Reverse Transverse Defects/Detail Fractures

ICRI-RCF WebEx

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Defect description

- Fatigue defect initiates at lower corner of gauge face
  - Typically initiators are flow lips resulting from severe plastic deformation down gauge face
- Fatigue crack propagation up from lower gauge corner and across rail head
  - Major growth direction is transverse, not vertical
  - Significant influence of lateral bending on growth behaviour

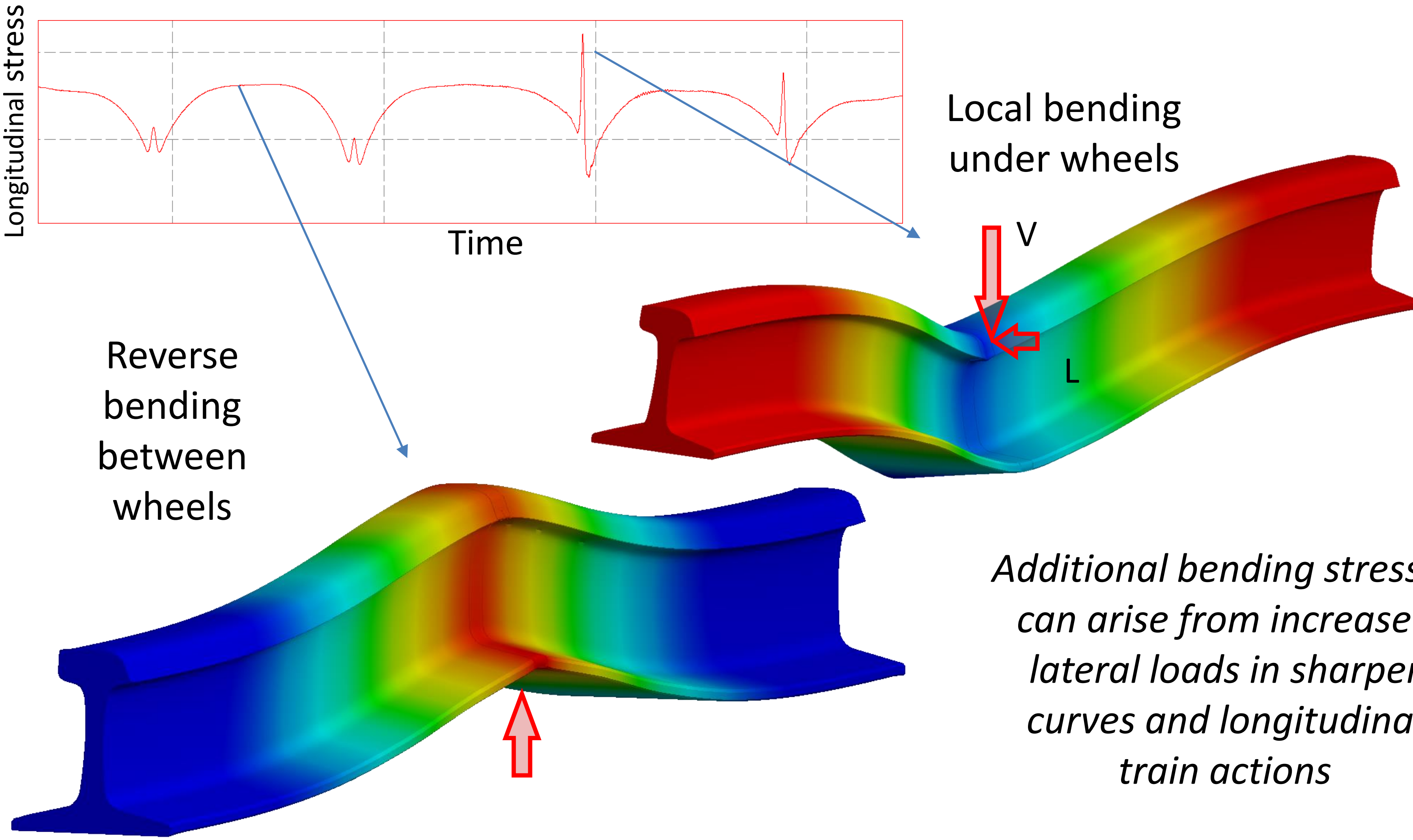
Industry awareness

- North America
  - Unique (well known?) defect classification
    - FRA Rail Defect Manual
  - Responsible for several broken rail derailments in Canada, USA
    - Examples from Norfolk Southern
- Australia
  - No previous reports of this defect type
  - Several defects reported in heavy haul systems in early 2016
    - 600m radius curve, high strength rail (worn), unlubricated
    - 2000m radius curves, intermediate strength rail (worn), unlubricated

Defect initiation

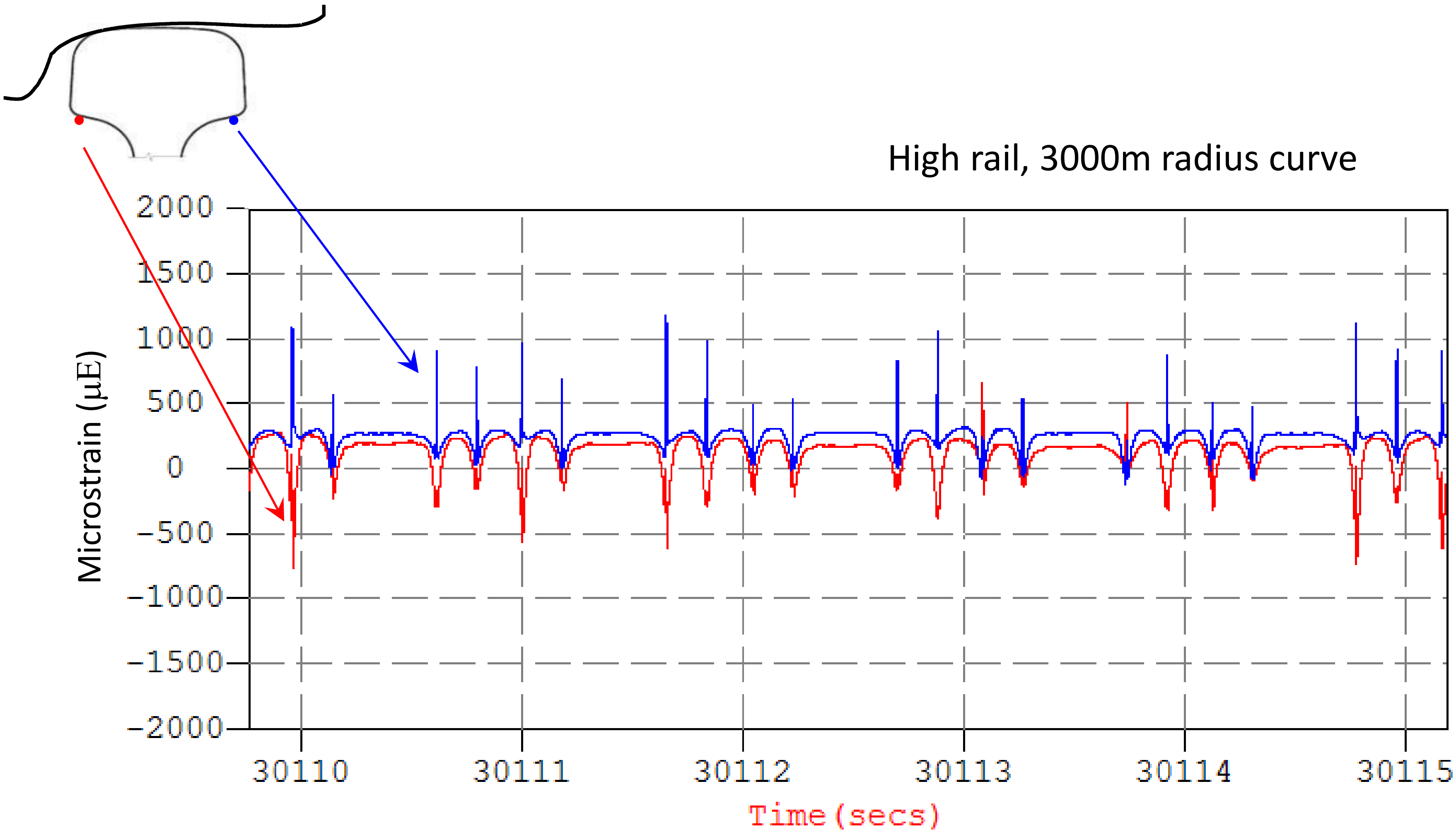
- Fatigue crack initiation at stress raiser (flow lip) at lower corner of gauge face
  - Lower corner of rail head is subjected to increasing longitudinal stresses as head wear increases; magnitude of these stresses ultimately dictates head wear limits
  - Stresses arise from:
    - Head-on-web lateral and torsional bending directly beneath wheel
    - Reverse bending due to uplift between wheels
  - Presence of flow lip provides potential fatigue crack initiation site

Bending modes and stresses in rail head



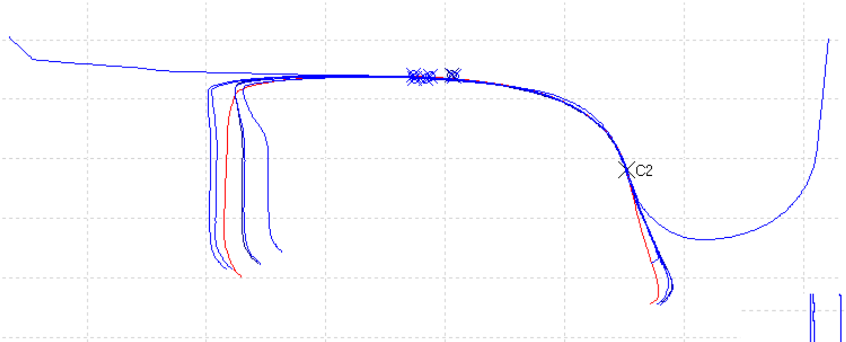
Additional bending stresses can arise from increased lateral loads in sharper curves and longitudinal train actions

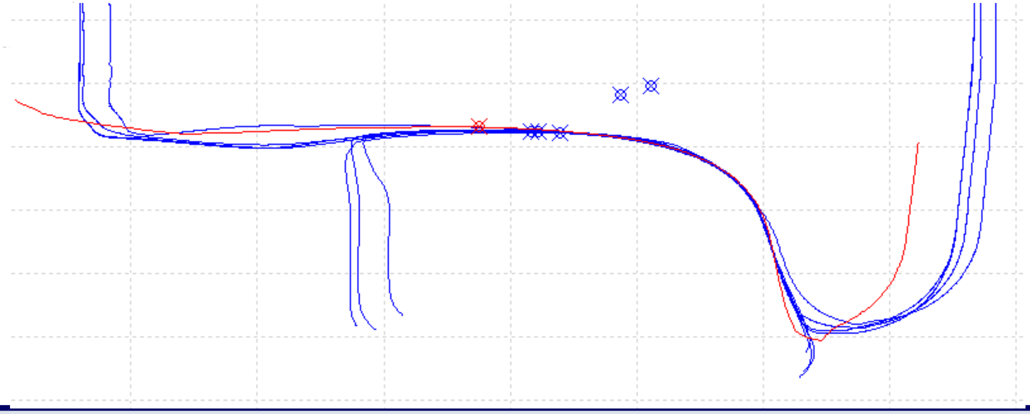
Longitudinal stresses at lower rail head



Wheel-rail contact conditions

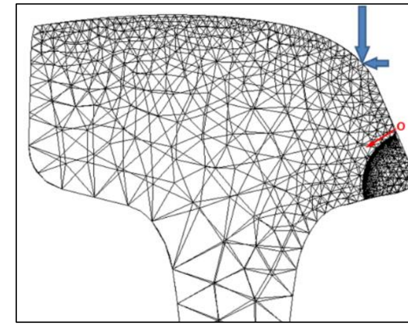
- *Defect initiation appears to require a combination of (a) flow lips and (b) high stresses from wheel-rail contact at lower gauge corner*

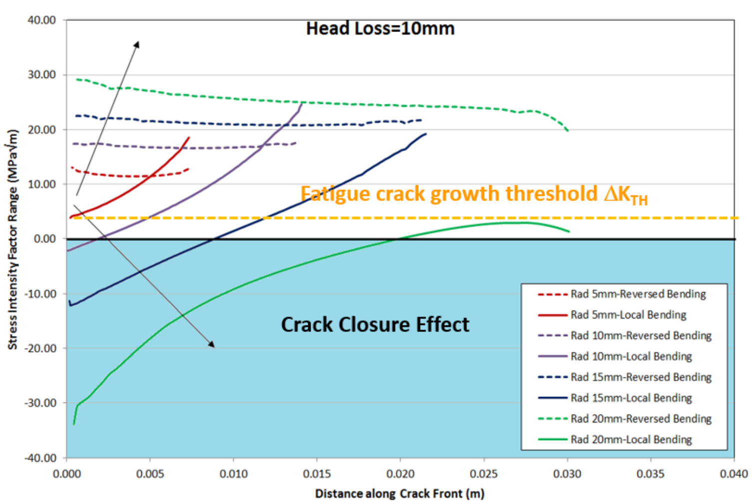


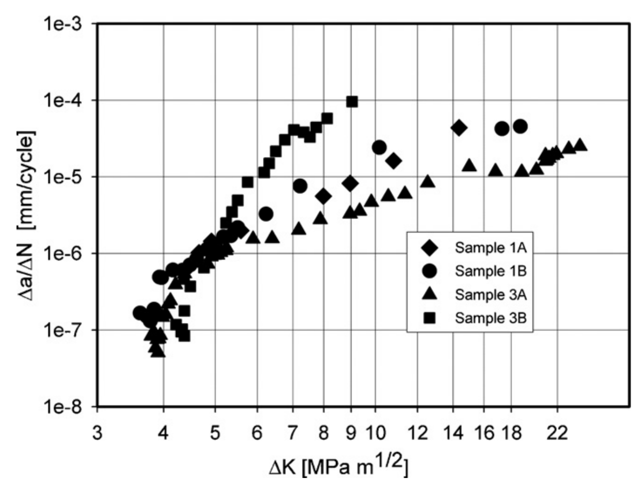


FEA of crack growth behaviour

- Local bending (limited wheels)
  - Promotes initiation and growth of small fatigue defects
  - Influence diminishes as crack size increases
- Reverse bending (all wheel passages)
  - Contributes to growth of defects at all stages
  - Influence increases as crack size increases
- Material characteristics
  - Fatigue crack growth characteristics vary in plastically-deformed material may increase potential for crack initiation





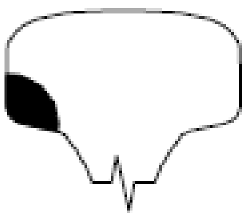


Bending stresses and defect growth

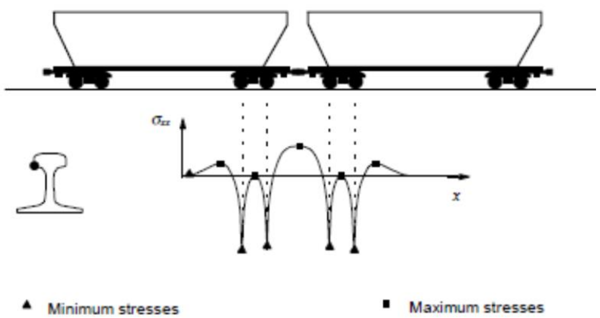
A. Fatigue cracks initiate in flow lip at lower gauge corner
   - Local bending of head is the dominant stress mode
   - Initial rate of crack growth appears to be very low, and possibly associated with flange contact towards lower gauge face
   - *Limited number of wheels may contribute to crack initiation and initial growth stages*

B. At larger crack sizes (>~15mm)
   - Increasing influence of stresses from reverse bending
   - Increased lateral loading results in higher bending stresses and increased crack growth rates
   - Major growth direction is transverse
   - *Increasing proportion of wheels contribute to crack growth*

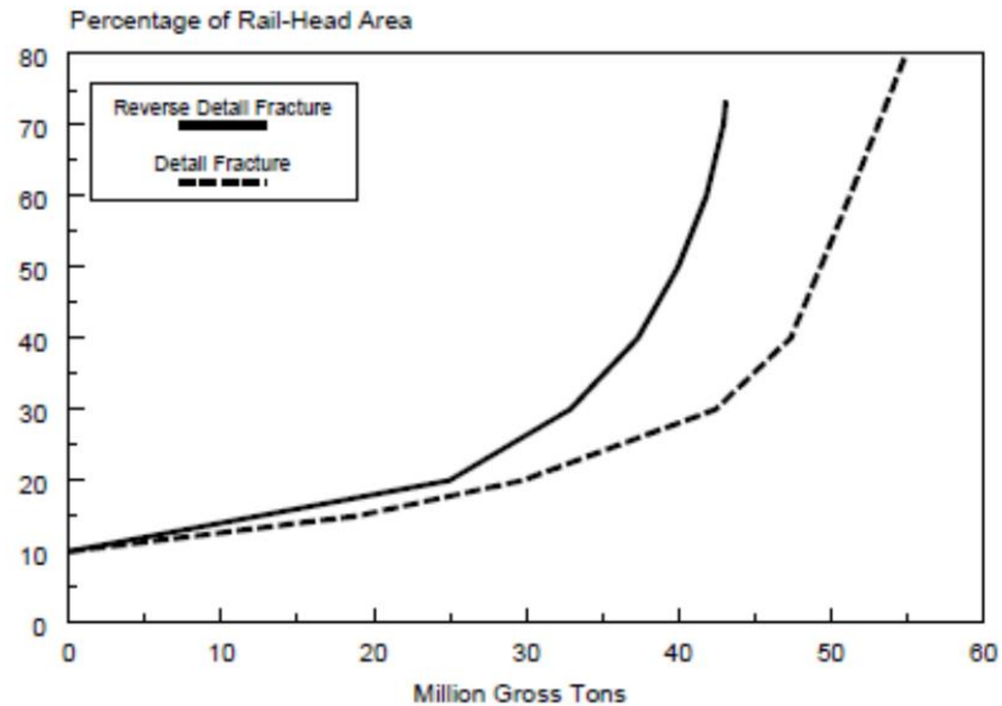
Comparison of predicted growth rates



Defect morphology

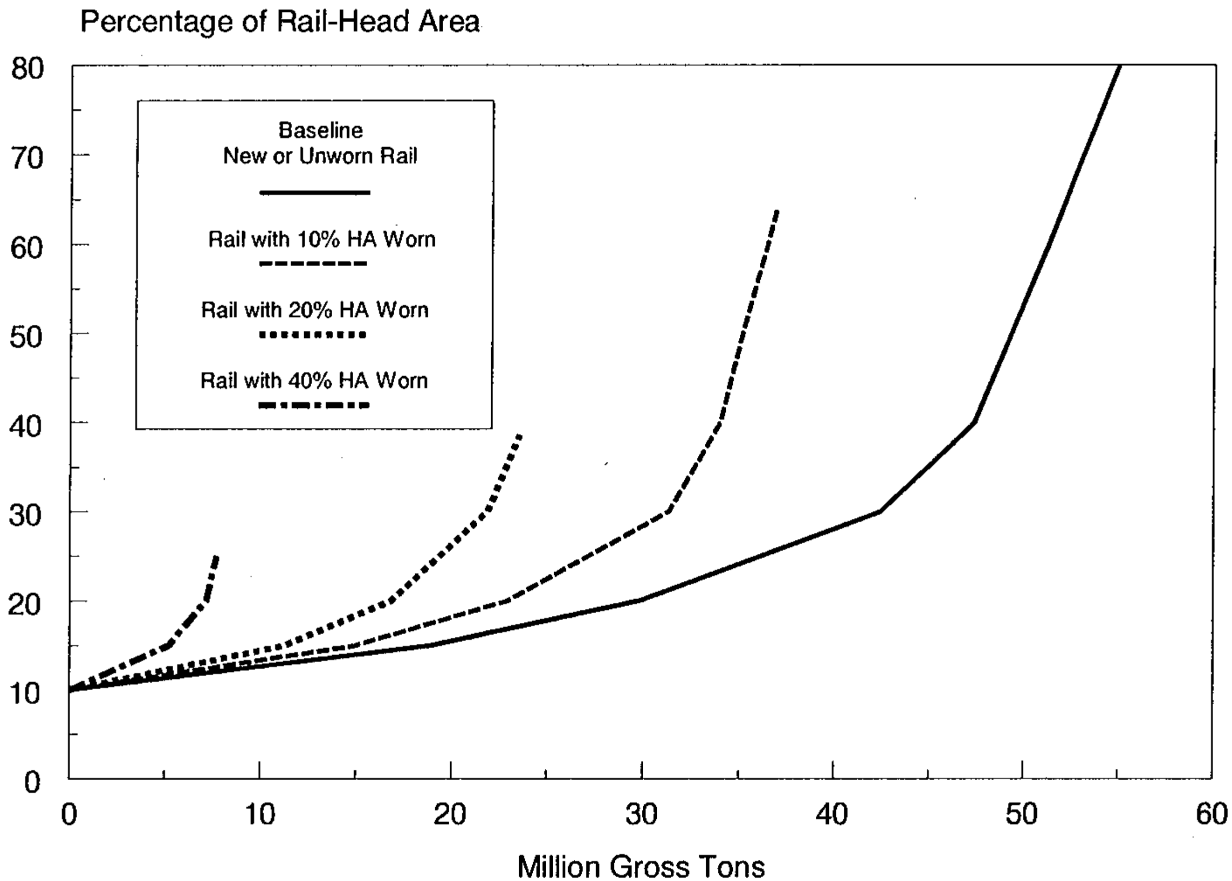


Loading spectrum



Jeong et al (1998), Propagation Analysis of Transverse Defects Originating at the Lower Gage Corner of Rail, FRA Report DOT/FRA/ORD-98/06

Influence of rail head loss on growth rates



Jeong et al (1998), Propagation Analysis of Transverse Defects Originating at the Lower Gage Corner of Rail, FRA Report DOT/FRA/ORD-98/06

Are reverse TD's a RCF defect?

- Surface condition (flow lip) which provides site for fatigue crack initiation results from poor wheel-rail contact conditions
  - Heavy plastic deformation lower gauge face
- Subsequent fatigue crack growth behaviour is similar to "conventional" TD's
  - Less influence of contact stresses on early stages of growth
  - Increasing influence of reverse bending stresses as crack sizes increase.

Future directions

- Industry questions:
  - Incidence of reverse TD’s and associated factors (rail type, head wear, curve radii, dry/lubricated, rail profile, defect sizes)
- Examination of representative defects
- Influence of wheel-rail contact conditions on:
  - Stresses in rail head
  - Development of defect initiators (flow lips)
  - Fatigue crack initiation
  - Fatigue crack growth/critical crack sizes

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