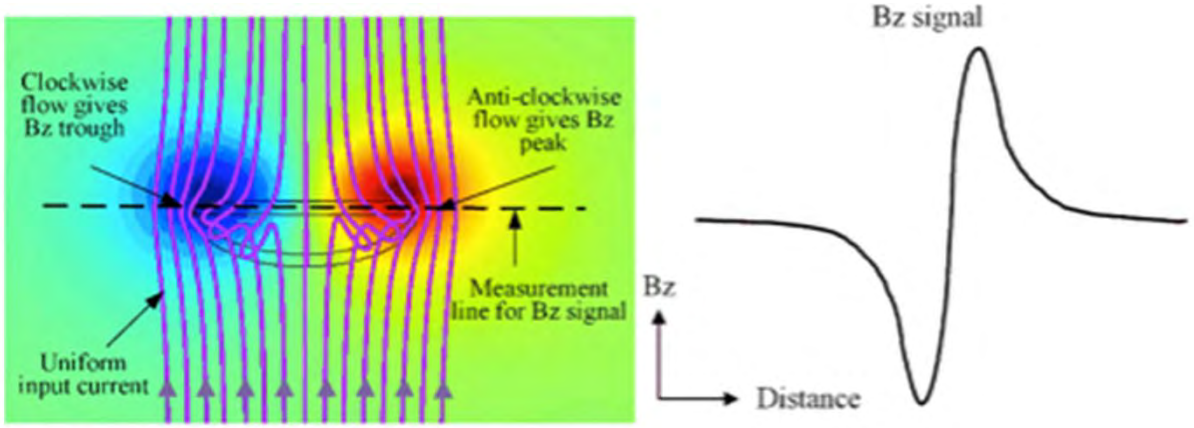
UNIVERSITY OF BIRMINGHAM

Modelling ACFM signals for RCF cracks

COMSOL Multiphysics software is used to model the interaction of the electric and magnetic fields generated by the ACFM sensor with RCF cracks in rail.



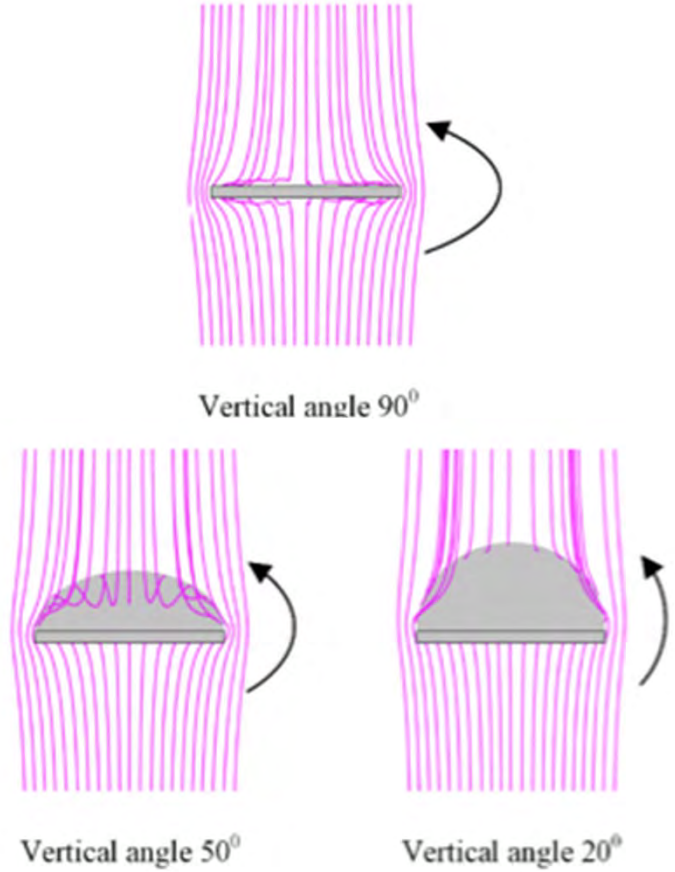
The **Bx signal** reflects the current flow below the crack and can be used to determine the crack pocket length.



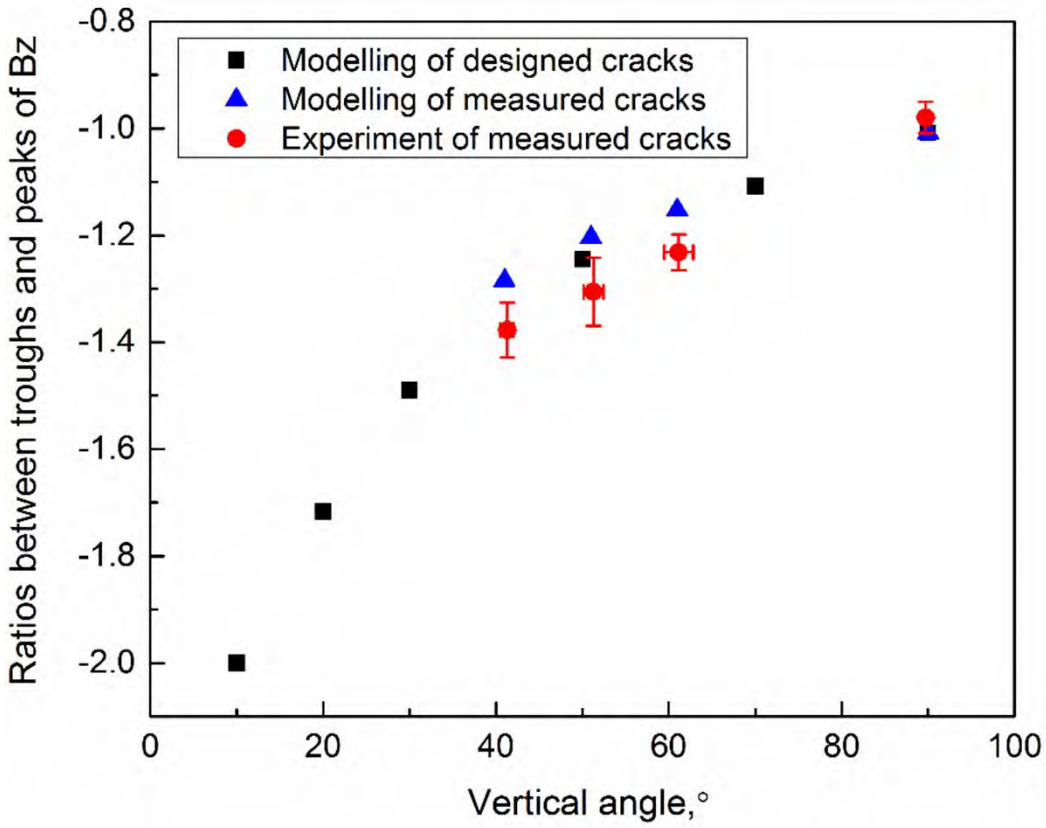
The **Bz signal** reflects the current flow around the crack ends and can be used to determine the crack surface length.

Modelling ACFM signals for RCF cracks

The **Bz signal** can also be used to determine the vertical angle (angle the RCF crack propagates into the rail) due to the shift in position of the current peak intensities.



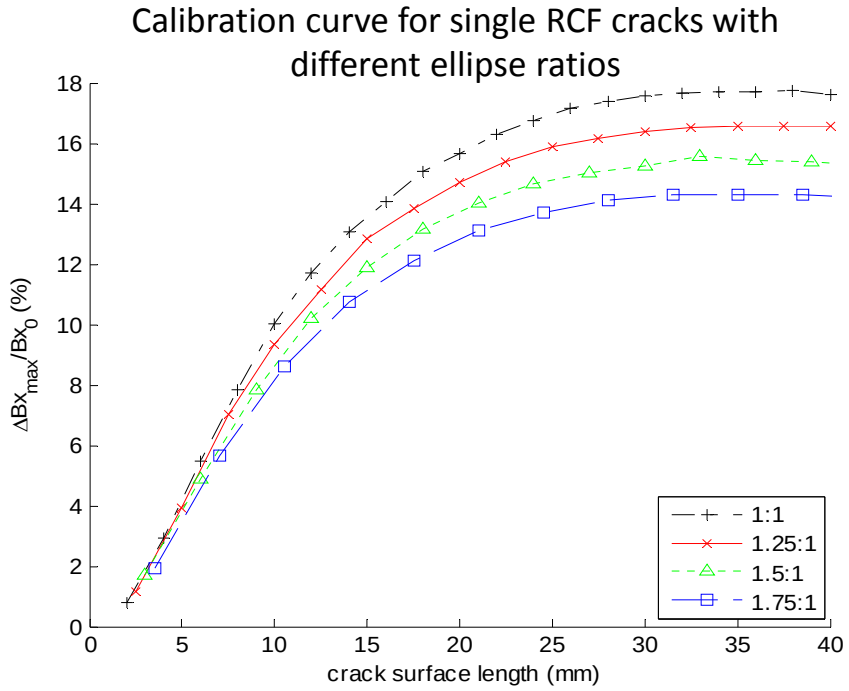
Asymmetry in current flow for an angled crack compared to a vertical crack.

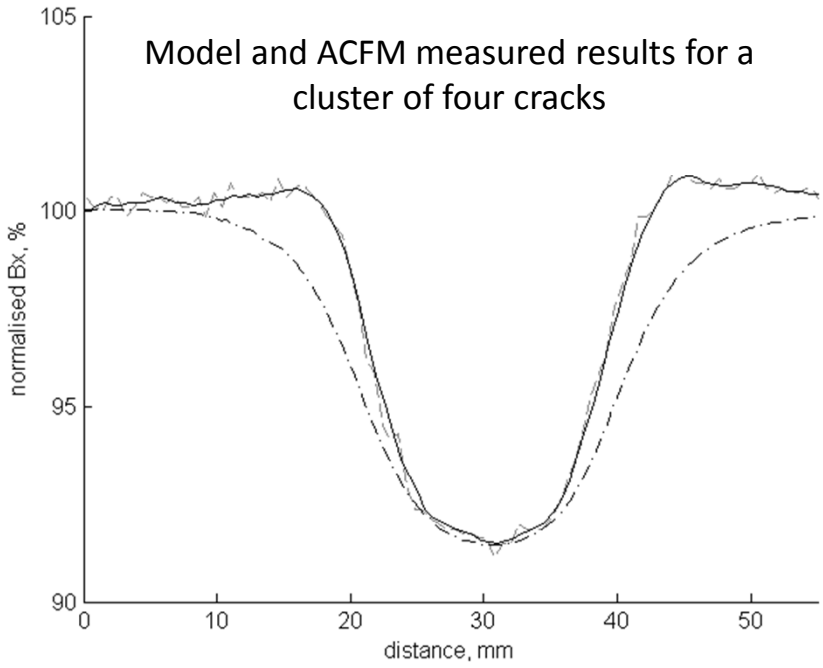


Relationship between crack vertical angle and Bz signal – model and experimental results for single cracks.

Modelling ACFM signals for RCF cracks

Sizing algorithms have been developed for single, isolated RCF cracks and for multiple (including closely spaced) RCF cracks. The model results have been verified through experimental trials using an ACFM pencil probe and both machined and real RCF cracks.





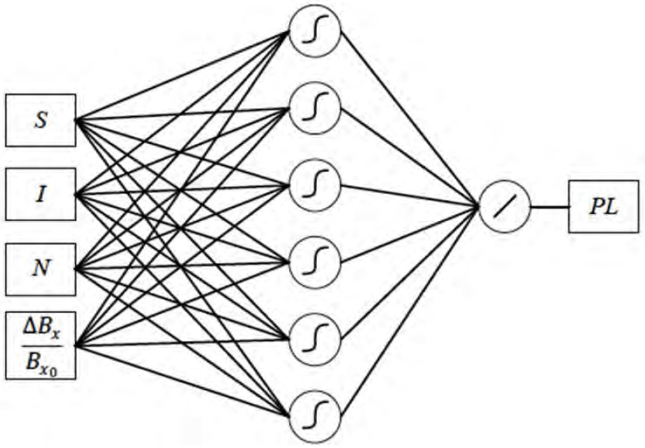
ACFM signals tend to saturate for large RCF cracks making the approach most suitable for light and moderate category RCF.

For closely spaced RCF cracks the ACFM signal shows a single indication. Details of the crack number (if less than 10) and spacing in the cluster is needed for accurate quantification.

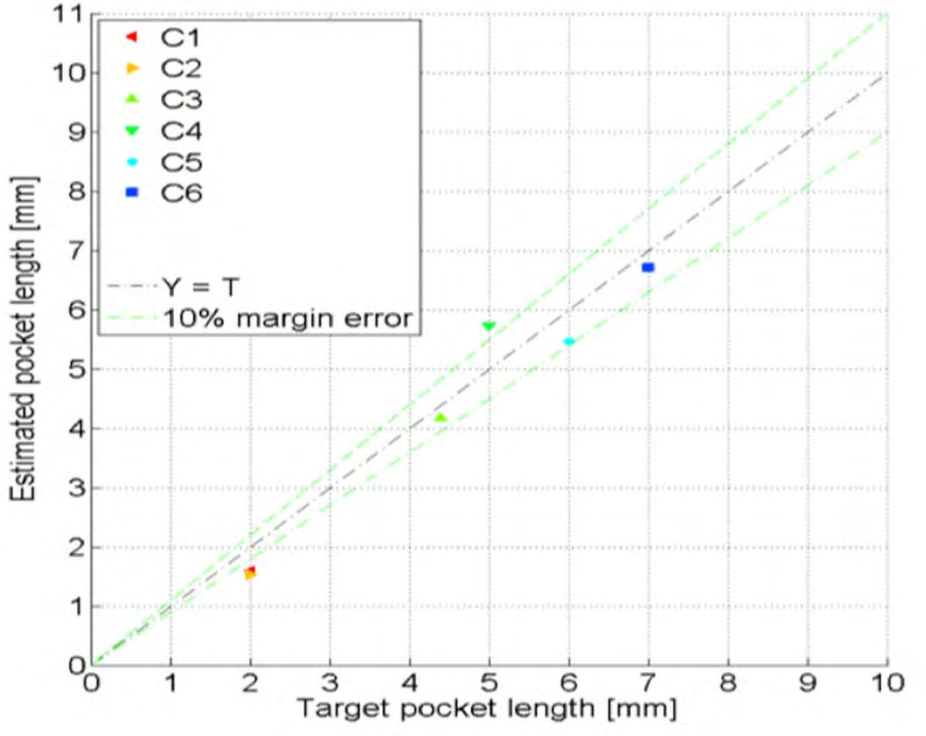
Modelling ACFM signals for RCF cracks

The ACFM response to multiple RCF cracks is very different to that of isolated cracks, hence significant sizing error will occur if using the single crack calibration curve.

A machine learning approach using an artificial neural network has been developed for the non-linear and complex relationships between the crack pocket length and the ACFM response for RCF crack clusters.



Artificial neural network approach for RCF crack sizing. Inputs are ACFM signal (Bx), surface length (S, potentially from Bz signal), number of cracks in a cluster and crack spacing.



Verification with exptal data for crack clusters has been carried out with good agreement.

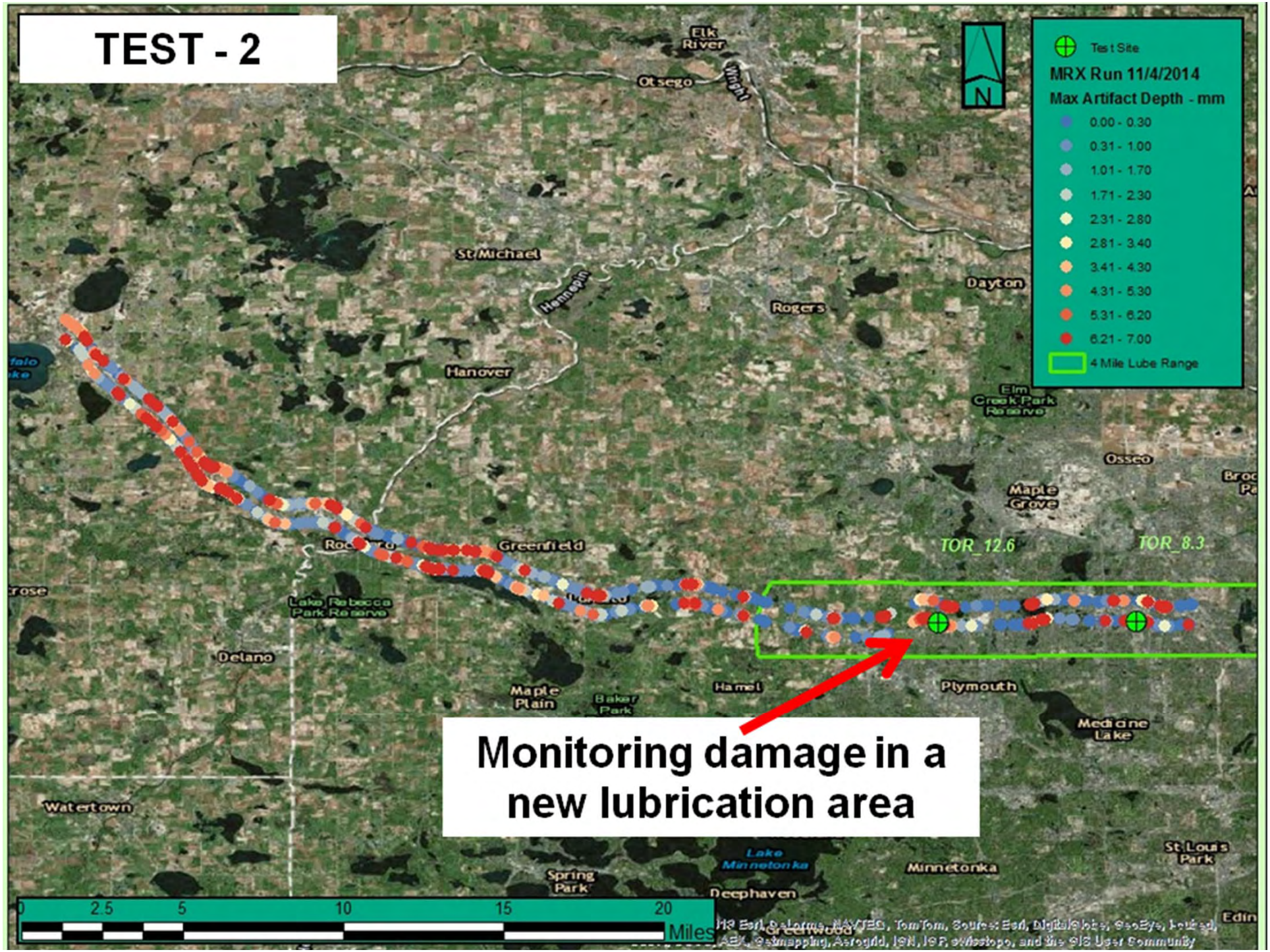
Status: MRX OPU (walking stick)

- London Underground
  - regular network surveys - 2 years now.
  - prioritization of grinding/milling/re-railing.
- Network Rail: awaiting 20 samples
- Deutsche Bahn
  - in final stage of approval.
  - squat depth sizing and 3-7mm head checking.
  - trials 0.2mm – 3mm head checking.
- Also – weld cracking

MRX – Vehicle Based RSCM Development

- Full prototype system operated in the US – covered 1500 miles

MRX TECHNOLOGIES


TEST - 2
Test Site
MRX Run 11/4/2014
Max Artifact Depth - mm
0.00 - 0.30
0.31 - 1.00
1.01 - 1.70
1.71 - 2.30
2.31 - 2.80
2.81 - 3.40
3.41 - 4.30
4.31 - 5.30
5.31 - 6.20
6.21 - 7.00
4 Mile Lube Range
N
Elk River
Otsego
St Michael
Hennepin
Dayton
Rogers
Hanover
Elm Creek Park Reserve
Osseo
Maple Grove
Greenfield
TOR_12.6
TOR_8.3
Lake Rebecca Park Reserve
Delano
Maple Plain
Baker Park
Hamel
Plymouth
Medicine Lake
Watertown
Lake Minnetonka
Minnetonka
Spring Park
Deephaven
St Louis Park
Monitoring damage in a new lubrication area
0
2.5
5
10
15
20
Miles

MRX TECHNOLOGIES

Status: Draisine (walking stick)

- 55+ Draisines sold/in use worldwide
- 25+ systems in use in Germany
- Shifted efforts to hy-rail testing in North America.
- Draisine use primarily to prove up the hy-rail system and transit line work

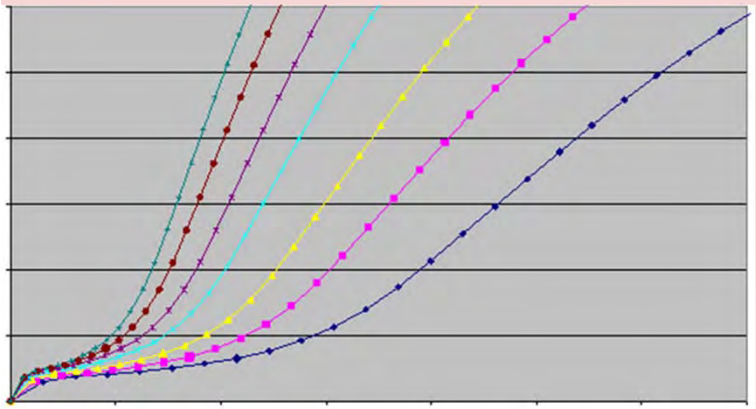
Rohmann hy-rail system

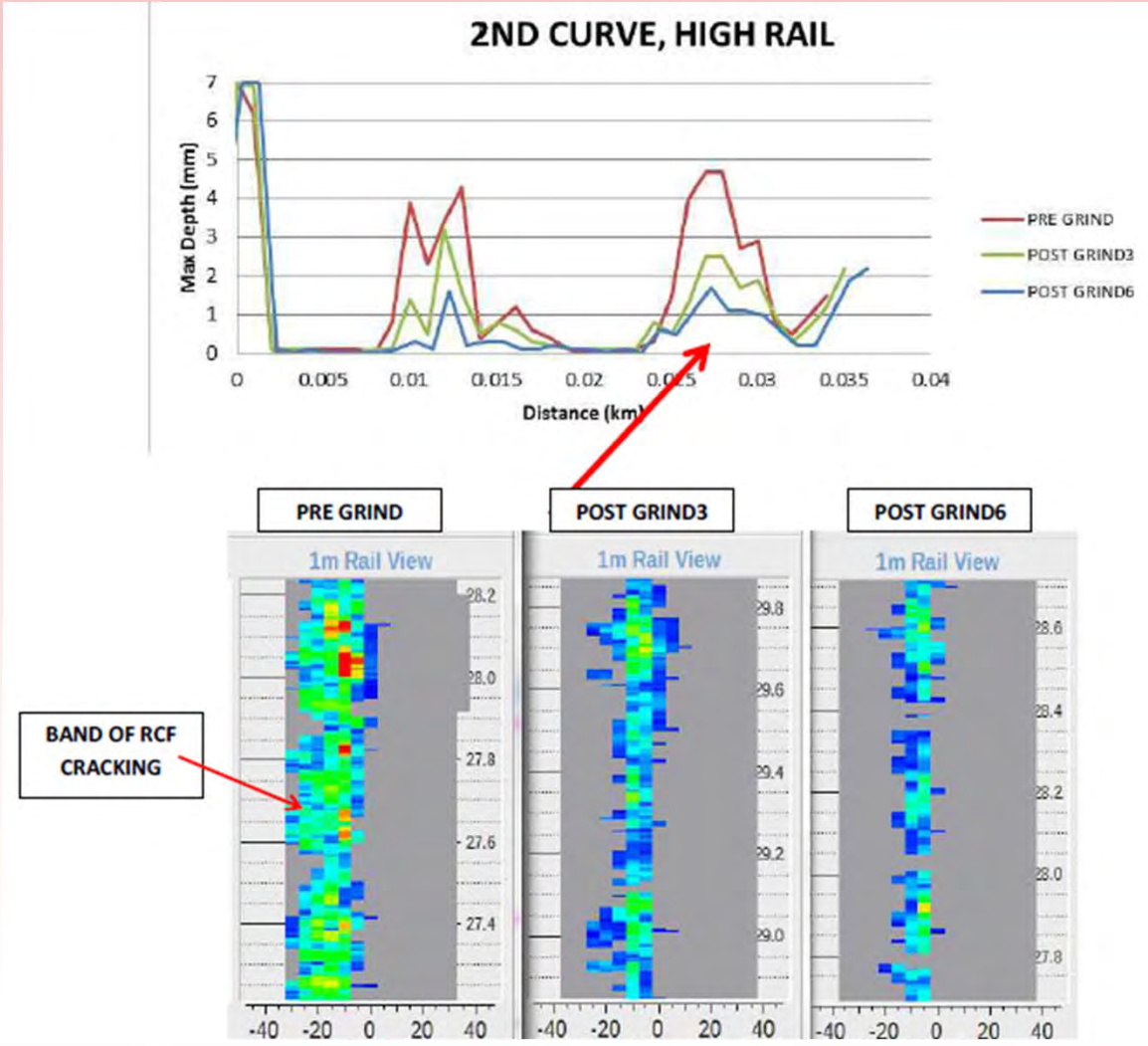
- up to 6 probes per rail x 11mm per probe
- up to 40 mph

Status: Sperry

- 1. Commence recording on CSX nonstop vehicle
  2. Integration with Ultrasonic and Induction rail test systems to provide comprehensive Rail Health
  3. Refinement of reporting from systems deployed on Network Rail Fleet of Ultrasonic Test Units
  4. Refined Crack Depth Algorithms and research into determination of Crack Angle

Magic Wear Rate?





Atlas of Rail Surface Fatigue?

BNSF Staples Subdivision
MP 210.7, high rail
1972 Tennessee
XX MGT since last grind
2.5 to 3.5 mm deep cracking

Please contact

Eric Magel

NRC, Canada

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