What is a squat?

• Squats are surface (or near-surface) initiated rolling contact fatigue (RCF) defects. They have also been called “dark spots”.
• Typically a crack starts to grow in the direction of travel and later grows in the opposite direction as well.
• The presence of the crack allows plastic deformation to form depressions above the crack – hence the name.
• Eventually spalling occurs, but much later than in most rolling contact situations.
Rail CRC Project R3-105

• Involved Railcorp, ARTC, QR, University of Queensland, Central Queensland University and Monash University.

• Growth of squats in track measured, and modelled. Crack growth in rail steel studied. Conditions leading to squat development modelled.

• Microscopy studies of squats conducted, residual stress measured, detection of thermal damage to track surface studied, statistical study of occurrence of squats conducted.
Surface appearance of a squat

- There is often a V shaped surface crack.
- Initiation is in the running band - but can be from existing gauge corner checking cracks.
- Darker region not polished by wheel-rail contact.
Fracture surface of a mature Australian squat

The portion of the crack surface reflecting light is horizontal. Crack grows down in both longitudinal directions (a saddle shape).

Direction of travel is to the right.
Where do squats occur?

- Where some disturbance of steady rolling contact is present.

  Transitions into curves, turnouts, welds, unsupported sleepers, regions of braking or acceleration, etc. Both in urban and on heavy haul lines.

- Where water is present.

  No squats in tunnels. Hydraulic entrapment of water in the crack and the squeeze film effect of water pushed out of a crack have been studied.
Fatigue v Wear

Squats do not form where wear is high
Eg steeper grades, softer rails.

**Squats do form where tractions are high**
if there is not too much sliding of wheels
– measured by creep $\gamma$.

**Frictional power**
The product of traction $T$ and sliding velocity is frictional power, measured by $T\gamma$. There is a range of frictional power that leads to squats, above that where cracks can initiate and below that where wear dominates.

**$T\gamma$ model – Burstow**
Really for one particular wheel and one particular track.
A transition into a curve can put $T\gamma$ in the critical range (S. Simson).
Squats were thought to initiate by cyclic plastic deformation of the rail surface, which can take 40 MGT of rail traffic. However, cracks are being found after about 10 MGT of traffic, suggesting other damage is occurring. Examination of rail specimens by etching with nitric acid consistently shows a thin “white etching layer” (WEL) on the surface (10’s of microns thick). This is hard and brittle causing cracks to initiate, especially on the edge of it. Did the WEL cause the crack or is it a consequence of the crack? Evidence is growing that it is the former.
Detecting a WEL (S. Mohan, CQU)

• A portable eddy current probe, operating between 500 kHz to 2 MHz, has been used successfully to identify WEL on numerous rail samples, and to distinguish WEL from surface cracking.

• Existing eddy current crack detection equipment could be adapted to identify WELs.

Signal measured
Crack growth

- Prof R. Jones at Monash measured crack growth in rail steel and fitted it to a growth law accurately.
- To use this we need to estimate stress at a crack as it grows.
- This becomes difficult once the contact zone changes, and the contact pressure distribution changes as the crack grows.
Squat growth measured on track

- Railcorp measured growth of squats at 2 sites in Sydney.
Residual stress

- Residual stress also affects crack growth.
- Neutron diffraction residual stress measurements on rail samples with WEL were made at the Australian Nuclear Science and Technology Organization in this project to investigate the residual stress in Australian rails.
- About -300 MPa transverse and axial compression in the head of the rail (purple contour). Residual compression is not confined to a narrow running band.
- Some vertical tension is present subsurface.
What can be done about squats?

- **Changing traction control**
  - Urban squats increased upon introduction of AC traction control systems.
  - Are the latest traction control systems encouraging drivers to use too much of the available traction? This is being investigated.

- **More aggressive grinding**
  - US railways seem to avoid squats. Is it because they grind rails more?

- **Less flexible rails**
  - Japanese experience also reports solving a squat problem by upgrading from 50 kg/m to 60 kg/m rail.

- **Avoiding low wear regimes**
  - Japanese railways found that low radius curves, or higher radius curves with low wear rates were a problem.
Data from Ishida

• Squats generated in curves where the wear rate is too low, regardless of the type of line.