Wheel/Rail Interface Management
A Tool for Controlling Noise

Rob Caldwell, P. Eng
Senior Engineer

National Research Council Canada
Centre for Surface Transportation Technology

WRI Transit Panel Session, May 3, 2011

Introduction to the WRI

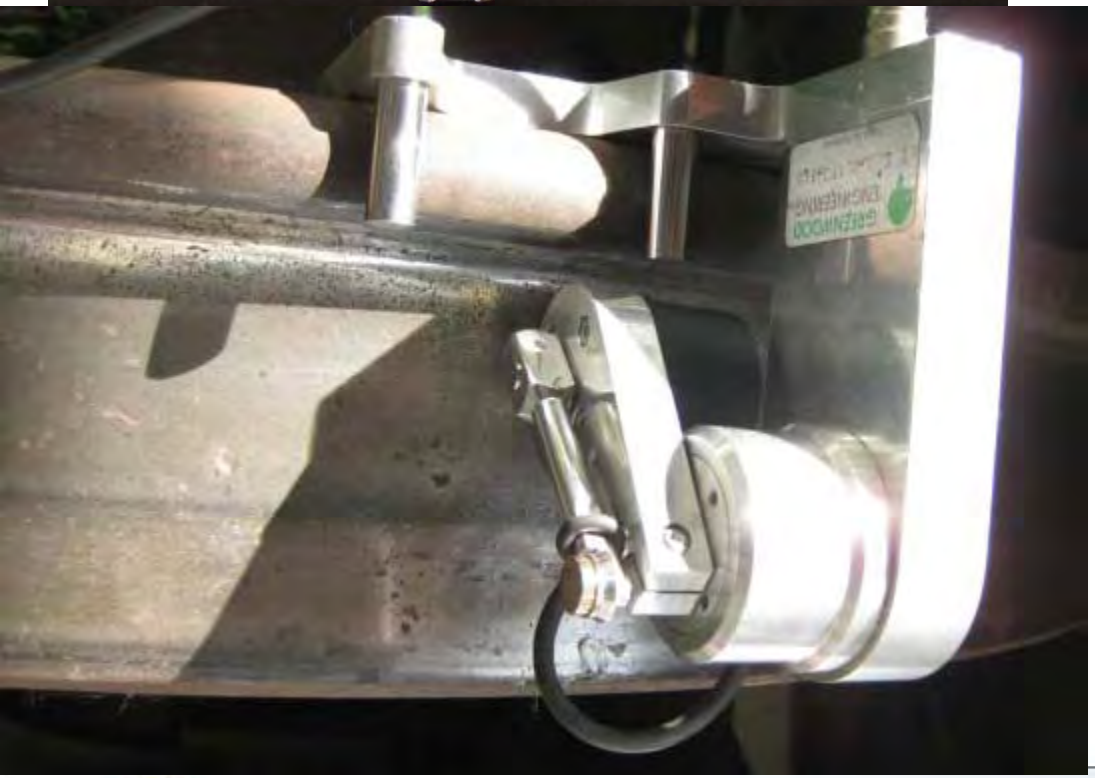
What is it ? Why is it important ?

What are the Noises ?

- Rolling Noise / Tangent Track Noise
  - Baseline noise, for smooth-ground rails and trued wheels
  - Due to the roughness of the wheels and rails
  - Produces the least vibration of track and truck components, extends time between maintenance cycles and component life
  - Also occurs in curves

What are the Noises ?

- Rolling Noise - Rough Surfaces
  - Wheels and/or rails that are excessively rough cause louder noise
  - Roughness due to minor surface imperfections in the contact bands… pits, small shells
  - Varying contact band (width, location) on the rail can also contribute to this noise



What are the Noises ?

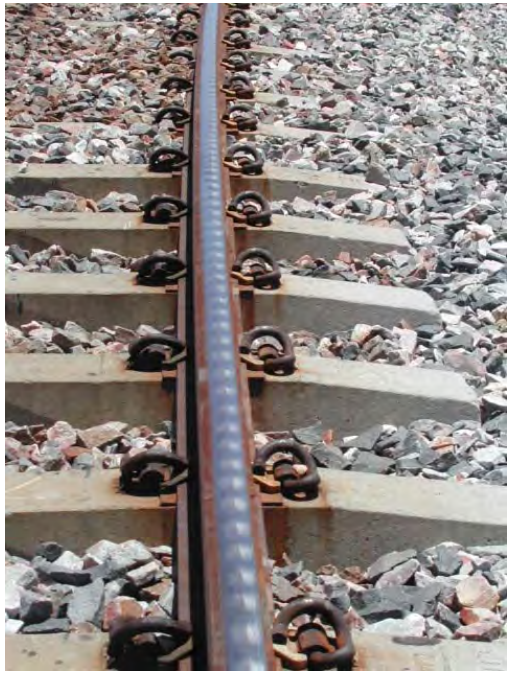
- Impact Noise
  - Due to significant RCF damage on wheels and/or rails, flatted wheels, dipped/peaked/misaligned welds, and rail joints
  - Wheel separation from rail, impact noise occurs when contact re-established
  - Separation can occur at a critical speed (function of wavelength and amplitude) for any smooth irregularity in longitudinal profile
  - Separation can occur due to wheel flats or rail joints; above the critical speed impact noise drops
  - At step-up joints, impact noise increases w/ speed

Damage Causing Impact Noise

What are the Noises ?

- Roaring Rail
  - Caused by rail corrugations
  - Considerably noisier than baseline rolling noise
  - Occurs in curves and tangents
- Howling wheels
  - Caused by wheel corrugations, or polygonization
  - Occurred on Vancouver SkyTrain

Noise from Corrugations



What are the Noises ?

- Wheel Squeal
  - Very piercing sound
  - Perhaps the most irritating of the noises
  - Can often overwhelm other noises, particularly at low speeds

What Causes the Noises ?

- Rough Surfaces
  - Shells are a form of RCF damage
    - caused by high contact stresses and/or high tractions
  - Pits caused by small debris crushed into surfaces
  - Varying contact band position caused by:
    - significant lateral track geometry disturbance
    - joining new rail to an existing one
    - change from canted to uncanted rail at a switch.

What Causes the Noises ?

- Impact Noises
  - Wheel slides due to hard braking w/ low COF
  - Wheel burns from rail-bound maintenance equipment under low COF conditions
  - Wide gap joints
  - Battered rail ends at joints
  - Badly shelled rails and wheels

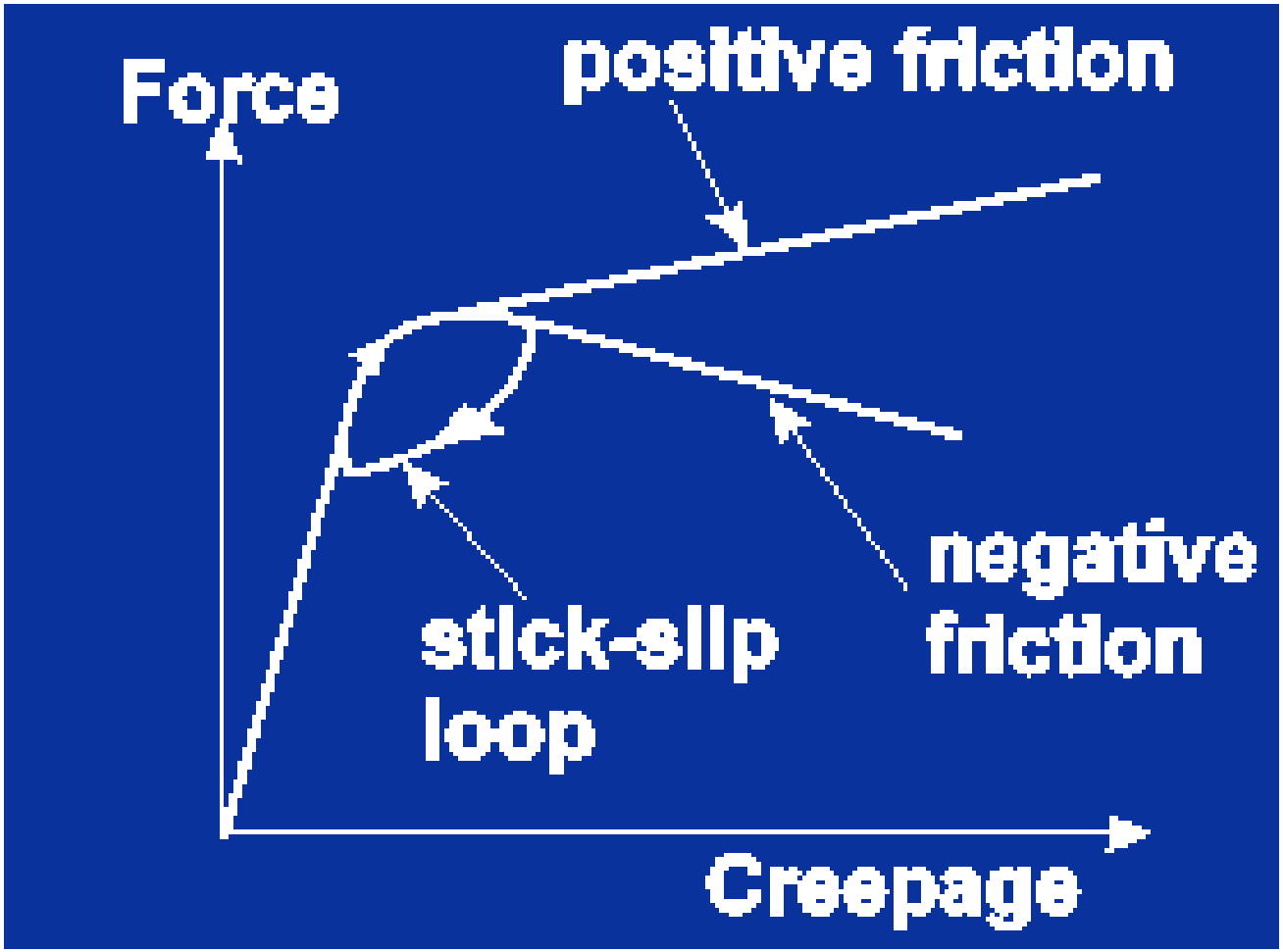
What Causes the Noises ?

- Roaring Rail
  - Wheel/rail conformality (hollow treads, flat rails) encourage corrugation
  - Roll-slip in areas of high traction demand (grades, station exits)
  - Corrugation results from a feedback mechanism, so self-reinforcing
  - Transits typically have uniform vehicle fleet, controlled speed… every vehicle contributes to growth and propagation

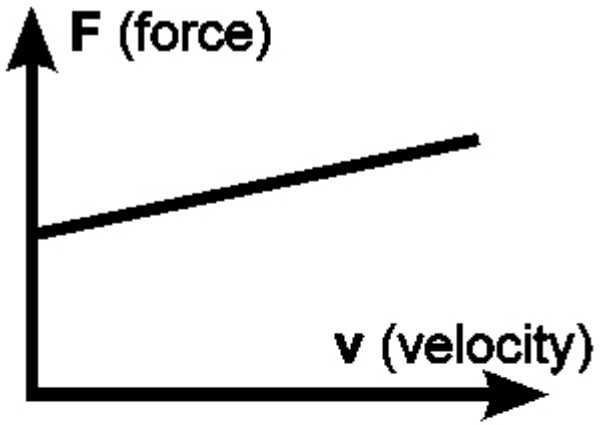
What Causes the Noises ?

- Squeal
  - Caused by stick-slip oscillation in the contact patch, during lateral slip of the wheel tread over the TOR… wheel plate vibrates out of plane
  - Stick-slip can occur if negative friction is present
  - Made worse by large AoA (poor steering, wide gauge)
  - Often occurs from the low rail wheel, but not if guard rail contact is present

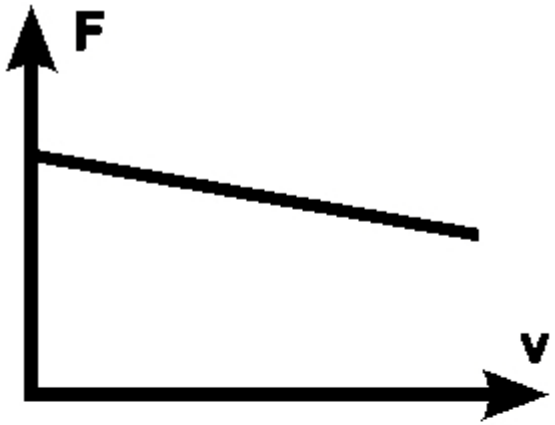
Friction Characteristic



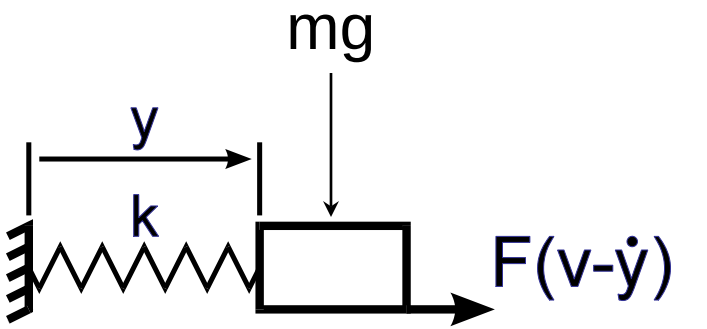
Stick-Slip - The Prony Brake

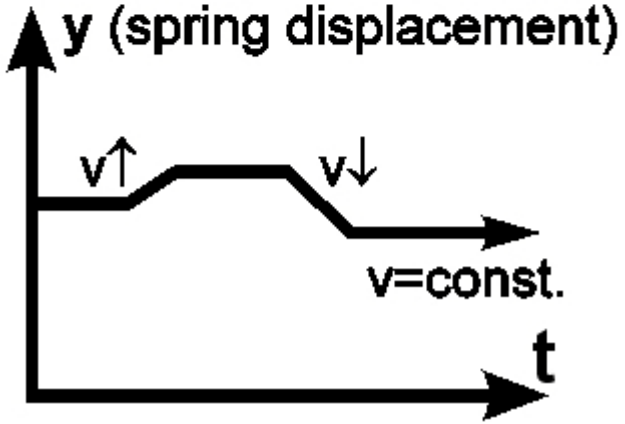


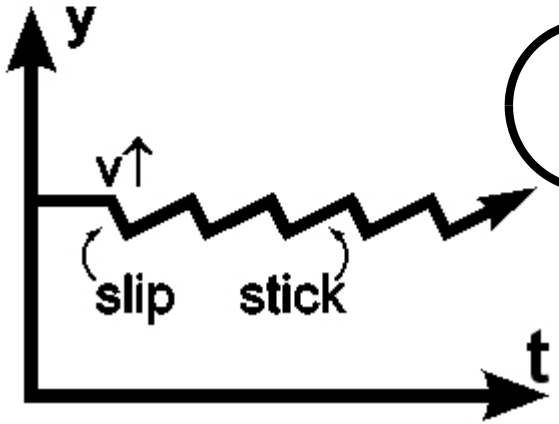
positive friction belt
STABLE



negative friction belt
UNSTABLE







What are the Treatments ?

- Rough Surfaces
  - Analyze the WRI, determine what caused the damage
    - high contact stresses – implement profiles that produce acceptable stresses for the W/R metallurgies
    - high traction stresses – implement TOR-FM
  - Grind the rail to remove the damage (shells/pits outside the contact band don't have to be removed)
    - significant post-grind noise reduction indicates that rough rail was a problem
  - True wheels to remove the damage

What are the Treatments ?

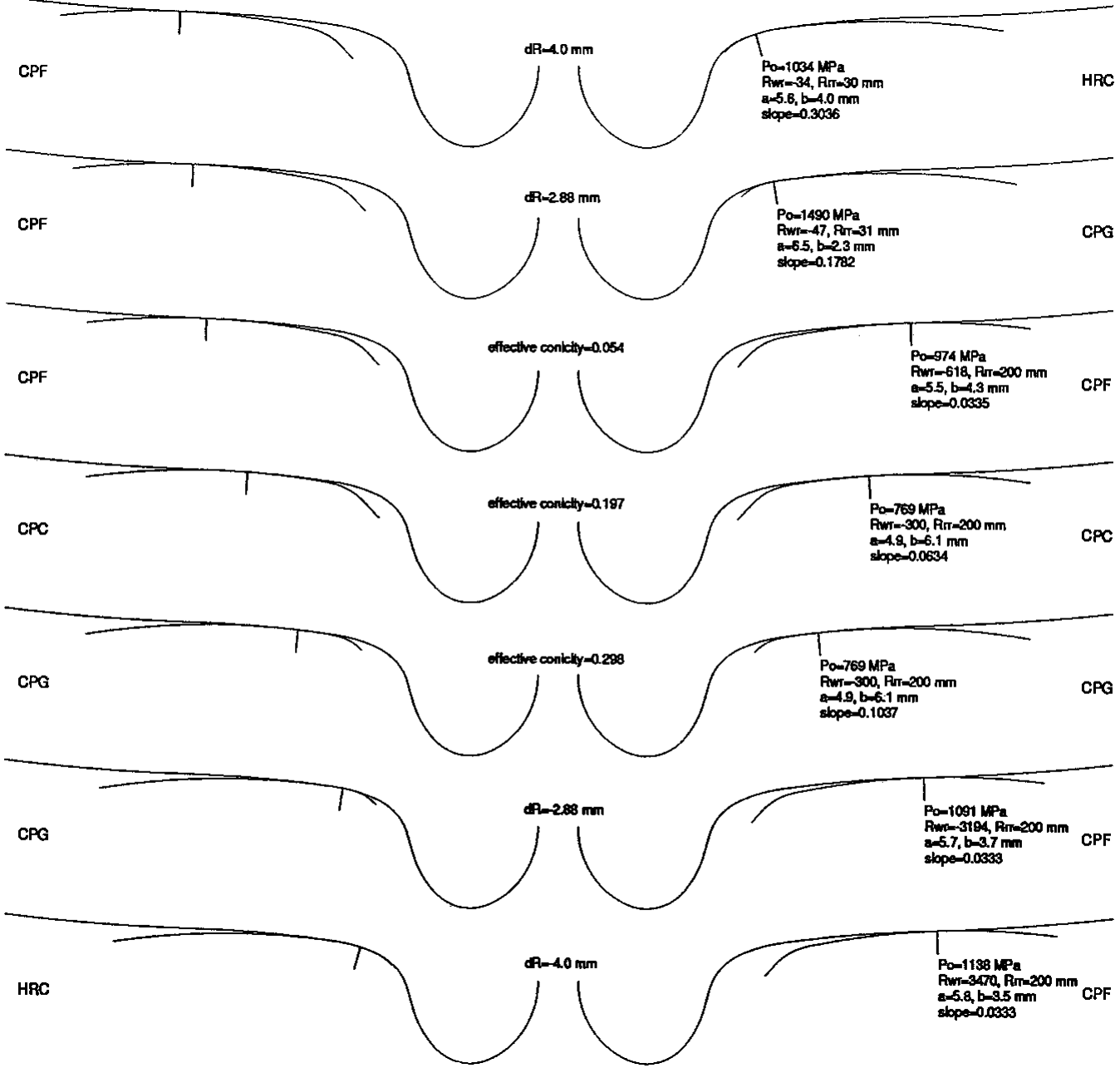
- Rough Surfaces (cont)
  - If profile designs and friction are appropriate, was damaged caused by deferred grinding ?
    - an optimized WRI still undergoes wear, and requires periodic profile maintenance
  - Correct geometry anomalies that cause irregular contact bands
  - Grind switches to profile so contact band is continuous through the switch

What are the Treatments ?

- Impact Noises
  - Wheel separation: grind to smooth out longitudinal profile
  - Flats: turn wheels to correct flats
  - Flat prevention: adjust lubricators to prevent TOR contamination, or try stick lubrication; adjustments to slip-slide control
  - Joint maintenance: reduce gaps, maintain running surface elevations
  - Field weld joints, grind them smooth and maintain w/ periodic grinding
  - Shells: must be removed by truing, or ground out if in the rail's contact band

What are the Treatments ?

- Roaring rail
  - Prevent W/R conformality, implement rail profiles that distribute wear across the tread
  - Grind rails periodically to maintain profile – any corrugations must be removed (less than 5µm roughness)
  - Need positive friction characteristic at TOR to inhibit roll-slip oscillations
  - Replace the rail
    - gets rid of existing corrugation, does nothing to prevent reoccurrence


CPF
dR=4.0 mm
Po=1034 MPa
Rwr=-34, Rrr=30 mm
a=5.6, b=4.0 mm
slope=0.3036
HRC
CPF
dR=2.88 mm
Po=1490 MPa
Rwr=-47, Rrr=31 mm
a=6.5, b=2.3 mm
slope=0.1782
CPG
CPF
effective conicity=0.054
Po=974 MPa
Rwr=-618, Rrr=200 mm
a=5.5, b=4.3 mm
slope=0.0335
CPF
CPC
effective conicity=0.197
Po=769 MPa
Rwr=-300, Rrr=200 mm
a=4.9, b=6.1 mm
slope=0.0634
CPC
CPG
effective conicity=0.298
Po=769 MPa
Rwr=-300, Rrr=200 mm
a=4.9, b=6.1 mm
slope=0.1037
CPG
CPG
dR=2.88 mm
Po=1091 MPa
Rwr=-3194, Rrr=200 mm
a=5.7, b=3.7 mm
slope=0.0333
CPF
HRC
dR=-4.0 mm
Po=1138 MPa
Rwr=3470, Rrr=200 mm
a=5.8, b=3.5 mm
slope=0.0333
CPF

What are the Treatments ?

- Squeal
  - Minimize AoA
    - increase rolling radius difference through profile design
    - maintain the profiles w/ grinding & truing
    - prevent wide gauge due to wear w/ lubrication
  - Prevent stick-slip with positive friction
    - vehicle or wayside implementation of friction modifier
  - Friction management slows wear deterioration of profiles, benefits are maintained longer

Summary

- Maintain transverse profiles to prevent noise due to RCF damage
  - grinding is not a means to correct track geometry defects
- Manage friction to
  - prevent profile deterioration
  - inhibit/delay corrugation formation (positive friction)
  - Inhibit squeal in curves