EFFECTS OF WHEEL/RAIL CONTACT PATTERNS and VEHICLE PARAMETERS on LOADED CAR HUNTING

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In 2006, failures of primary suspension adapter pads were reported on a particular type of grain car:

- Loaded high capacity (286k lbs) grain hoppers
- Truck hunting: *loaded hunting is unusual*
- M-976 trucks with improved tracking
- Routes with specific rail wear patterns and tighter gage
Primary Suspension Adapter Pads

- Polymer pads improve axle steering, reduce W/R forces and rolling resistance
- Loaded Hunting motions appeared to cause failures:
  - Primary suspension pads
    - If a pad does fail, it is typically only 1 out of 8 in a car
  - Constant contact side bearings (CCSB)
Initial Lateral Stability (Hunting) Tests

- 50 mph Tests performed at TTC
## Initial Lateral Stability (Hunting) Tests

- Tests performed at TTC

<table>
<thead>
<tr>
<th>Wheel Profile and Conicity</th>
<th>Empty ~ Standard Pads</th>
<th>Loaded Hunting Threshold Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Summer Standard Pads</td>
</tr>
<tr>
<td>Worn λ&gt;0.6</td>
<td>65 mph</td>
<td>47.5 mph</td>
</tr>
<tr>
<td>KR λ&gt;0.2</td>
<td>80 mph</td>
<td>65 mph</td>
</tr>
<tr>
<td>AAR1B λ&gt;0.05</td>
<td>&gt;80 mph</td>
<td>75 mph</td>
</tr>
</tbody>
</table>

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Initial Hunting Test Conclusions

- Loaded car hunting a function of
  - Car body mass and inertial properties
  - High W/R Conicity
    - Worn wheels
    - Worn rail profile in straight track
  - Adapter pad stiffness

- Loaded car hunting also a function of:
  - Center plate friction
    - Steel center plates reduced hunting
  - Side bearing friction restraint
Grain Car Wheel Wear and Effects on Conicity

- **Conicity ($\lambda$) on TTCI Hunting test zone**

- Relatively low wear in this region

- Higher wear in this tread region

- **Average Conicity, RTT 34 Rail**

  - Mileage (*1000)
  - Conicity
  - New AAR-1B
  - Avg
  - Max
  - Min

- 96,000 miles
- 160,000 miles
- 35,000 miles

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High Conicity W/R Contact Conditions

- Increased conicity on tangent track after ~ 160,000 km
- Tangent rail head profiles:
  - Certain new rail sections
  - Tight gauge
  - "Flattened" crowns
  - Flow to the gauge corner
Wheel / Rail Profiles

- Accelerated initial flange wear

- Associated with initial mismatch & 2-point contact between new wheel & worn high rail in curves
Wheel / Rail Profiles

- Reduced flange wear after ~ 50,000 miles

Associated with single point contact & a large radius differential generated on the high rail in curves
W/R Conicity as a Function of Mileage, Car and Truck Arrangement

- **Car/Truck types**
  - Gen I: Grain car with steel adapters
  - Gen II: Grain car with polymer adapters
  - Coal: Coal car with steel adapters
  - Coal HD: Coal car with polymer adapters

- **Root causes for differences are still unknown but suspected to be a function of:**
  - Curving ability
  - Vehicle stability
W/R Conicity as a Function of Rail Profiles for a Particular Grain Car Route

- Analysis of conicity for 108 axles on 25,000 measured rail profiles from 19 miles of tangent track

Conicity $\approx 0.1$

Rails producing lower conicity

Conicity $\approx 0.4$

Rails producing higher conicity

Mainly due to worn wheels

Percentage of Exception (Wheels)
New AAR-1b wheels produce low conicity on all rail profiles.

Rails with a low rail shoulder produce lower conicities, high shoulder gives high conicity.

Conformal contact tends to produce low conicity.

Flattened rails, gauge flow and narrow gauge produce high conicities.
Tangent Track W/R Conicity Summary (cont.)

- Tight gauge is highly correlated to high conicity in tangent track

<table>
<thead>
<tr>
<th>Distance (feet)</th>
<th>Gage Spacing inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>12200</td>
<td>56</td>
</tr>
<tr>
<td>12220</td>
<td>56.1</td>
</tr>
<tr>
<td>12240</td>
<td>56.2</td>
</tr>
<tr>
<td>12260</td>
<td>56.3</td>
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<td>12280</td>
<td>56.4</td>
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<tr>
<td>12380</td>
<td>56.9</td>
</tr>
<tr>
<td>12400</td>
<td>57</td>
</tr>
</tbody>
</table>

- High conicity was found on only 10% of track
- Rail grinding to relieve reduce flattened rails, relieve the gauge corner and remove metal flow in the gauge corner could reduce conicity
- A more conformal new wheel profile could change the rapid initial wear pattern of new wheels
Truck Hunting and Warp Dynamics

- Loaded hunting tests revealed:
  - Predominantly in-phase motion (warp) of the wheelsets & truck bolster
  - Little longitudinal deflection of the adapter pads
  - Dependence on moments due to the adapters / adapter pads & truck rotation on stability
Truck Warp Test Results

Avg. stiffness = 140 klb-in/mrad

High warp restraint similar to previous tests of the same truck type when friction wedges have little motion

Avg. stiffness = 12.5 klb-in/mrad

Warp stiffness reduced by factor of about 11 due to friction saturation with large wedge motions from combined body vertical/lateral motions
NUCARS® simulations to evaluate W/R forces and effects of Carbody and Suspension Parameters

40,000 lbs net lateral axle force
W/R Forces due to Loaded Hunting

- NUCARS® simulations of loaded grain car hunting show potential for very high W/R forces

- Large Net Axle L/V ratios could cause track panel shift

- Large truckside L/V could cause gauge widening and rail rollover
Progression to Loaded Car Hunting

- Accelerated wheel wear occurs in curves as a result of a “mismatch” between the high rail profile & that on tangent track
  - 2-point contact
  - High rail “conditions” the wheel of a car making flange contact to a conformal profile

- “Conditioning” results in high conicity, especially on particular sections of tangent track
  - New rail of particular section
  - “Flattened” rail with material flow to the gauge corner
  - Sections of track with tight gauge
Progression to Loaded Car Hunting (cont.)

- High conicity on tangent track
  - On sections where higher speeds occur
  - High creep forces under load excite the wheelsets
    - to yaw/warp the truck frame
    - to yaw within the truck frame on soft adapter pads
- Wheelset & truck yaw excite particular (longer) car bodies in a yaw-dominated mode (includes roll)
- Car body yaw and coupled roll motions saturate the truck wedge system, reducing the warp restraint
- Reduced warp restraint results in resonance between wheelset, truck & car body yaw above certain threshold speeds
Progression to Loaded car Hunting (cont.)

- Truck warp restraint breaks-down almost completely
- Wheelset hollowing (& conicity) increases as a consequence of the hunting motion
- Loaded car hunting occurs:
  - At progressively lower speeds
  - On increasingly longer sections of tangent track
- Pad failure results together with degradation of constant contact side bearing elements
Loaded Car Hunting: Conclusions

- Loaded car hunting is a system problem:
  - Only certain car types – many cars with trucks do not hunt
  - Depends on truck center spacing, car body inertial characteristics (centers of gravity & moments of inertia associated with high capacity cars for low density bulk products)
  - Wheelset and truck constraints (adapter pad stiffnesses, loss of warp restraint due to friction wedge motion)
  - Track (rail profile mismatch, rail deformation, tight gauge)
Many types of car with these trucks do not experience loaded car hunting:

- Need “tune” the car and truck suspension parameters to the specific car body characteristics:
  - Truck spacing, inertial parameters (CG height, yaw and roll moments of inertia)
  - Wheelset and truck constraints (adapter pad stiffnesses, truck warp restraint)

Loaded hunting may lead to very high W/R forces

- Possibility for increased risk of track damage and derailment (Oct 2009 tests will measure forces w/IWS)
Way Forward: Standards and Testing

◆ Primary Suspension Pad Durability Standards
  ● AAR MSRP, Volume H, Section 4.3.2

◆ Develop M-976 and Chapter 11 Loaded Hunting Test/Analysis Requirements (2009)
  ● What wheel profile?
  ● What car body and inertial parameters? (M-976)
  ● What performance criteria?

◆ Loaded Hunting Tests at TTCI (Oct/Nov 2009)
  ● Support development of loaded hunting tests
  ● IWS to measure W/R forces while hunting
Way Forward: Wheel and Rail Profiles

- Rail grinding to relieve reduce flattened rails, relieve the gauge corner and remove metal flow in the gauge corner could reduce conicity

- A more conformal new wheel profile could change the rapid initial wear pattern of new wheels
  - A new wheel profile design for freight cars is being evaluated at TTCI to replace the AAR-1b
  - Based on worn wheel shapes
  - More conformal to existing rail profiles in curves and straight track
  - Narrower flange for more gage clearance
Way Forward: Car and Truck Design

◆ Immediate:
  ● Replace adapters & pads with standard adapters
  ● Consequent reduction in curving performance (increased wheel wear & wheel RCF)

◆ Intermediate:
  ● Stiffer pads
  ● Partial improvement in tracking performance (reduced wheel wear & wheel RCF)

◆ Long term:
  ● Improved freight truck with reduced stiffness pads & increased warp restraint
  ● Reduced wheel wear & eliminated RCF
Thank you for your attention!

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