Rail Maintenance: Internal Defects, Surface Conditions and Maintenance Techniques

by

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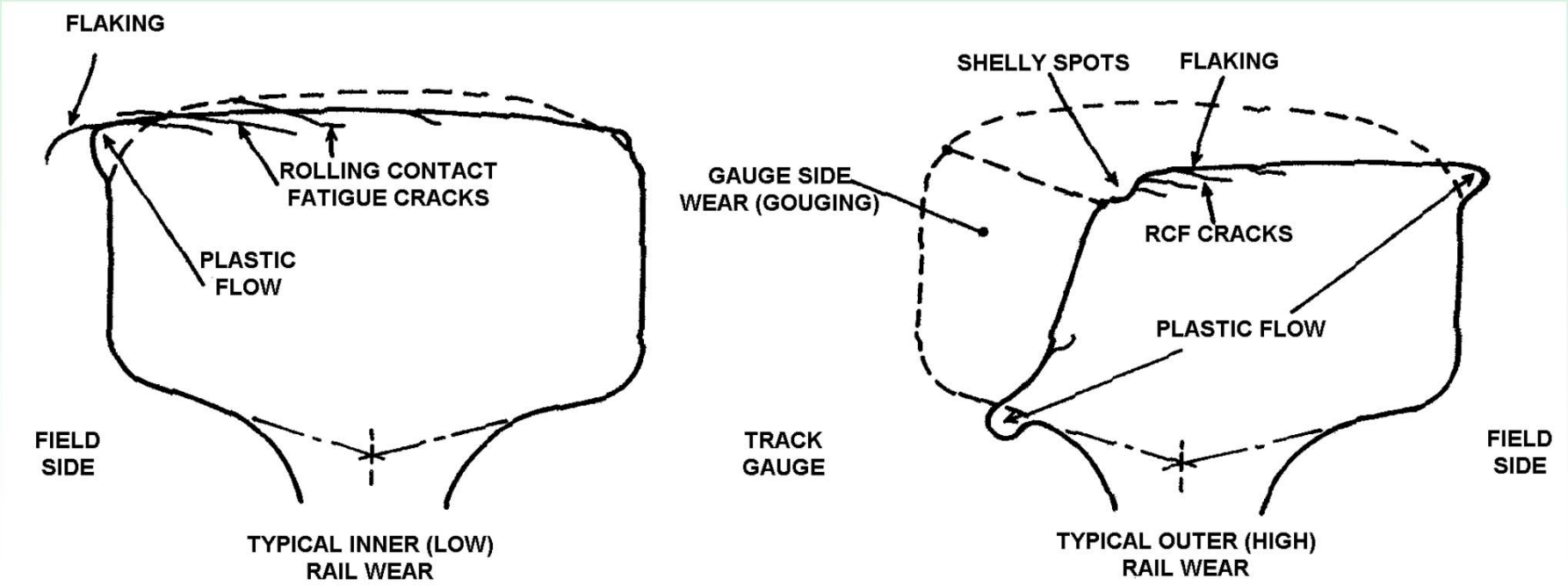
Why do we do Rail Maintenance

- Safety
- Economy
- Avoid Impacts of
  - Unscheduled Repairs
  - Squeal and corrugation noise
  - Ride quality

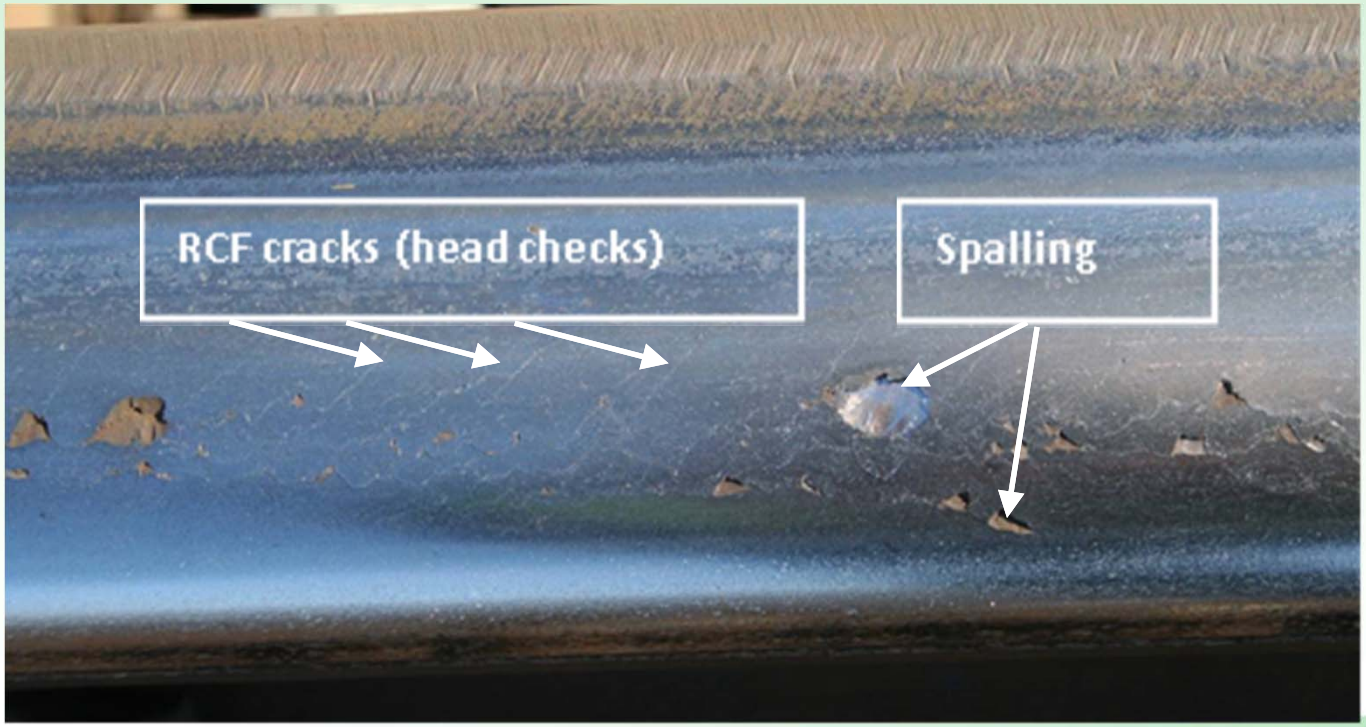
If Mother Nature is your Track Maintenance Engineer



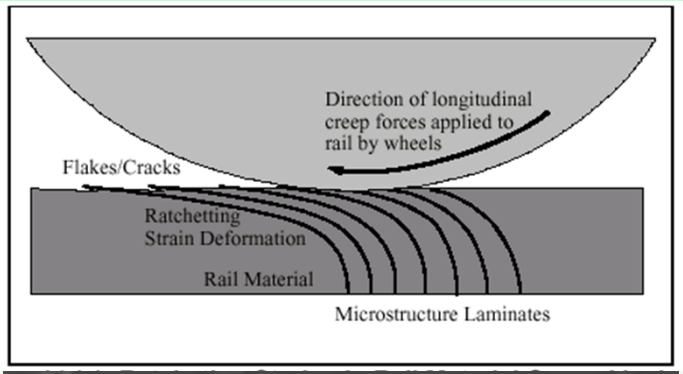
Pro-Actively Manage Rail Maintenance to

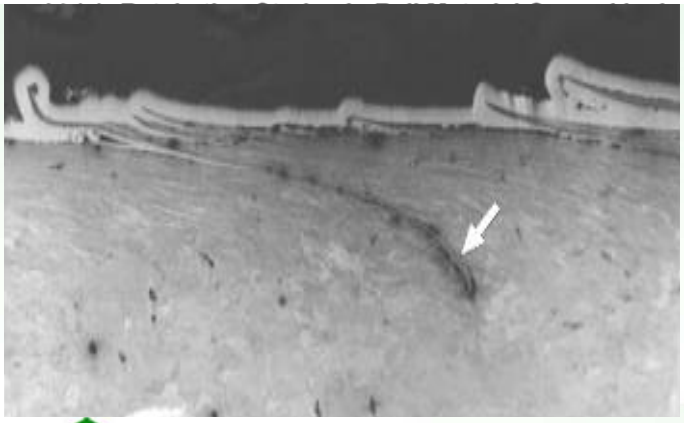
- Reduce rail wear section loss
- Control gauge face wear
- Control rolling contact fatigue (RCF)
- Reduce formation of defects and fractures

Rolling Contact Fatigue (RCF) cracks



How do RCF Cracks Form





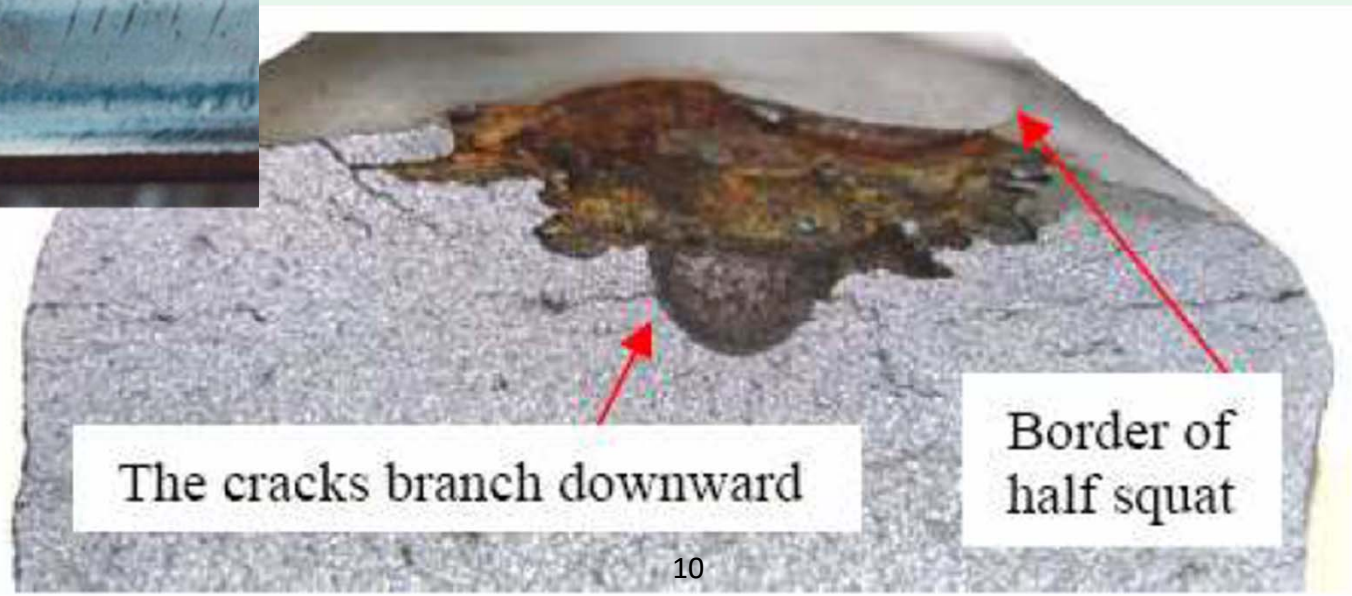
- **33 MGT = 1 million wheels passes on heavy haul track**
- **A certain fraction of wheels plastically deform the rail in the direction of applied tractions (due to ΔR and AoA).**
- **Each loading cycle "ratchets" the surface layer until the ductility of the steel is exhausted**
- **Eventually a crack is generated (usually within 1 to 5 MGT)**

RCF Cracks on Heavy Haul Rails

RCF Cracks Develop on Welds

RCF Cracks on Mass Transit

Squat – RCF Defect



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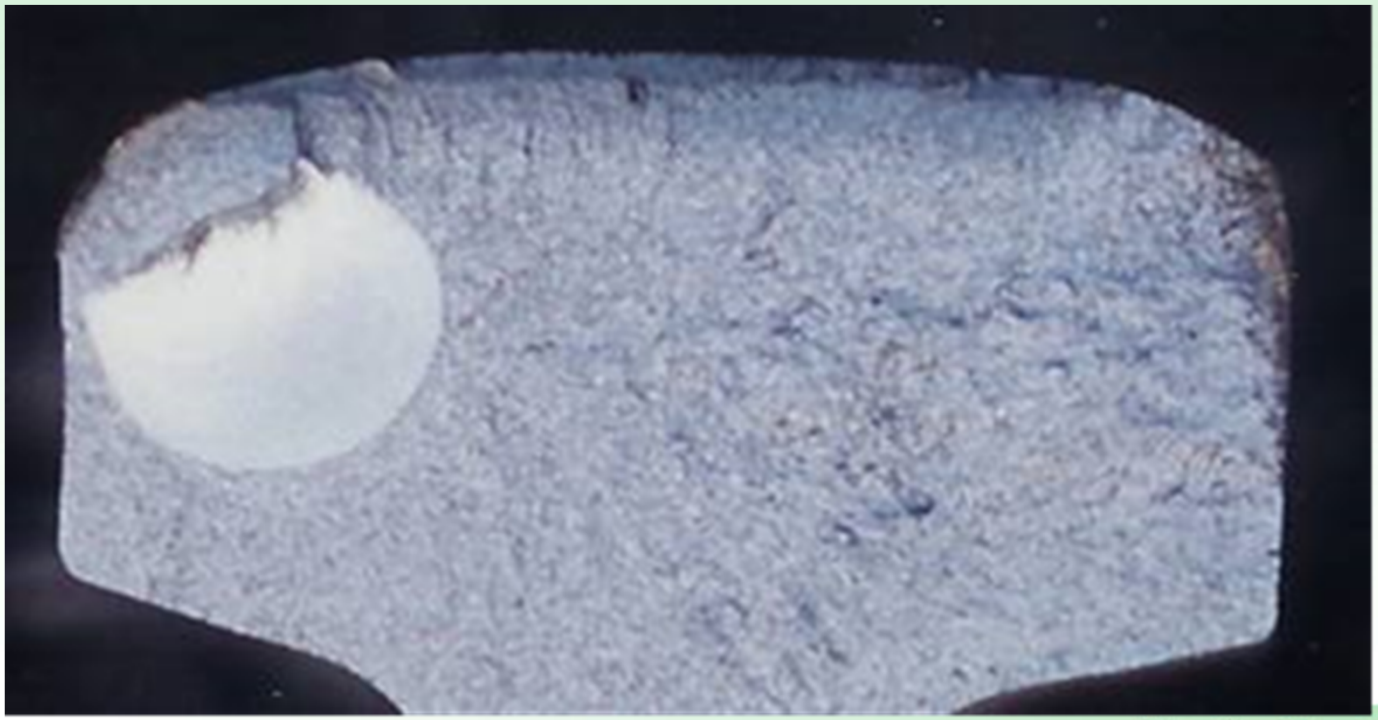
Severe RCF
(Deep Cracks, Crushed Head)

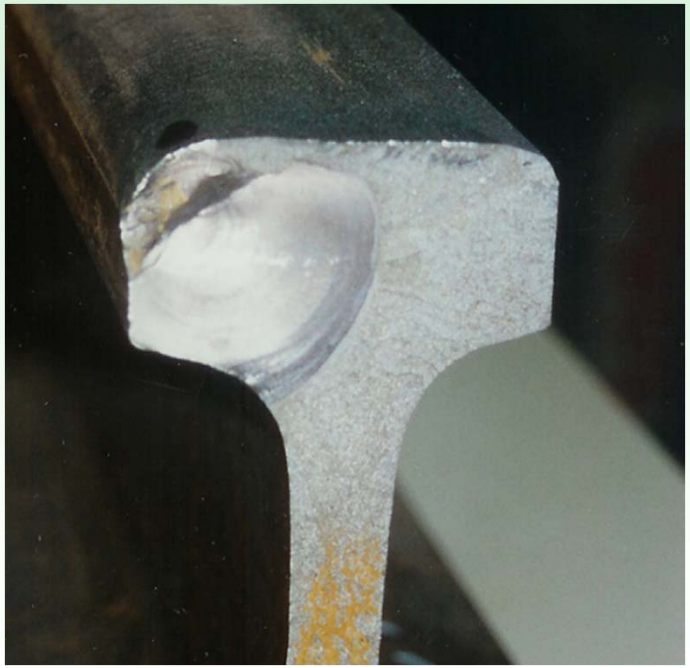
Transverse Defect (From Severe RCF)

Spalled Out Deep Seated Shells (G.C. RCF)

Transverse Crack From Deep Seated Shell

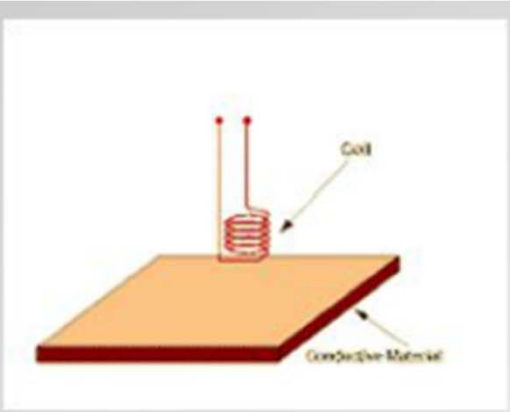


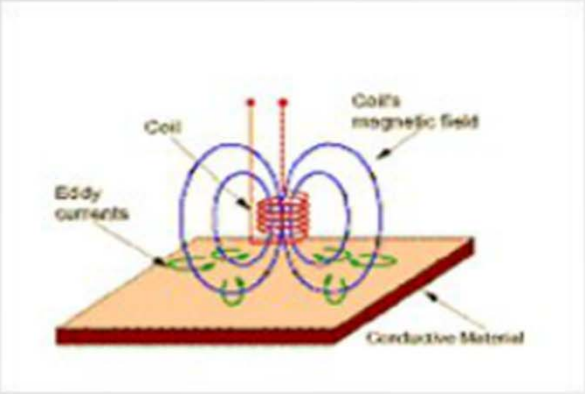
Broken Rail From Deep Seated Shell

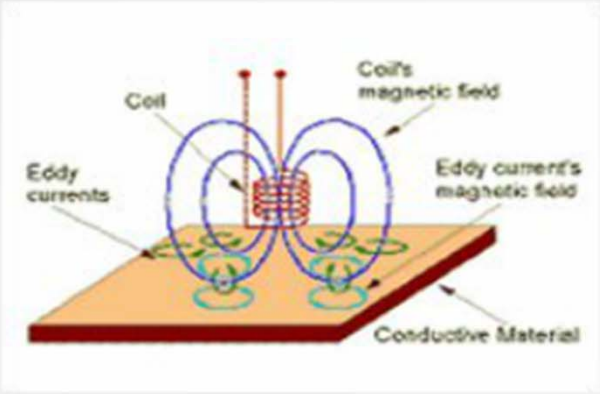


The Basis for Eddy Current Inspection

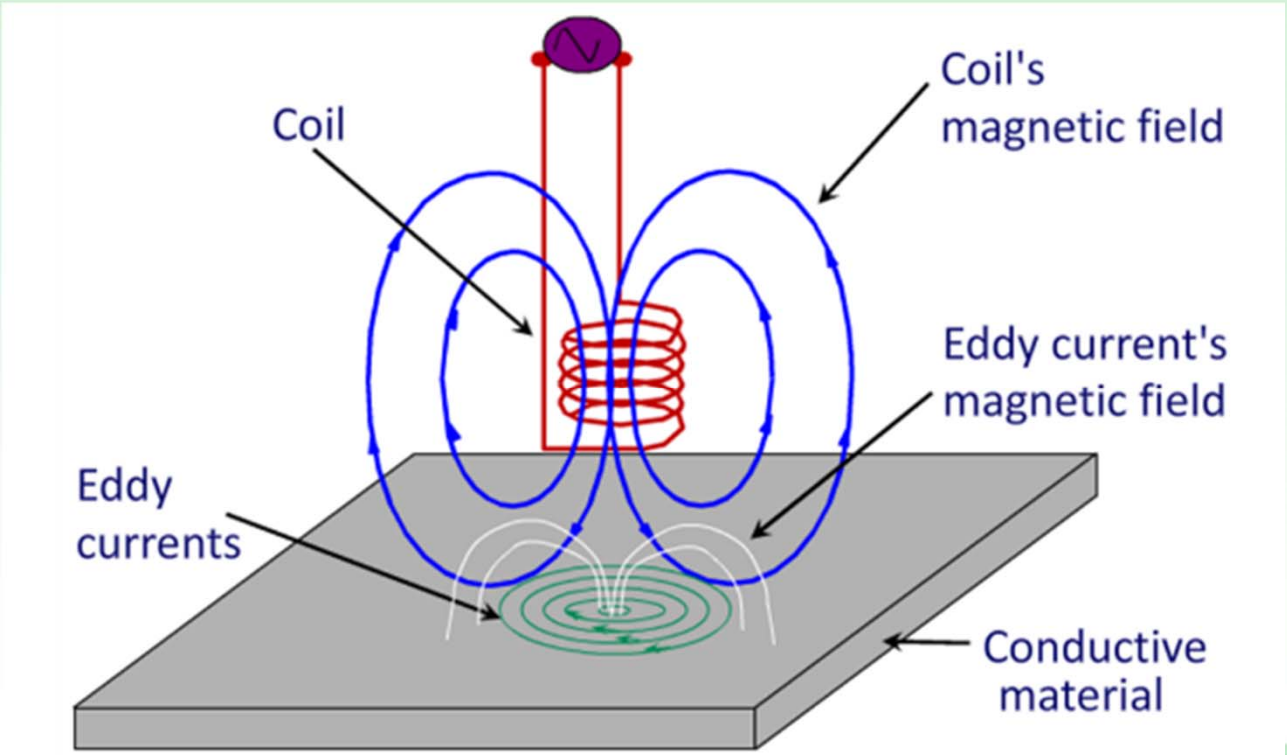
- The test probe is a coil of wire through which alternating current is passed.
- When the probe is close to a conductive material, the probe changing magnetic field generates current flow in the material.
- The eddy currents produce their own magnetic fields that interact with the primary magnetic field of the coil.
- By measuring changes in the resistance and inductive reactance of the coil, information can be gathered about the test material







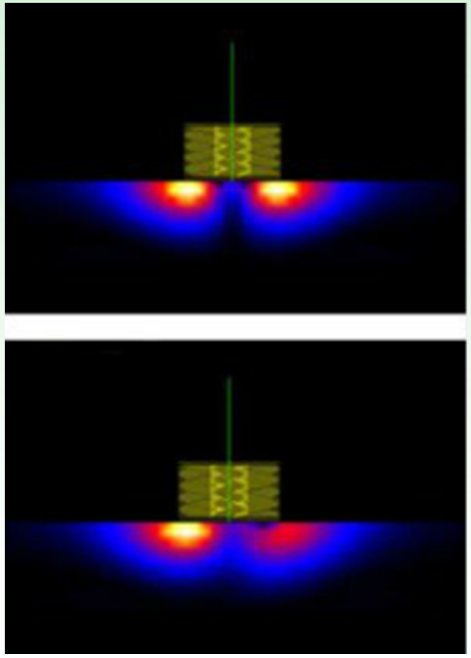
Coil and Eddy Current Magnetic Fields



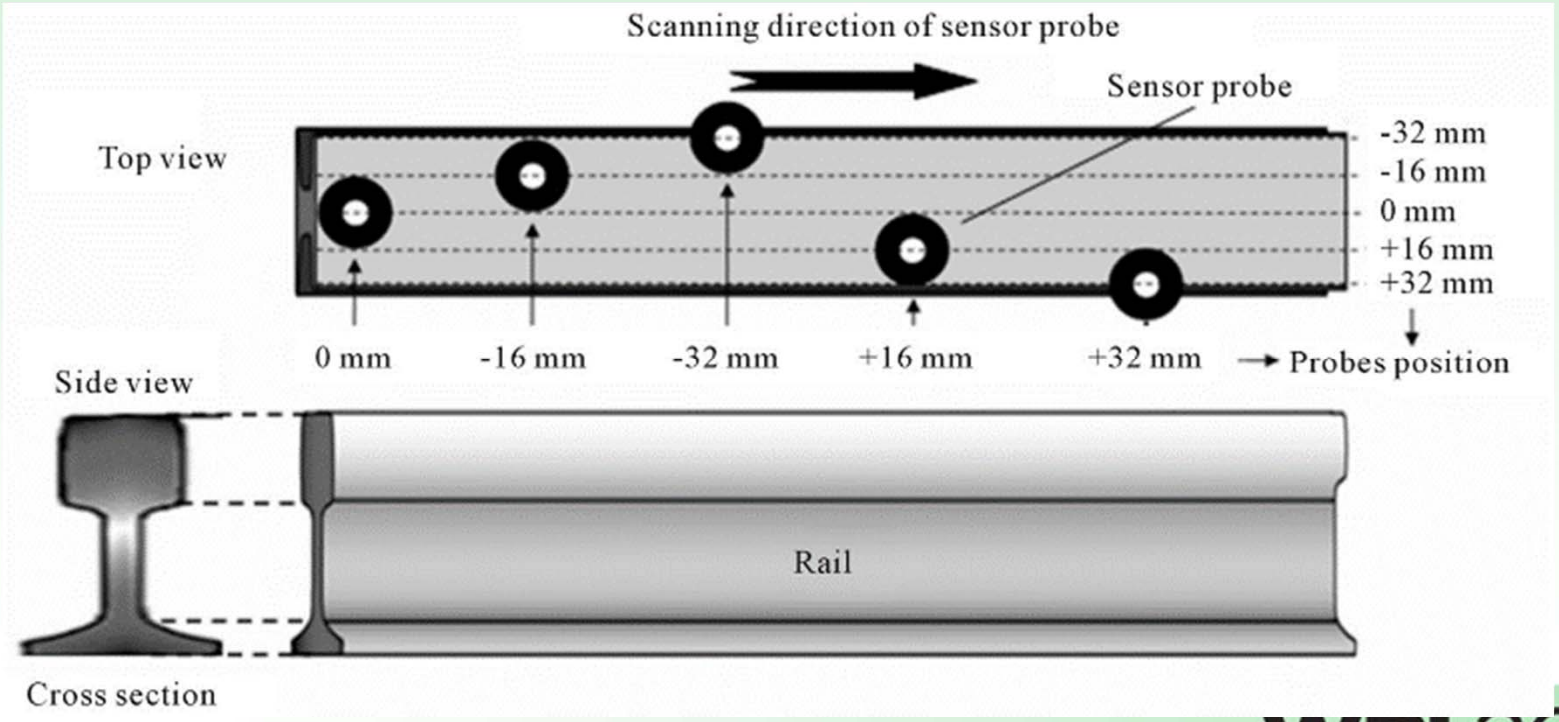
Eddy Current Applications

Detects surface breaking cracks

- **Cracks are detected when they disrupt the path of eddy currents and weaken their strength**
- **Surface crack detection by sliding probes is used in many industries including railroads, commercial aircraft…**



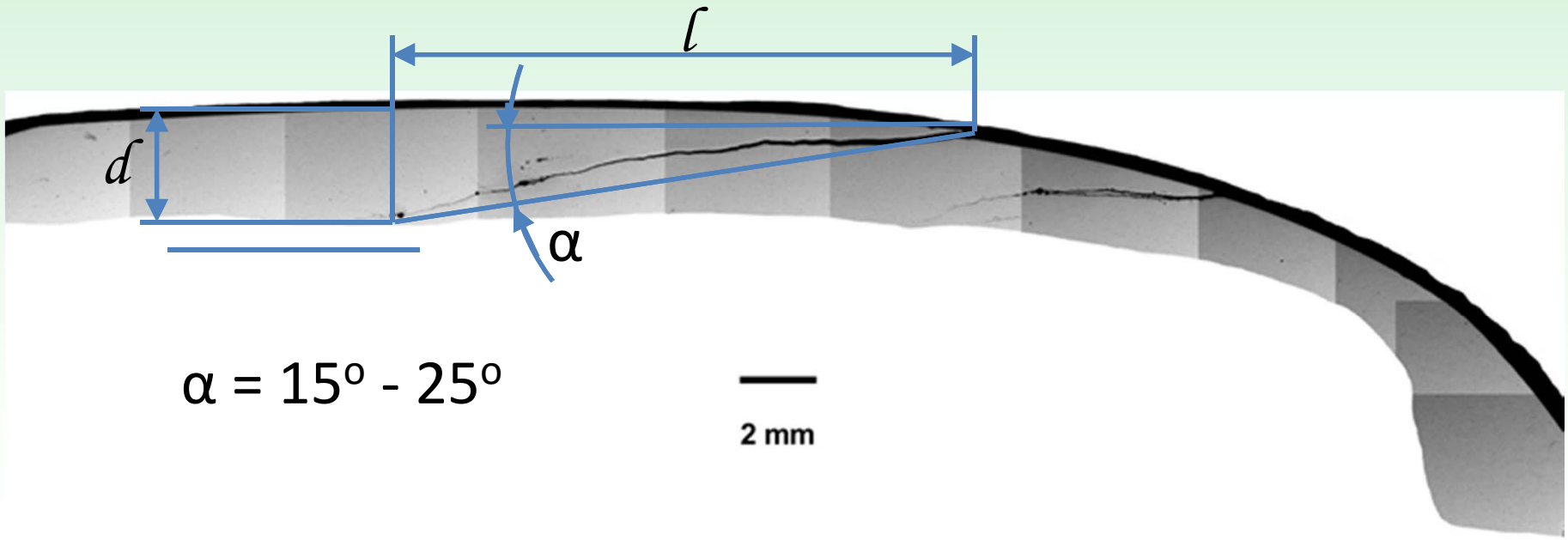
Multiple Eddy Current Probes are Needed to Cover the Rail Crown



The Probe Array Used by DB

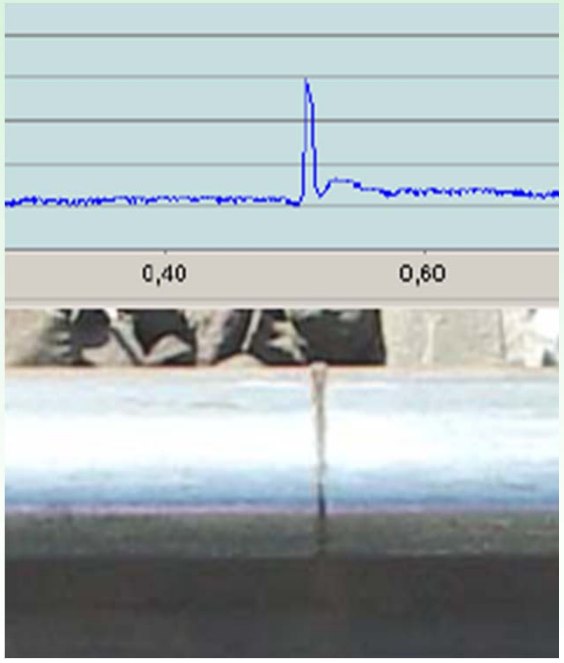
Walking Stick (One Rail) and Trolley (Two Rails, 20MPH) Used by ARM

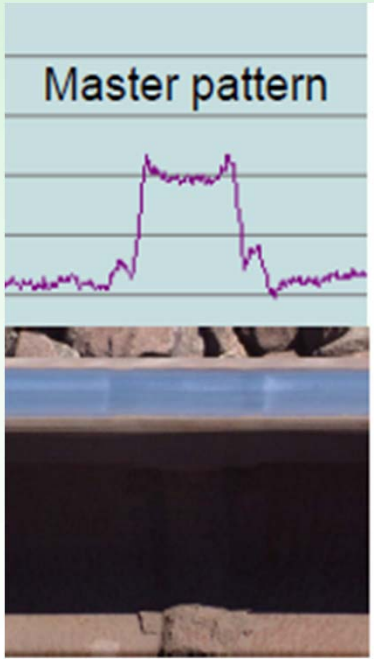
Depth of a Crack is Estimated from Crack Inclination



$\alpha = 15^{o} - 25^{o}$

Other Eddy Current Signals
Rail Joints and Thermal Welds





Capability of Eddy Current Sensors in Detecting Various Surface Defects

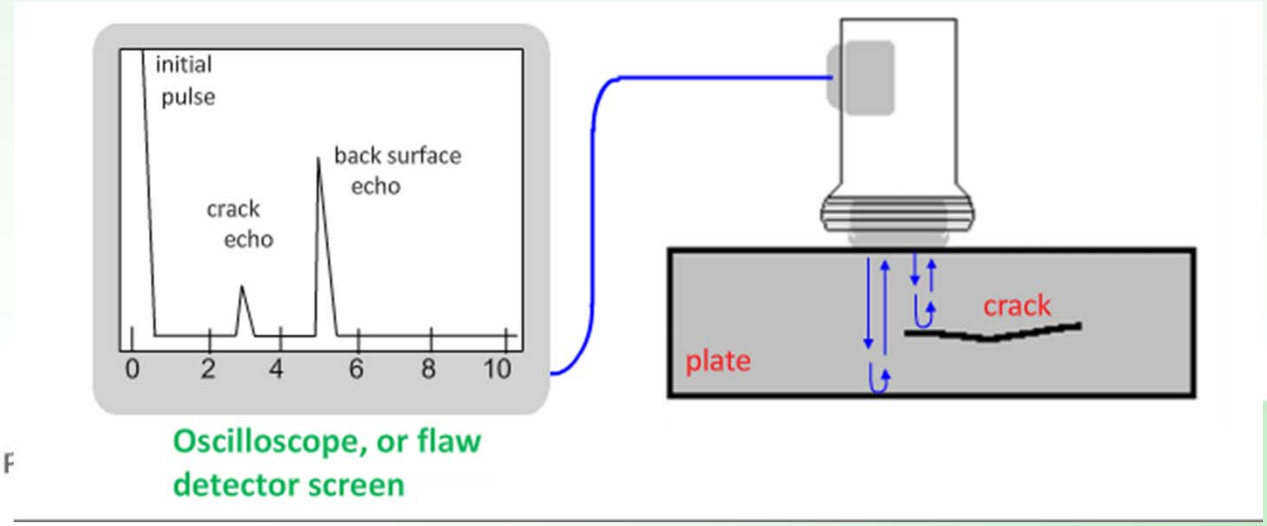
Category	Detectabiity	Statement
Rolling Contact Fatigue	Very good	Quantity, location, period
Wheel burns	Very good	Location, extent
Indentures	Very good	Quantity, location, period
Grinding marks	Very good	Quantity, location, period
Rail joints	Very good	Location, kind
Squats	Good	Quantity, location
Short/long pitch corrugations	Good	Location, pitch
Welds	Good	Location, kind, lack of fusion

Detection of non-RCF Defects

- **Initiation and formation of defects can have many causes ranging from internal flaws to external damage of rail section**
- **Ultrasound echo is preferred detection technique to find defects in rail**

Ultrasonic Inspection (Pulse-Echo)

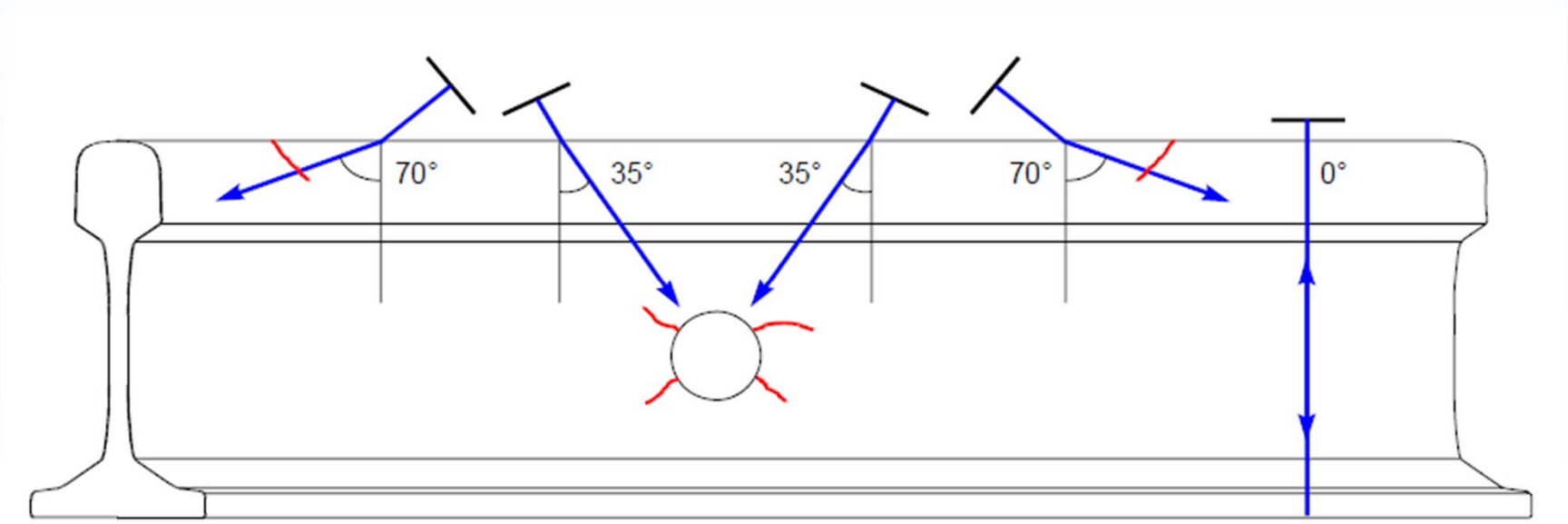
- High frequency sound waves are introduced into a material and they are reflected back from surface or flaw
- Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound



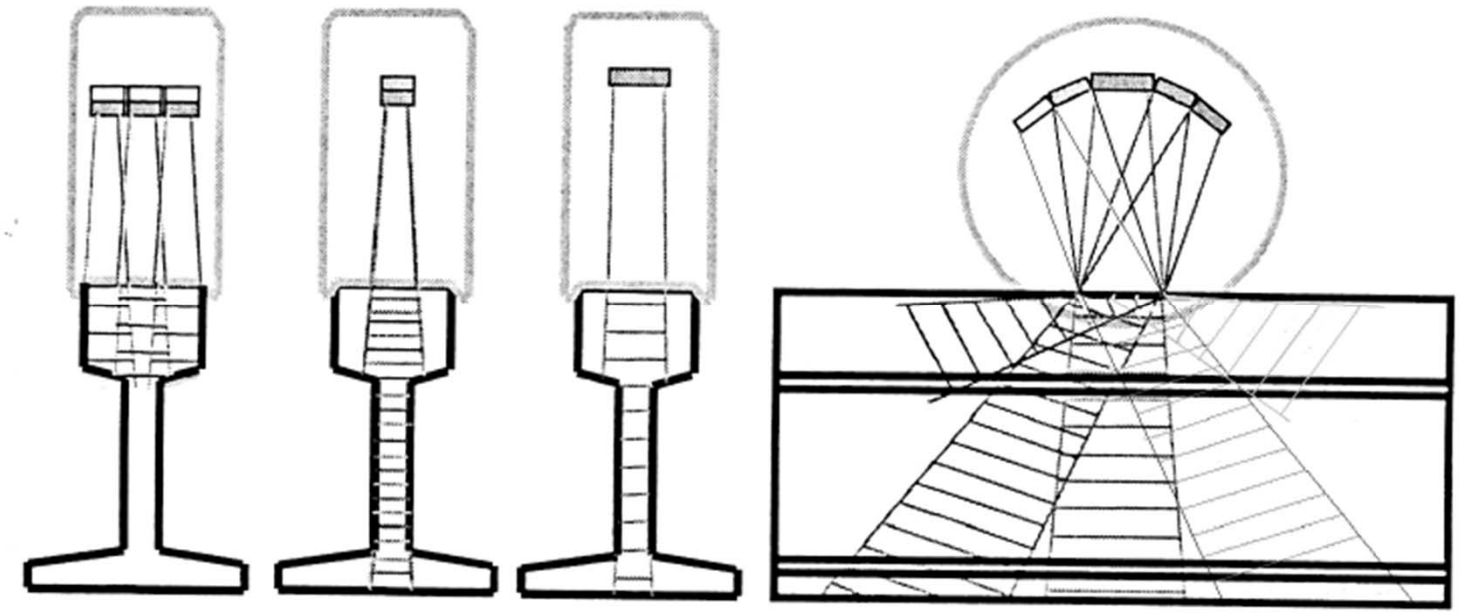
Ultrasonic Flaw Detection Systems
Detect Reflectors
Not Defects

RCF Crack
is One of the Reflectors

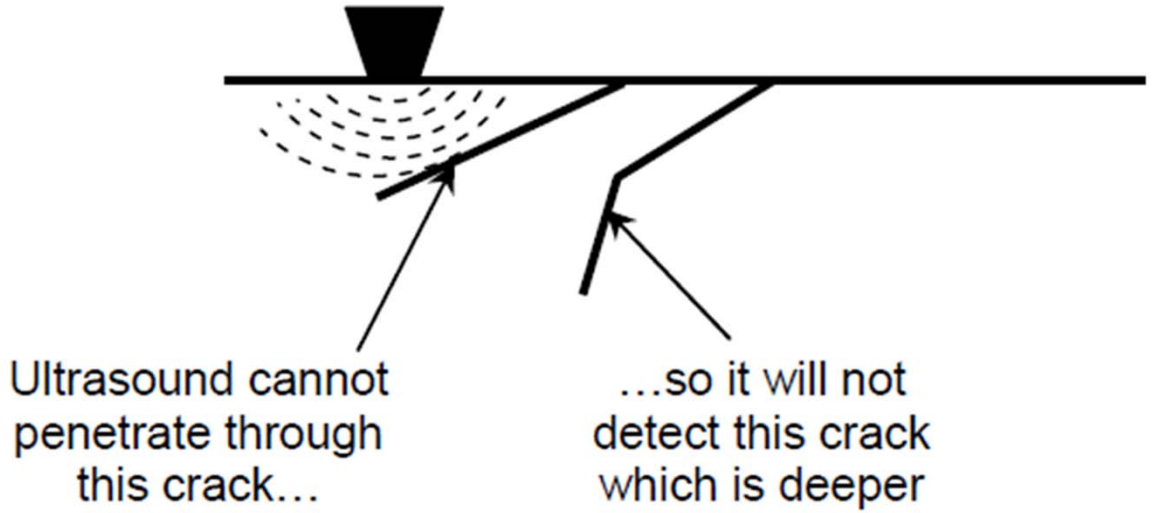
Multiple Probes to Detect Reflections from Horizontal to Vertical Cracks



Multiple Ultrasonic Sensors to Increase Overall Rail Section Detection Capability



Shadowing of Ultrasonic Sound by RCF Crack (Head Checks, Squats..)

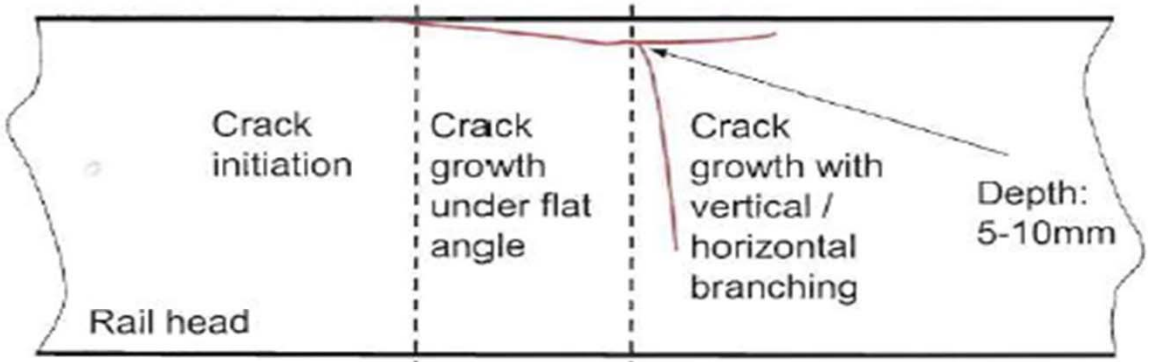


Deutsche Bahn Crack Growth Model

Crack growth divides into three stages

DB NETZE

Head Checks – Path of crack and speed of crack growth



Rate of crack growth (steel grade R260)	after 5-10 Mio Lt	1 to 2 mm 100 Mio Lt	~1 mm / 1 Mio Lt
ZfP-system for evaluation	VT, ET (St>0.2mm)	VT, ET (St≤2.7mm)	VT, UT

St = damaging depth
VT = visual check
ET = eddy-current text
UT = ultrasonic check

Source: project IOS, TP 1, Dr. René Heyder, VTZ 35, 06.04.2008

Can We Use That Rail?

- **A Defect found by Ultrasound must be cut out: Safety Mandate (FRA compliance)**
- **RCF can often be removed by grinding, rail remains in service: Economic Choice**

Example of Economic Choice: RCF Damaged Rail that was Never Ground = Waste of Money

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Strategies to Control RCF Cracks

- Using high hardness high cleanliness rail steels
- Top of the rail friction management
- Grinding to recommended rail profiles (gauge corner relief, optimized high rail, low rail, and tangent track rail profiles)
- Grinding on preventive cycle (chase the Magic Wear Rate)

Make Your Grinding Count – Grind Preventively

- Preventive grinding is about cycles. At how many MGT's and at what speed (depth of cut) we should grind?
- Monitor RCF with Eddy Current probes to confirm if Magic Wear Rate is maintained and sustained
- Utilize Eddy Current data to decide about grinding interval, grinding speed, repeat passes (if any) and choice of rail grinding pattern

Eddy Current and Ultrasound Testing Synergy

- Untreated RCF cracks inhibit Ultrasound detection of defects
- Eddy Current monitoring enables economic management of RCF cracks
- Combining Ultrasound and Eddy Current testing improves safety and economy of rail operations

Moving Forward

- It's never too early to start preventive maintenance that includes Eddy Current monitoring
- Eddy Current monitoring greatly enhances planning of preventive grinding cycles and reliability of Ultrasonic detection technology

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