Forensic Analysis of RCF defects

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Rail Flaws

- Surface defects or internal defects
- Cause: Rail manufacturing, installation and operation
- They reduced service life, can cause rail failure and possible derailment

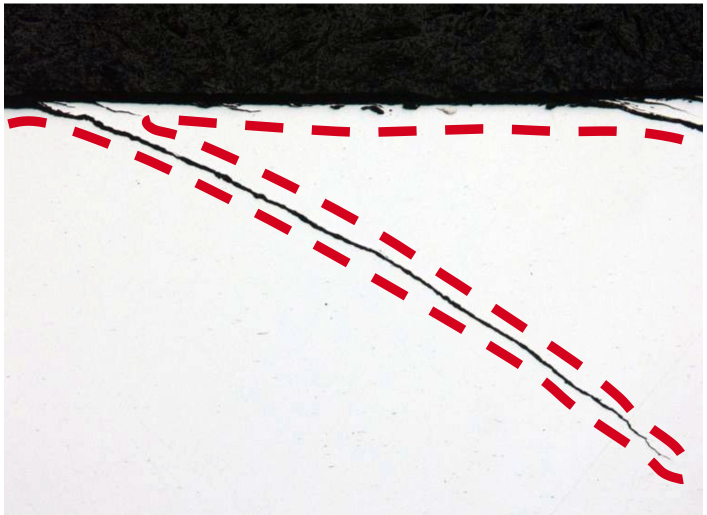


Surface Defects: Visual

- Look at the rail
  - – yes/no, subjective severity, no depth information
- Dye penetrant test for enhanced contrast
- Image analysis for detection and classification

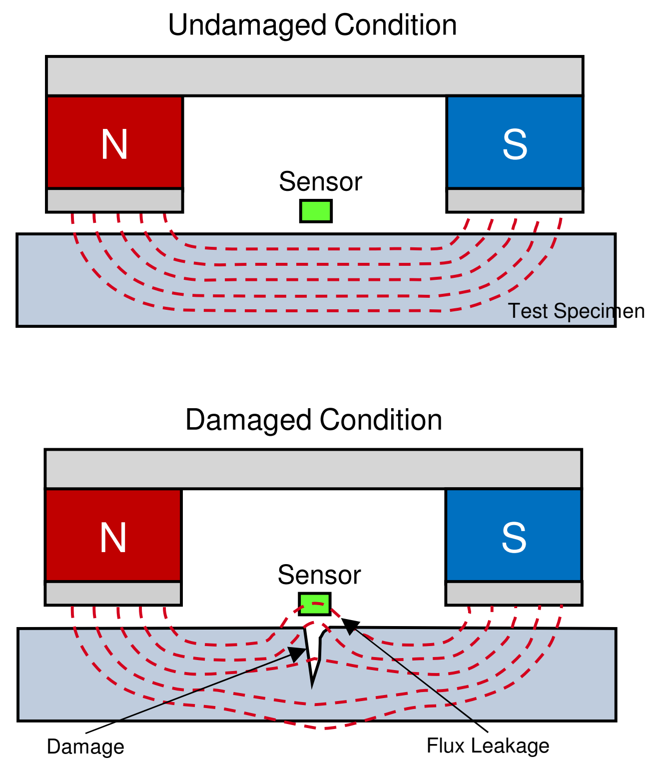
Surface Defects: Eddy Current

- Stray current induced in rail surface
  - Magnetic field of stray current measured
- Stray current needs to bypass surface breaking defect
  - Change in magnetic field
- Information about crack length
  - Depth calculated with assumed crack angle
  - Max crack depth about 3mm



Surface Defects: Magnetic Flux Leakage

- Test specimen magnetized
- A crack will cause the magnetic field to leak on the surface
  - Indication of depth and severity
  - Up to 7mm defect depth

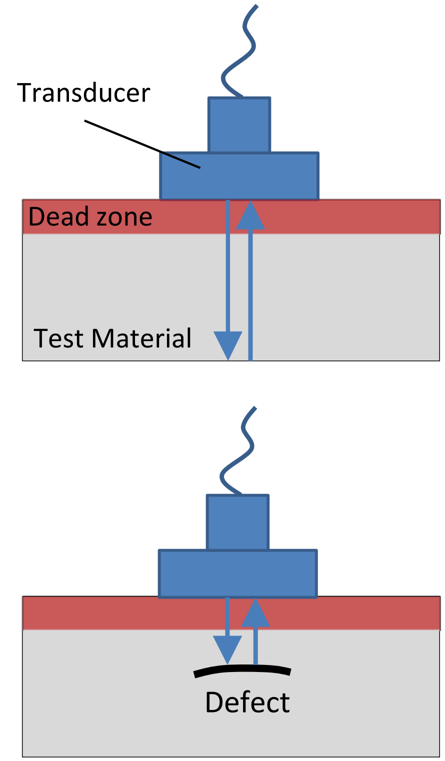


Surface Defects: Electromagnetic Field Imaging

- Focused magnetic field is projected into specimen
  - Interaction (deformation) of magnetic field with surface breaking defects measured
- Rail application part of ongoing research

Internal defects: Ultrasound

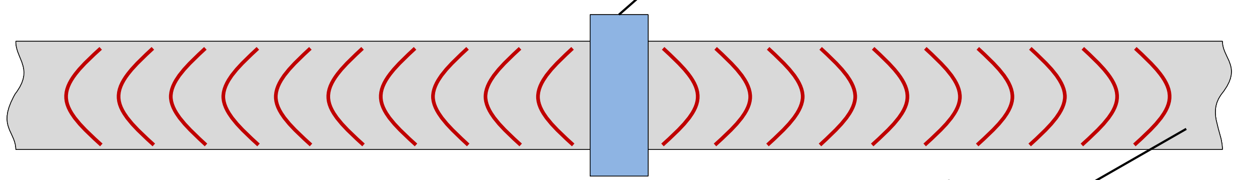
- Ultrasound: Sound frequency above 20 kHz (rail: 2-5MHz)
- Sound pulse (wave) send into material
  - Reflection by defect: depth and severity
- Only internal defects: dead zone during first 5-8 mm



Schematic drawing

Internal Defects: Guided Waves

- Acoustic wave propagates along an elongated structure
  - Guided by boundaries of structure
  - Defect will reflect wave
- Rail application part of ongoing research



Current overview

- Ultrasonic technology is the primary technology used on U.S. railroads.
- As any non-destructive test methods, these technologies are susceptible to physical limitations such as acoustic coupling and rail head surface conditions.
- The predominant types of poor rail head surface conditions are shells, engine burns, spalling, flaking, corrugation, and head checking.

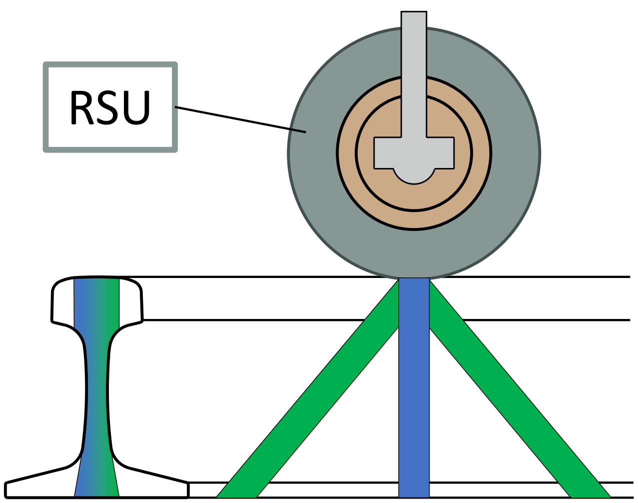
Conventional Ultrasound

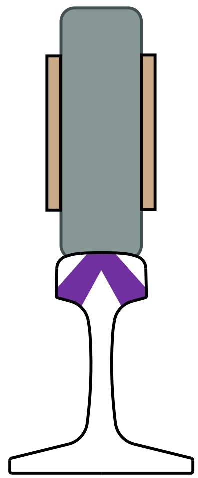
0° Transducer : Horizontal rail flaws (Shells, Horizontal Split Head, Split Web)

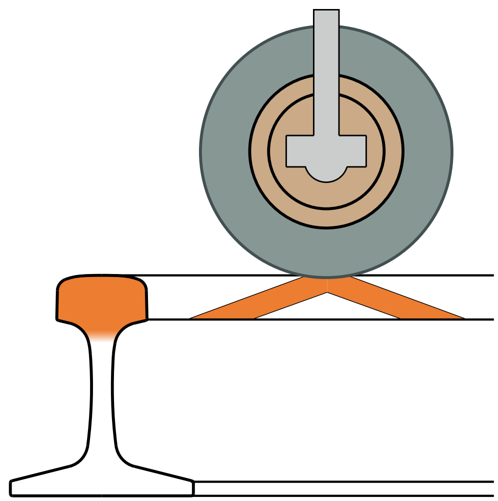
Side-Looker: VSH

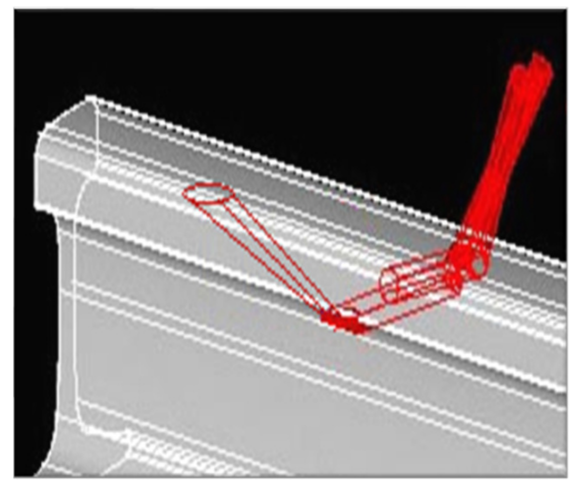
70° Transducers: TDs, Weld defects

Oblique 70°: TD under bad surface conditions







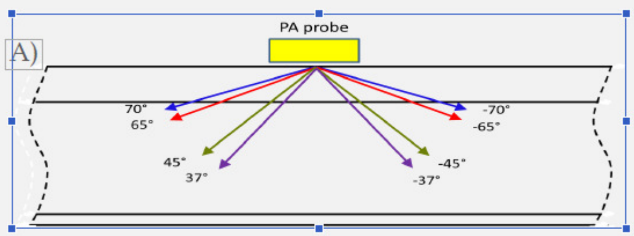


40° Transducers: Bolt Holes, Web defects

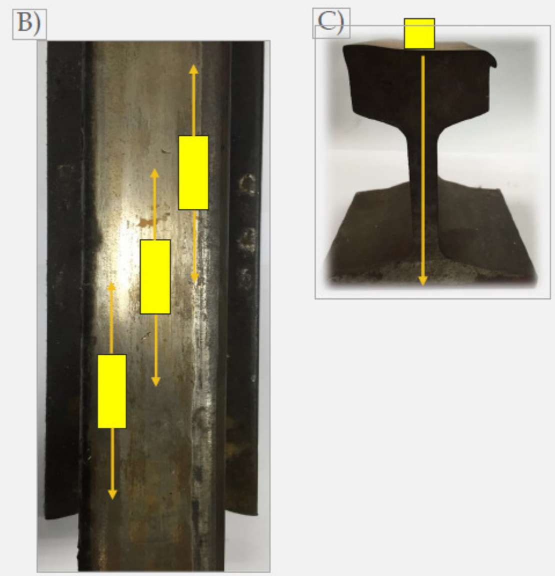
Phased Array

multi-beam generation per pulse

FAAST with 1D linear PA probe

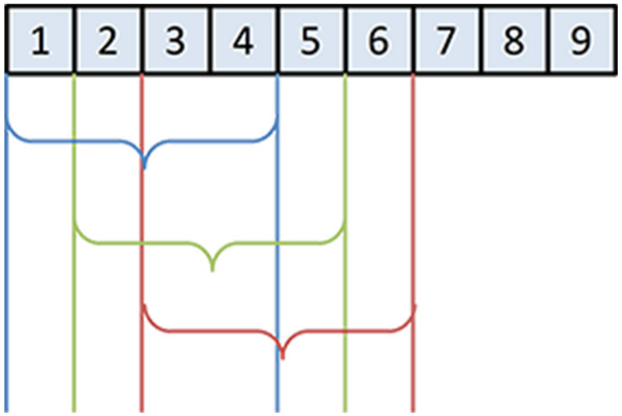


- Up to 16 direction per probe in 1 single shot
- Real time data processing up to 16 beams per probe
- Covers the full length of the rail to the feet
- Select the angles by Software settings instead of mechanically



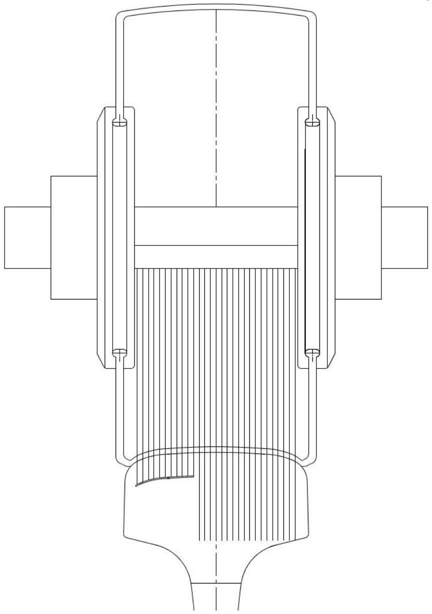
Linear Array/Linear Phased Array

Linear Array



Group of Elements Sequentially Pulsed

Linear Phased Array



All Elements Pulsed

Governmental Regulations (US)

- FRA Reg 213 and 213.3
- No specified calibration standards.
- Mandated test frequencies based on service failure per year per mile of track.
- 213 Start and stop testing remediation of defects with 4 hour of detection.
- 213.3 Continuous testing slow orders based on type and size of defects range from 10 m.p.h. to 30 m.p.h.

Governmental Regulations (EU)

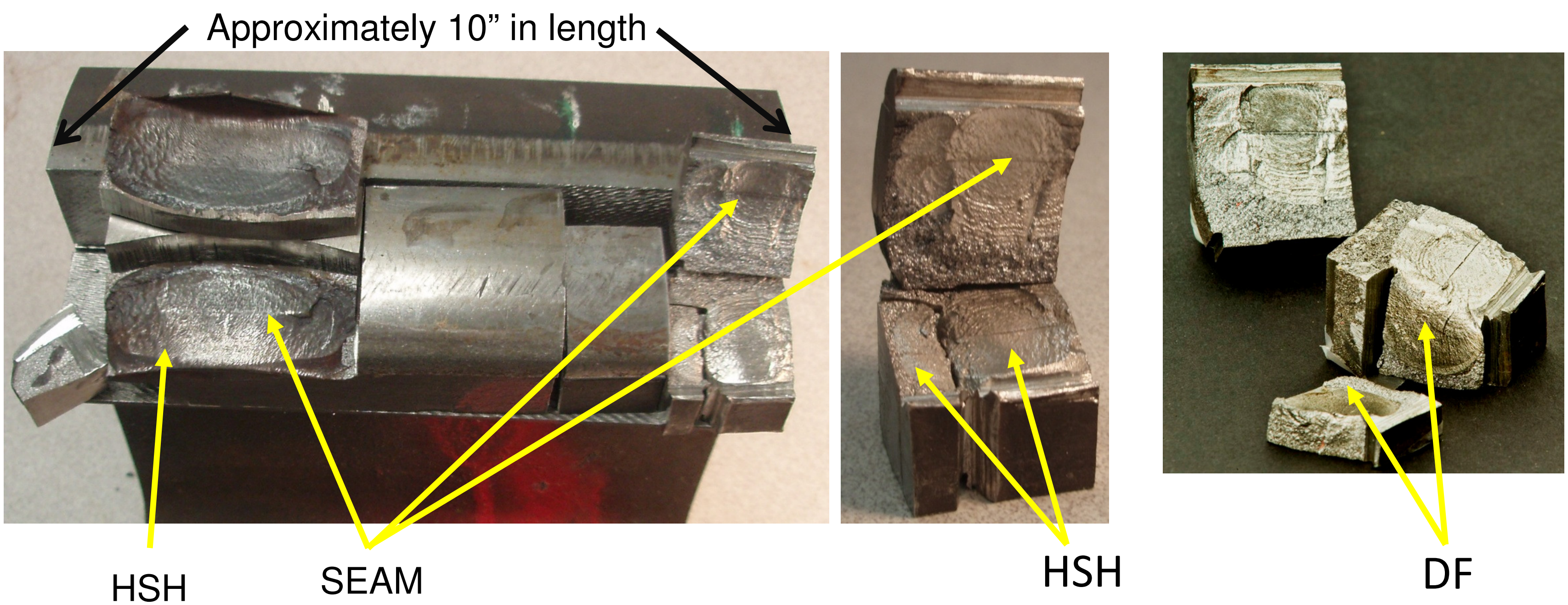
- Europe EN 16729-1 Standards
- Defines specific Ultrasonic calibration reflector sizes and positions for various region of the rail.
- Test frequencies or remedial actions defined by each railroad
- German Railways:
  - 3 different defect classes (class 1: immediate action)
  - Testing interval: 4 months – 30 months (track speed)
  - High speed track: 4 months

Technology Evolution

- Since 1995, test frequencies in defect prone areas have increased from 2 to 12 times per year. One of the major metric used to determine the inspection frequency is service failures per year per mile of track.
- In 2005 a study of service failures on Class I railroads by TTCI indicated that certain internal rail defects may be undetectable with the current ultrasonic technology.
- During a 2005 RITF meeting, BNSF reported that while investigating DF service failures they noticed that some gage corner DFs displayed a horizontal component.

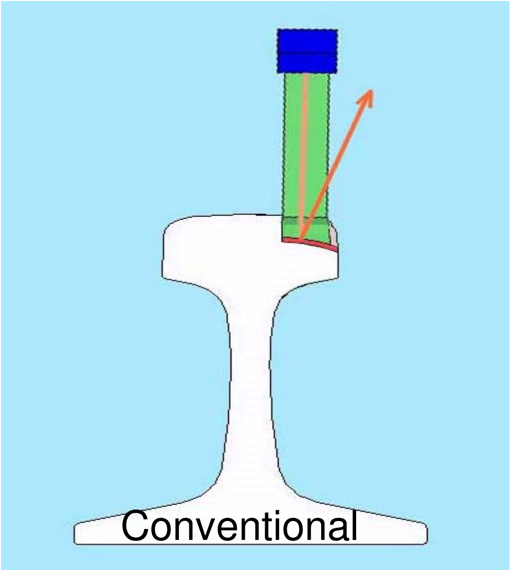
Gage Corner DF

In 2007 we had introduced an enhanced detection method for TDs located in the gage corner masked by rail geometry and Horizontal head defects in the gage corner, these were initiated by a seam located in plastic zone generated by excessive loads on post grinding facets.

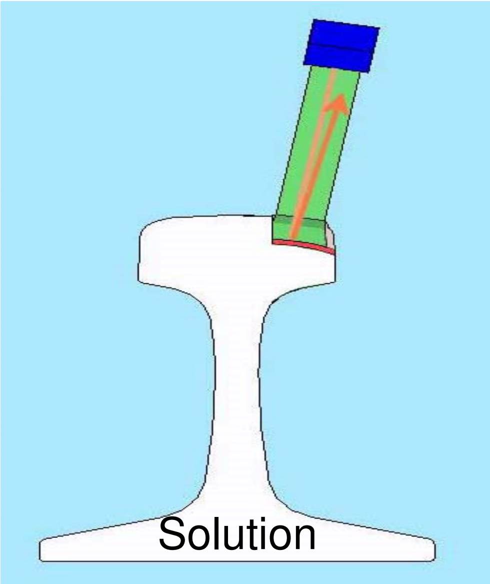


- This technology significantly increased the number of detected DFs, it did not eliminate the DF service failures.

Beam reflected away from transducer



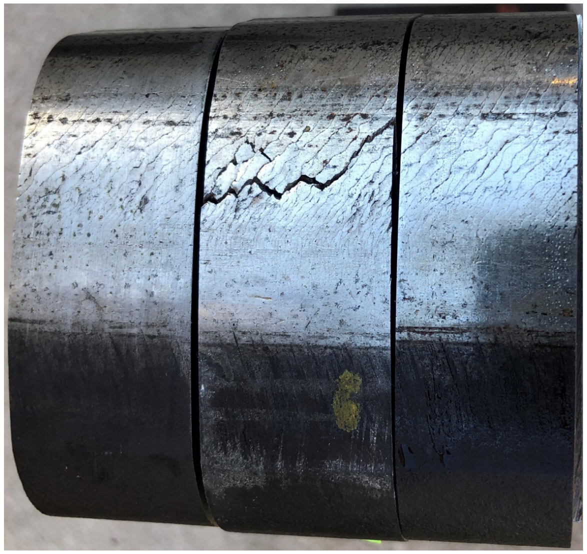
Beam reflected to the transducer



- In recent years, efforts have been put fourth to detect Deep shells, Squats, Flattened rail, crushed head and etc.
- 2019 A discussion with the BNSF regarding DF failure associated with deep seated shells, prompted an investigation and found that deep seated shells did exist and analyzed this first sample.
- This was a 24” piece that has 4 deep shells 12” from an engine burn fracture.

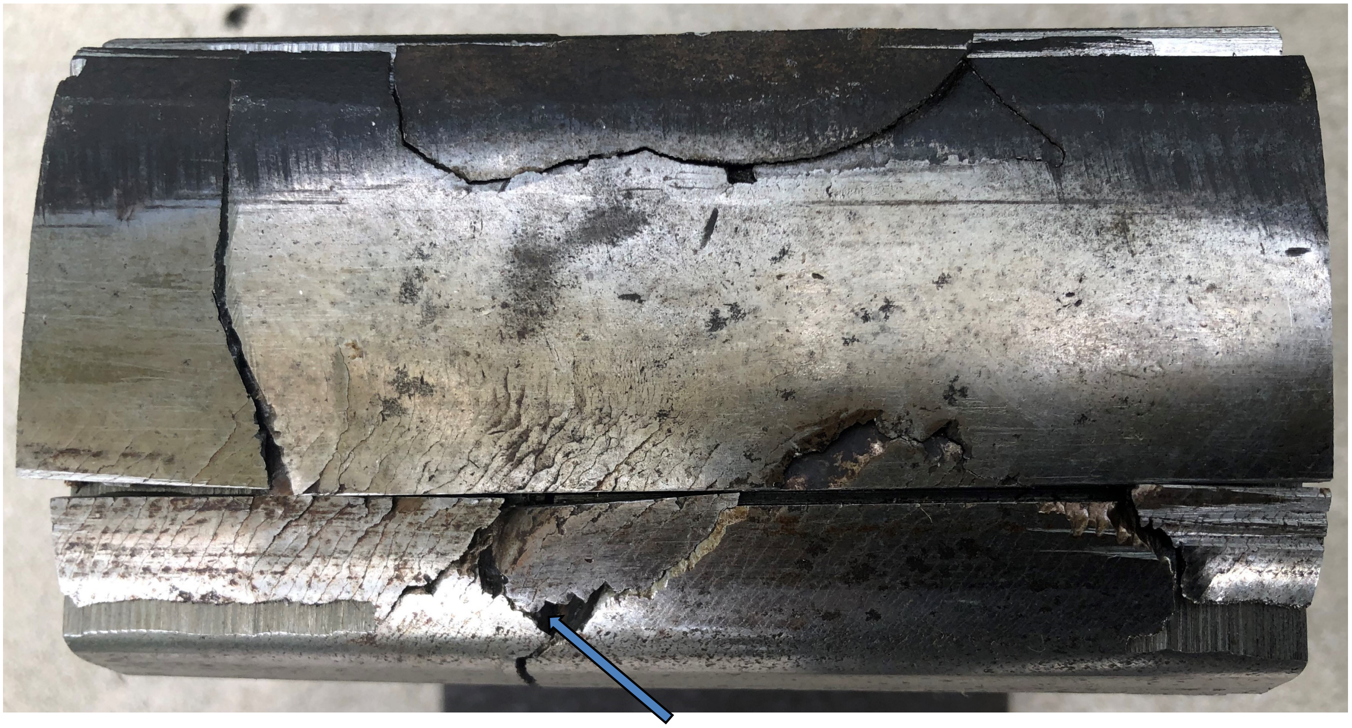


We have found that RCF (head checking) will randomly grow, merge and eventually spawn TD's at the merging zone. Consequently, the same detection problem exists that prevents reliable detection of TD's in and around these condition.



CASE STUDIES

Case Study 1



After many test cycles this sample was tagged as having a small 10% TD

CASE STUDY 1

Our analysis showed the presence of a deep shell approximately 2” wide by 7” Long

Genesis of the TD

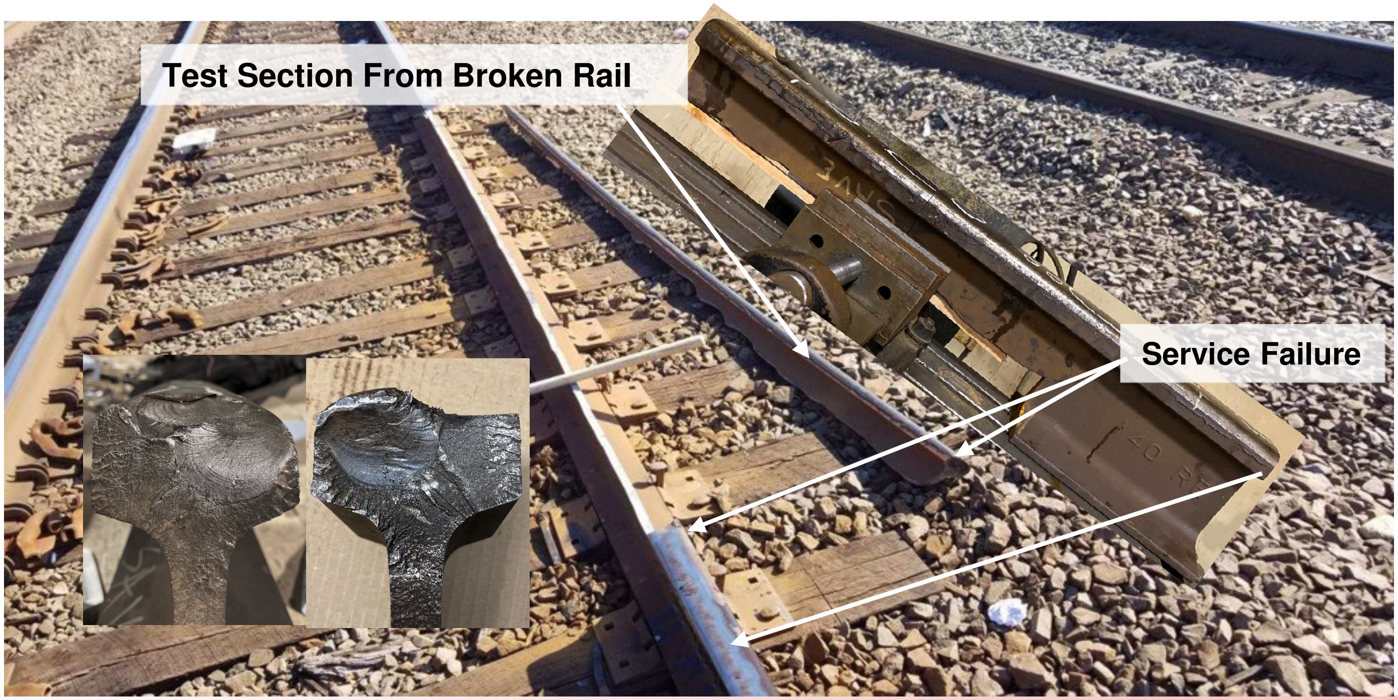
CASE STUDY 1

Gage Corner

Further analysis exposed the presence of three overlapping TD's ranging from 30% to 40%

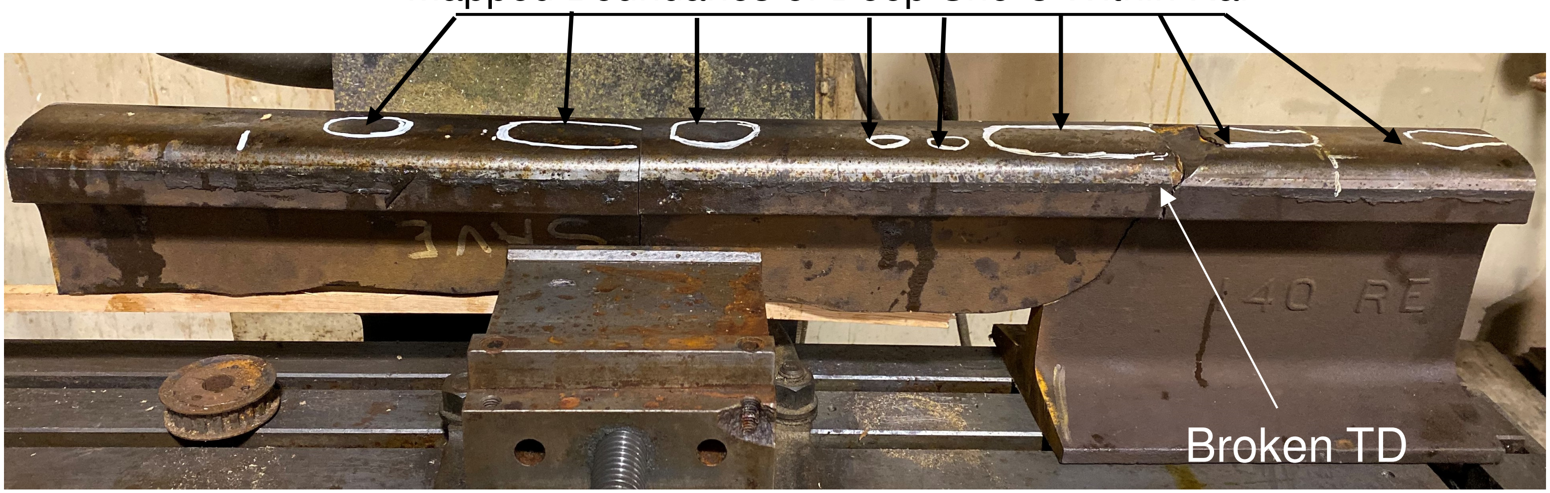
CASE STUDY 2 SERVICE FAILURE

The inability to detect the large TD resulted in a service failure, 15 feet of rail broke off after the trains last car went over the defect area.
The TD, initiated underneath deep head shelling and it appears to have slow growth, however the large deep shell horizontal component blocked its detection before failure.



CASE STUDY 2 SERVICE FAILURE

Field UT examination found moderate to heavy head checking surface conditions. Most of its length was free of any deep horizontal shells (greater than ½") however, within a 3' to 4' section around the service failure, we did find at least seven deep shells. These deep shells ranged from ¾" to over 8" in length and 1/16" to over 3/8" deep.



CASE STUDY 2 SERVICE FAILURE

Sectioning and examination on and around the deep shells found several small TDs at different growth stages.

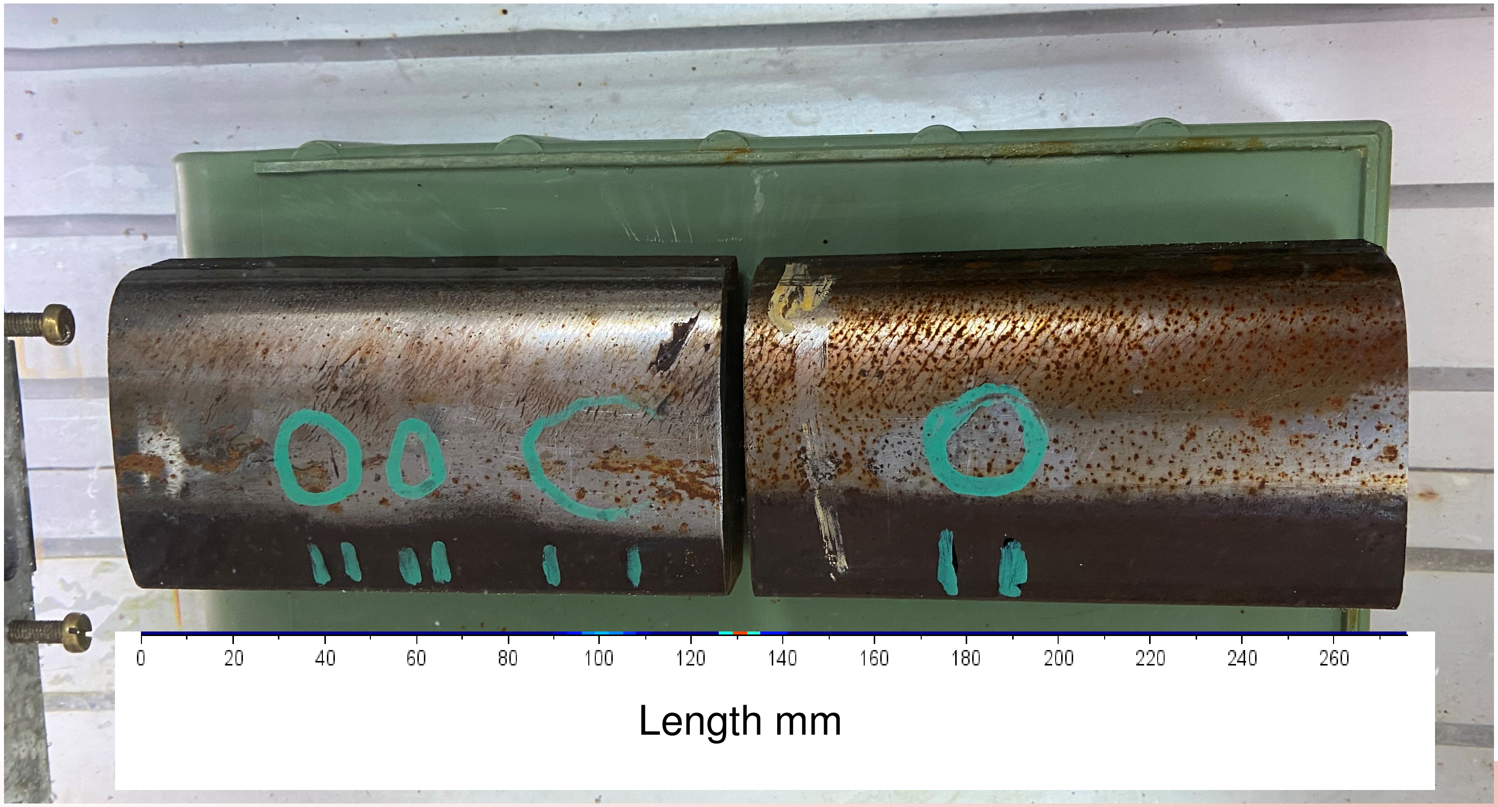
Service Failure

Transvers defects ranging from 5% to 20%

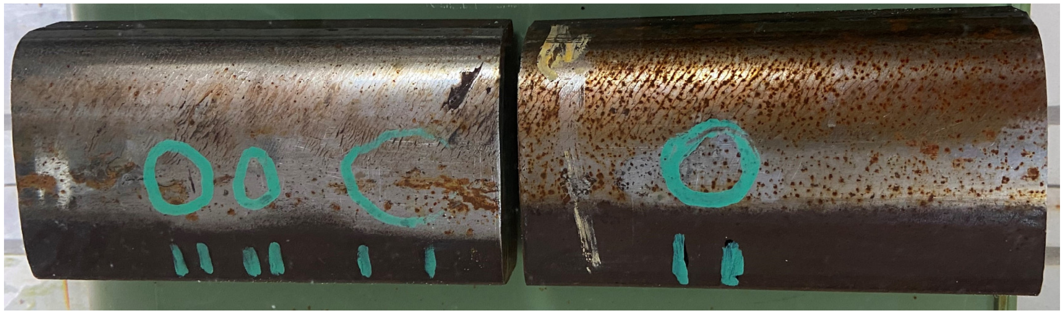
New Technology Patented and Patent Pending

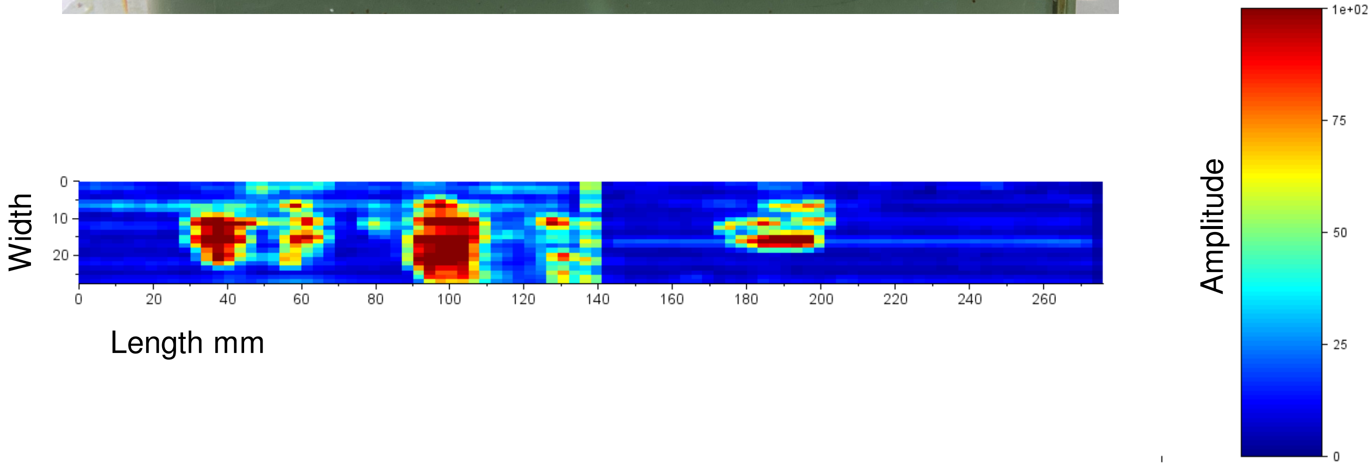
- New detection system with the following features:
  - Ability to locate, size, and classify deep shelling at test speeds.
  - Create amplitude C-Scan
  - Create TOF, C-Scan
  - Create Compiled Thickness profile

Test Samples

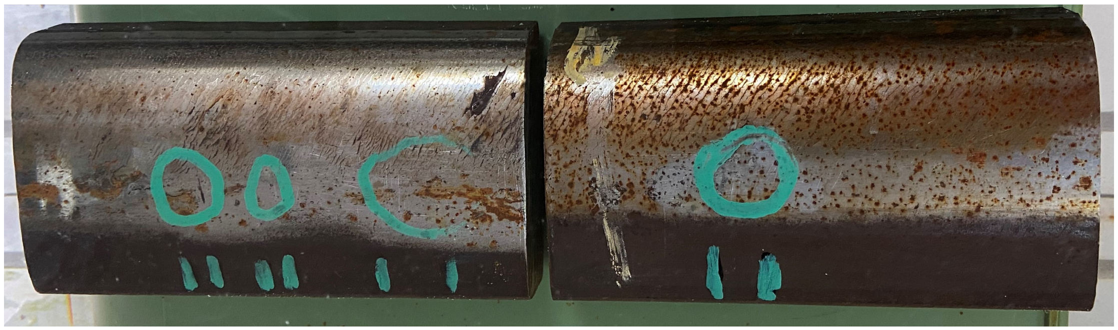


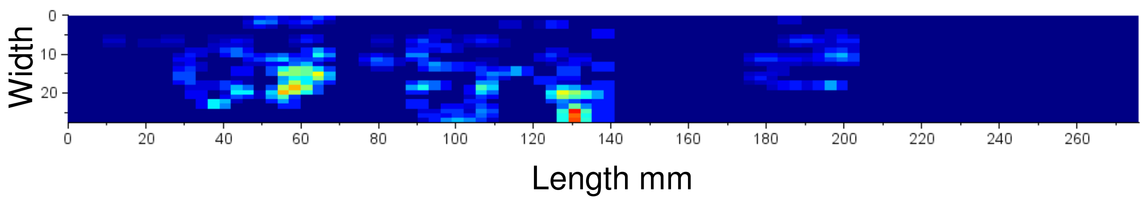
C-Scan Amplitude

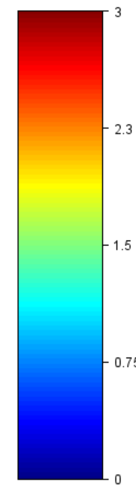




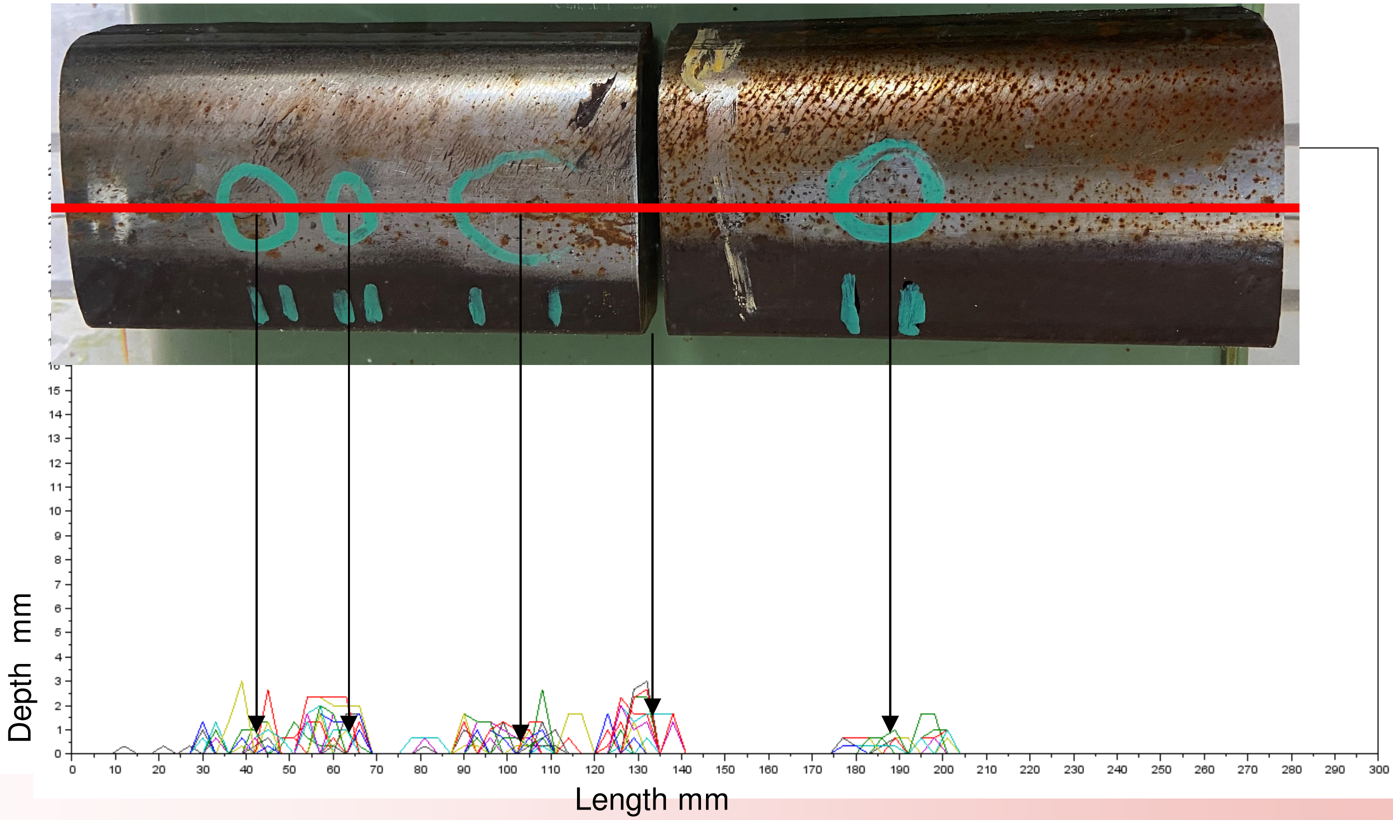
C-Scan TOF Depth







Compiled Thickness Profile



New Ultrasound Technology

- Patented phased linear array technology
- Avoid Service failure by identifying precursors to masked TD's
- System Mapping of head check shelling locations (severity and depth)
- Detection of surface defects and internal defects
- Prevent rail failure by allowing timely rail replacement

Thank you for your attention!