Rail Maintenance:
Internal Defects,
Surface Conditions and
Maintenance Techniques

by

Gordon Bachinsky

PRINCIPLES COURSE • MAY 3, 2016
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

RCF cracks (head checks)

Spalling
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

The cracks branch downward

Border of half squat
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

\[ \alpha = 15^\circ - 25^\circ \]
Other Eddy Current Signals
Rail Joints and Thermal Welds
### Capability of Eddy Current Sensors in Detecting Various Surface Defects

<table>
<thead>
<tr>
<th>Category</th>
<th>Detectability</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolling Contact Fatigue</td>
<td>Very good</td>
<td>Quantity, location, period</td>
</tr>
<tr>
<td>Wheel burns</td>
<td>Very good</td>
<td>Location, extent</td>
</tr>
<tr>
<td>Indentures</td>
<td>Very good</td>
<td>Quantity, location, period</td>
</tr>
<tr>
<td>Grinding marks</td>
<td>Very good</td>
<td>Quantity, location, period</td>
</tr>
<tr>
<td>Rail joints</td>
<td>Very good</td>
<td>Location, kind</td>
</tr>
<tr>
<td>Squats</td>
<td>Good</td>
<td>Quantity, location</td>
</tr>
<tr>
<td>Short/long pitch corrugations</td>
<td>Good</td>
<td>Location, pitch</td>
</tr>
<tr>
<td>Welds</td>
<td>Good</td>
<td>Location, kind, lack of fusion</td>
</tr>
</tbody>
</table>
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..)

Ultrasound cannot penetrate through this crack...

...so it will not detect this crack which is deeper
Deutsche Bahn Crack Growth Model

Crack growth divides into three stages

Head Checks – Path of crack and speed of crack growth

<table>
<thead>
<tr>
<th>Rail head</th>
<th>Crack initiation</th>
<th>Crack growth under flat angle</th>
<th>Crack growth with vertical / horizontal branching</th>
<th>Depth: 5-10mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of crack growth (steel grade R260)</td>
<td>after 5-10 Mio Lt</td>
<td>1 to 2 mm 100 Mio Lt</td>
<td>~1 mm / 1 Mio Lt</td>
<td>VT, UT</td>
</tr>
<tr>
<td>ZfP-system for evaluation</td>
<td>VT, ET (St&gt;0.2mm)</td>
<td>VT, ET (St≤2.7mm)</td>
<td>VT, UT</td>
<td></td>
</tr>
</tbody>
</table>

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

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