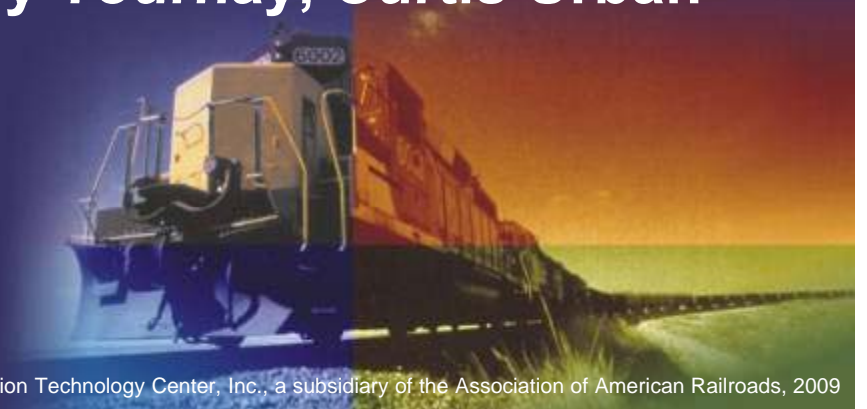




EFFECTS OF WHEEL/RAIL CONTACT PATTERNS and VEHICLE PARAMETERS on LOADED CAR HUNTING

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Background

- ◆ 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

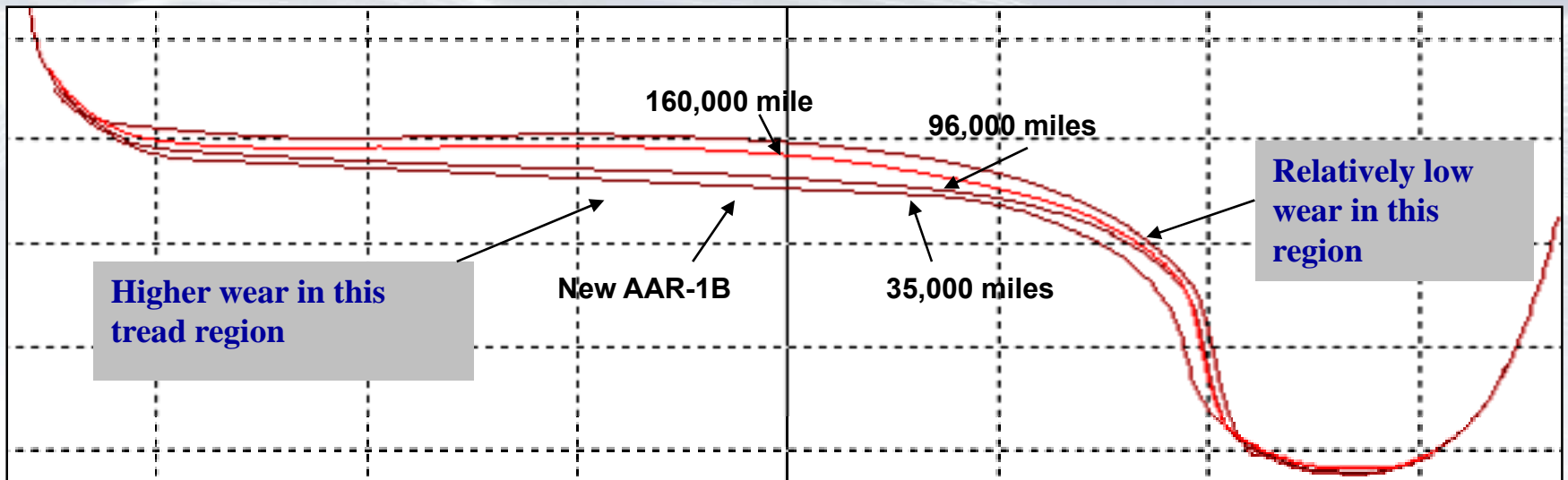
Wheel Profile and Conicity	Empty ~ Standard Pads	Loaded Hunting Threshold Speed			
		Summer Standard Pads	Winter Standard Pads	Stiffer Pads	Standard Steel Adapters
Worn $\lambda > 0.6$	65 mph	47.5 mph	55.5 mph	65 mph	70 mph
KR $\lambda > 0.2$	80 mph	65 mph		75 mph	80 mph
AAR1B $\lambda > 0.05$	>80 mph	75 mph		80 mph	80 mph

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**

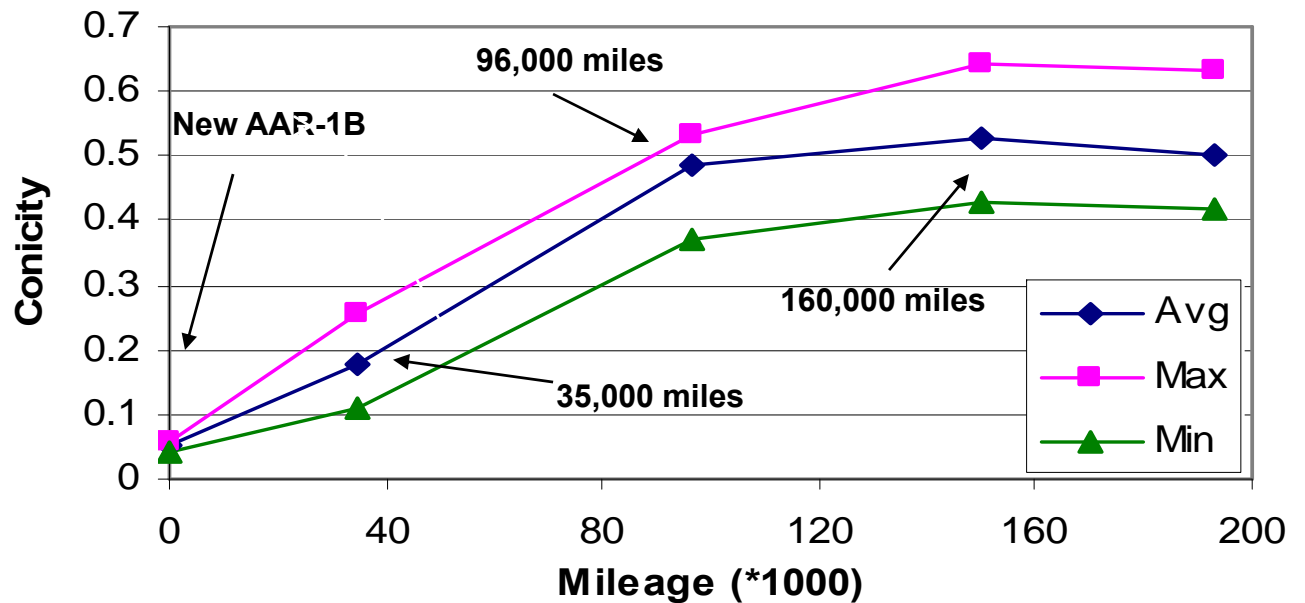
- ◆ **Loaded car hunting also a function of:**
 - **Center plate friction**
 - ◆ **Steel center plates reduced hunting**
 - **Side bearing friction restraint**

Grain Car Wheel Wear and Effects on Conicity



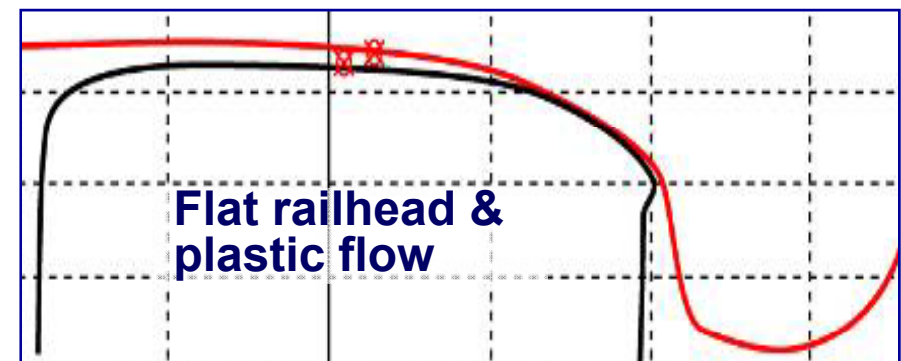
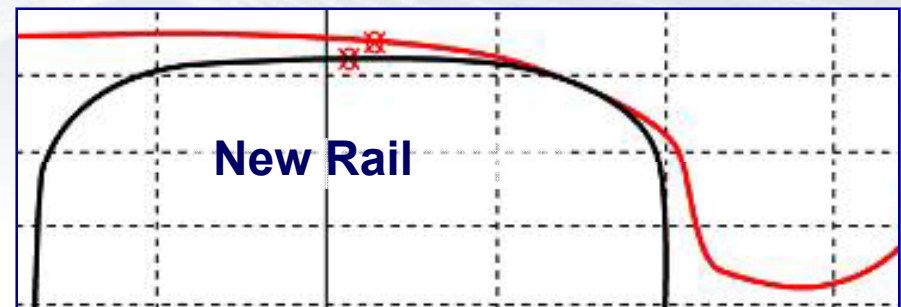
◆ Conicity (λ) on TTCI Hunting test zone

Average Conicity, RTT 34 Rail



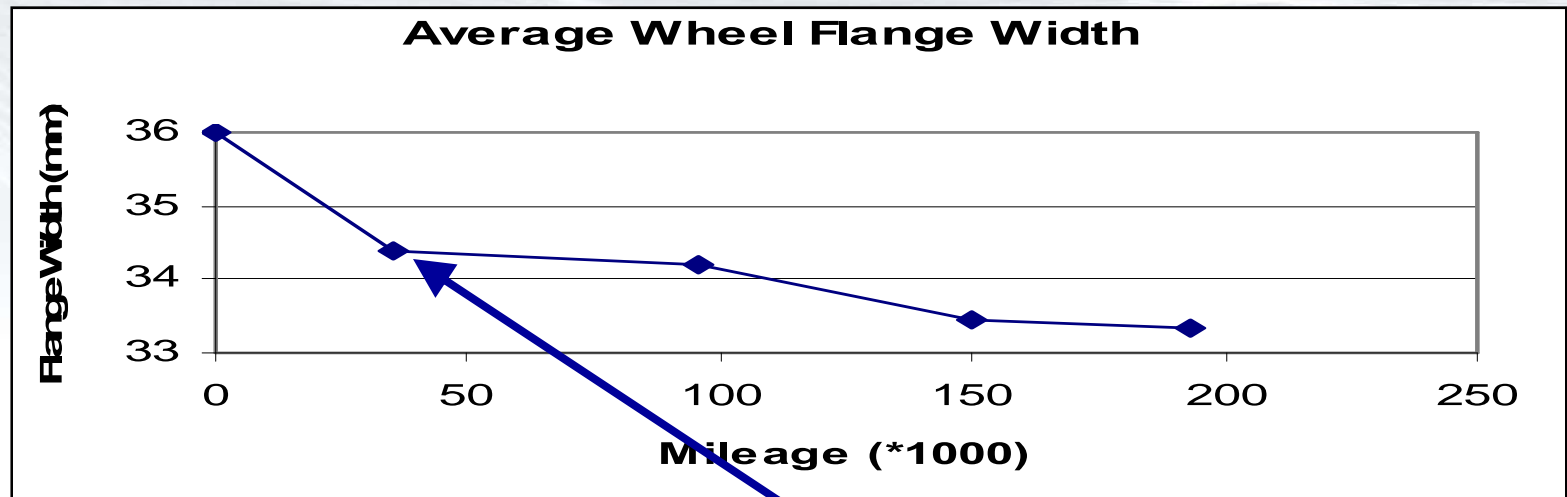
High Conicity W/R Contact Conditions

- ◆ 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

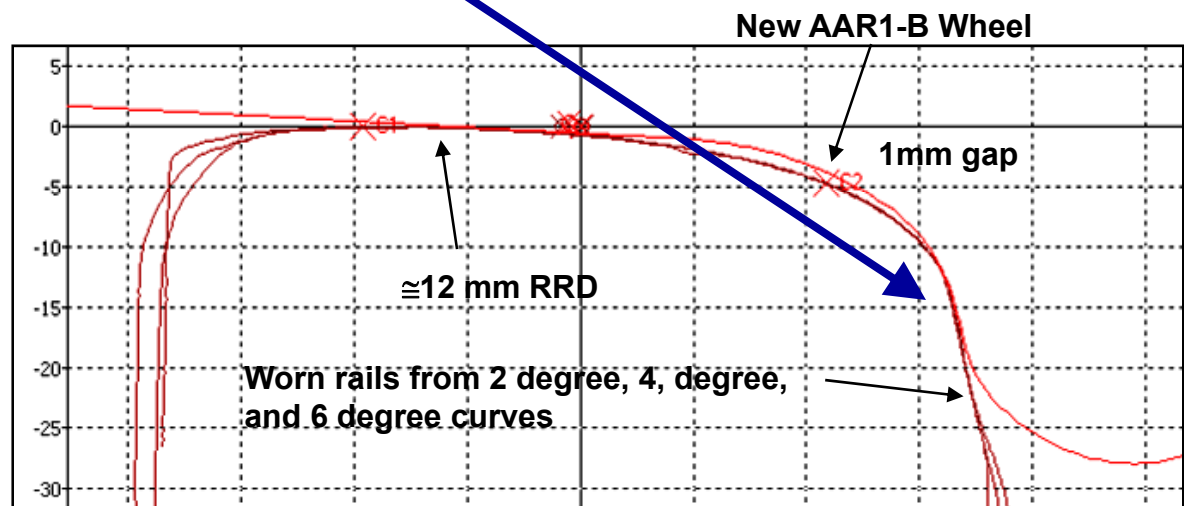


Wheel / Rail Profiles

◆ Accelerated initial flange wear

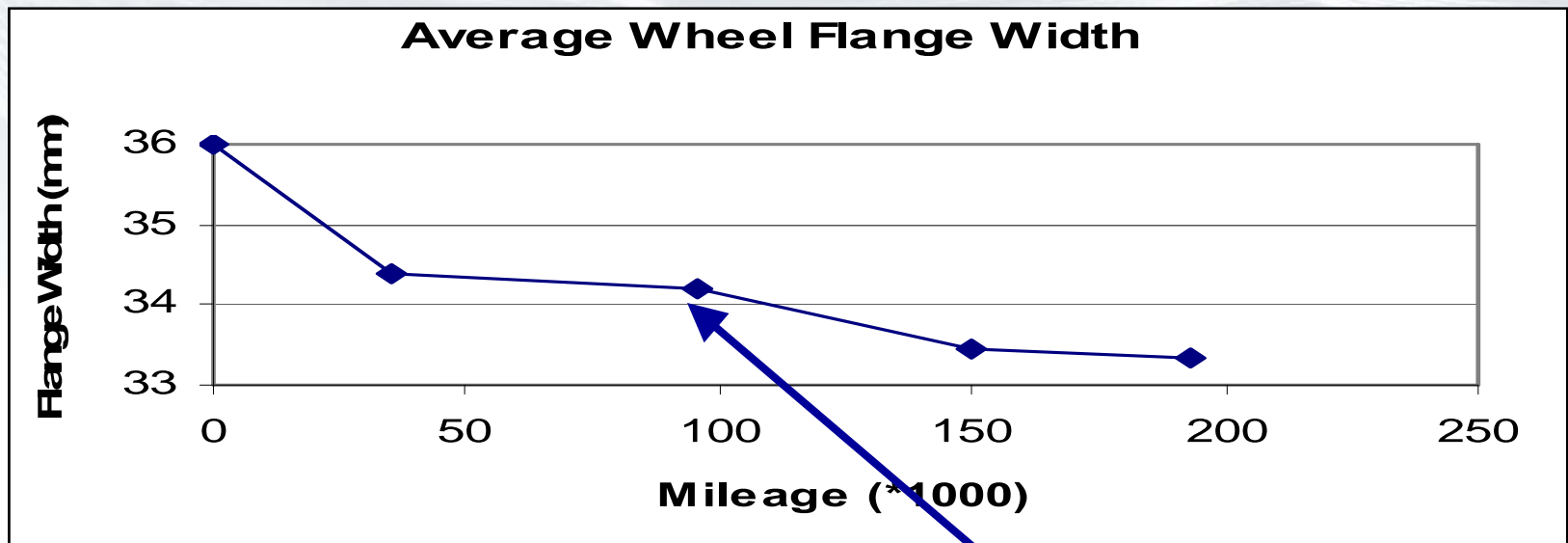


◆ Associated with initial mismatch & 2-point contact between new wheel & worn high rail in curves

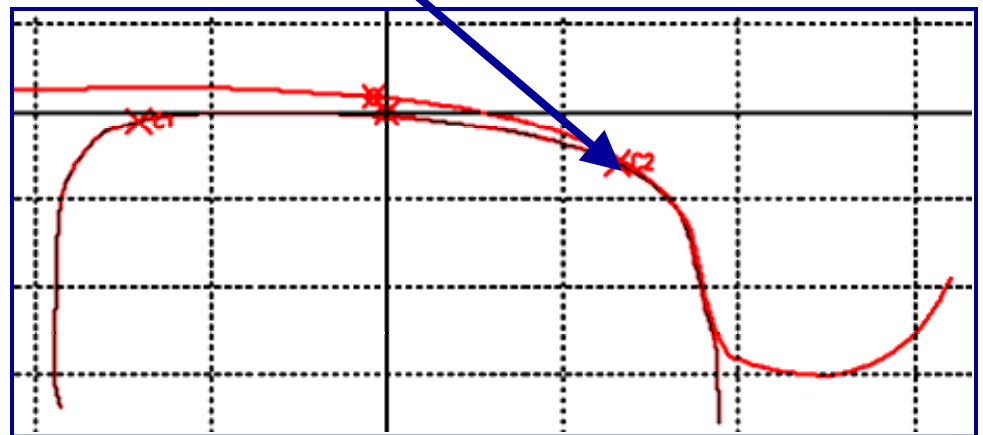


Wheel / Rail Profiles

- ◆ Reduced flange wear after ~ 50,000 miles



- ◆ Associated with single point contact & a large radius differential generated on the high rail in curves



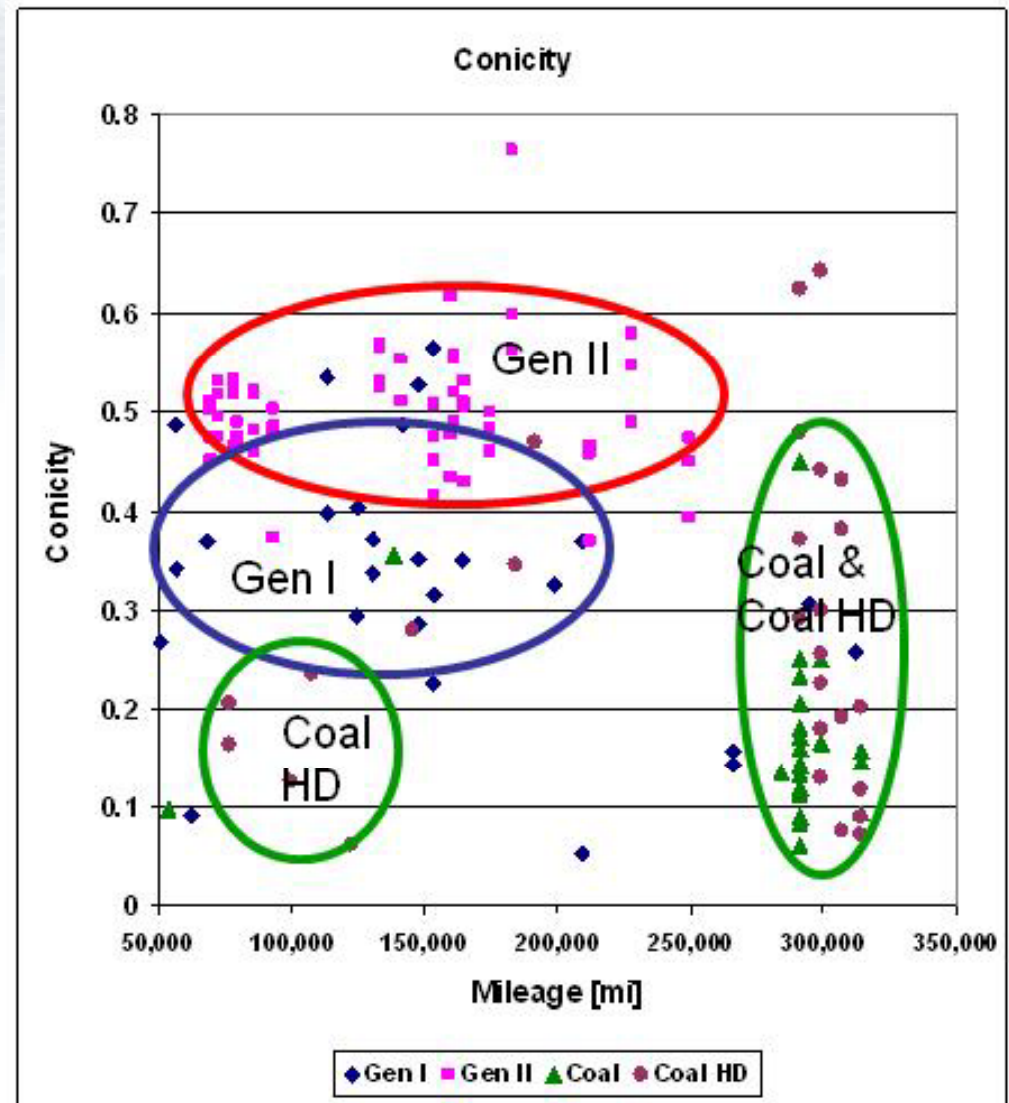
W/R Conicity as a Function of Mileage, Car and Truck Arrangement

◆ Car/Truck types

- Gen I: Grain car with steel adapters
- Gen II: Grain car with polymer adapters
- Coal: Coal car with steel adaptors
- Coal HD: Coal car with polymer adapters

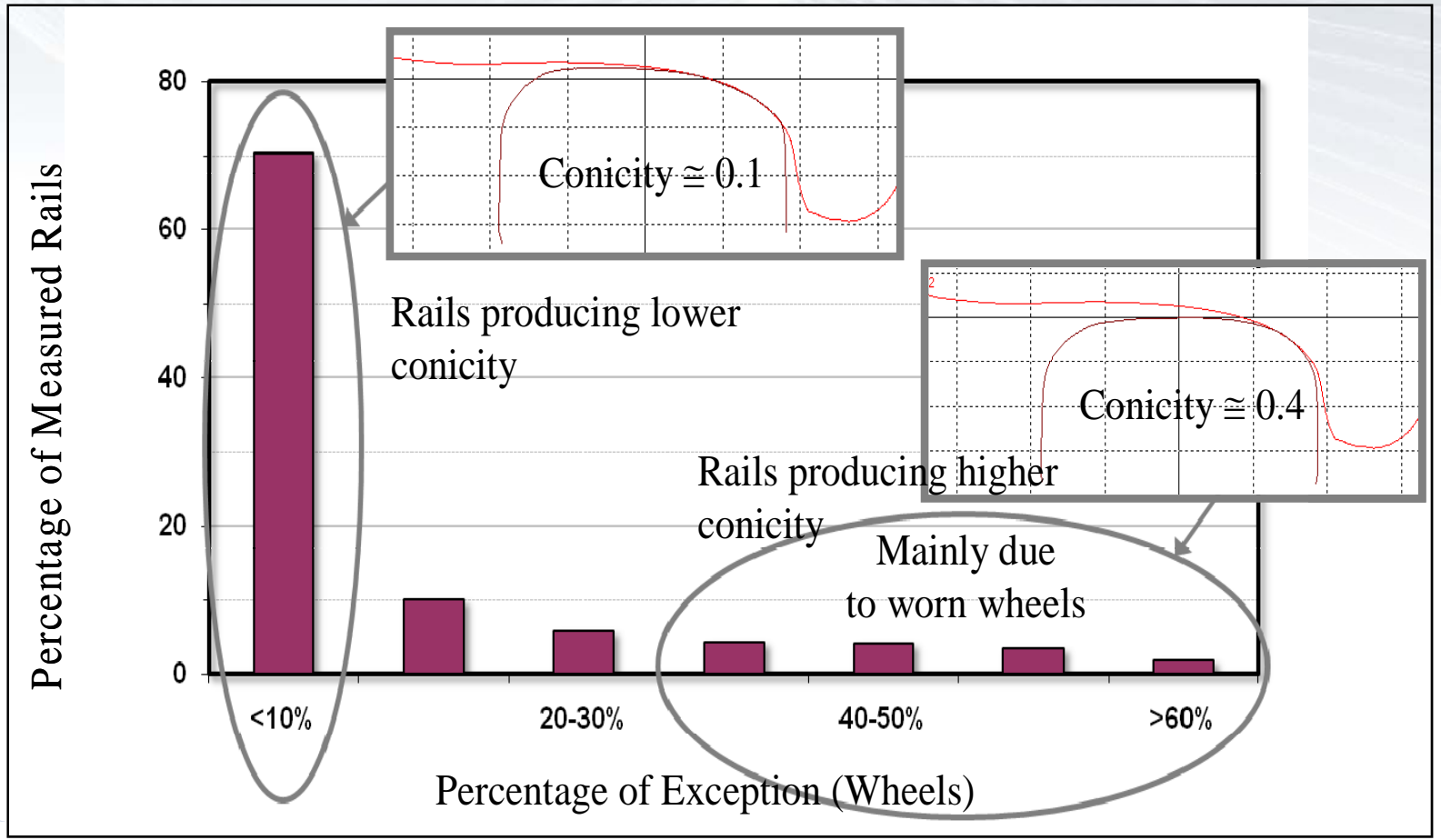
◆ Root causes for differences are still unknown but suspected to be a function of:

- Curving ability
- Vehicle stability



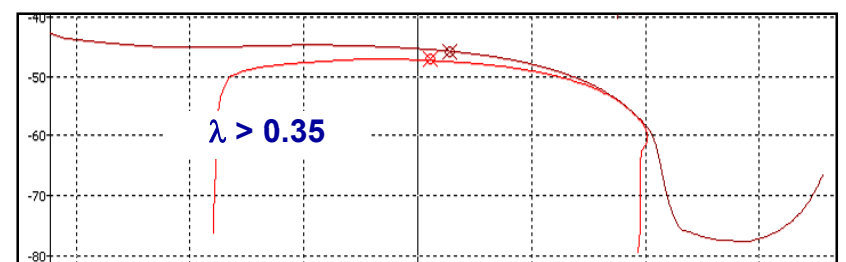
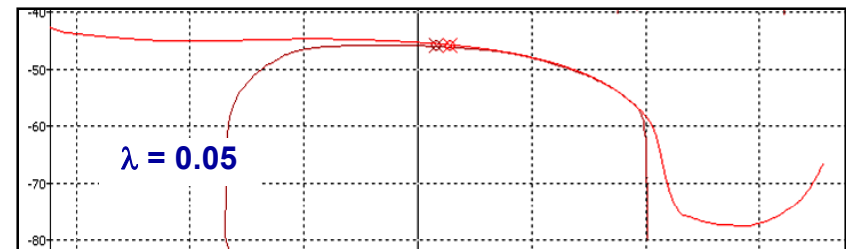
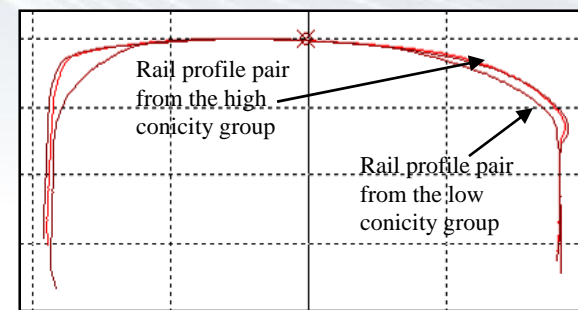
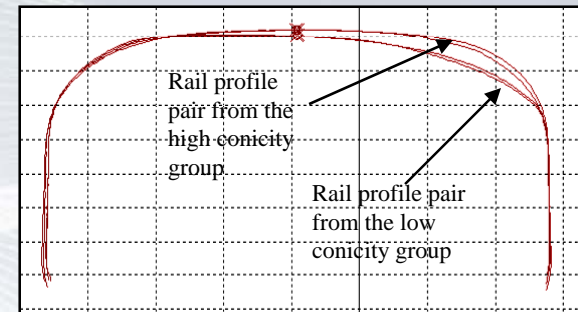
W/R Conicity as a Function of Rail Profiles for a Particular Grain Car Route

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



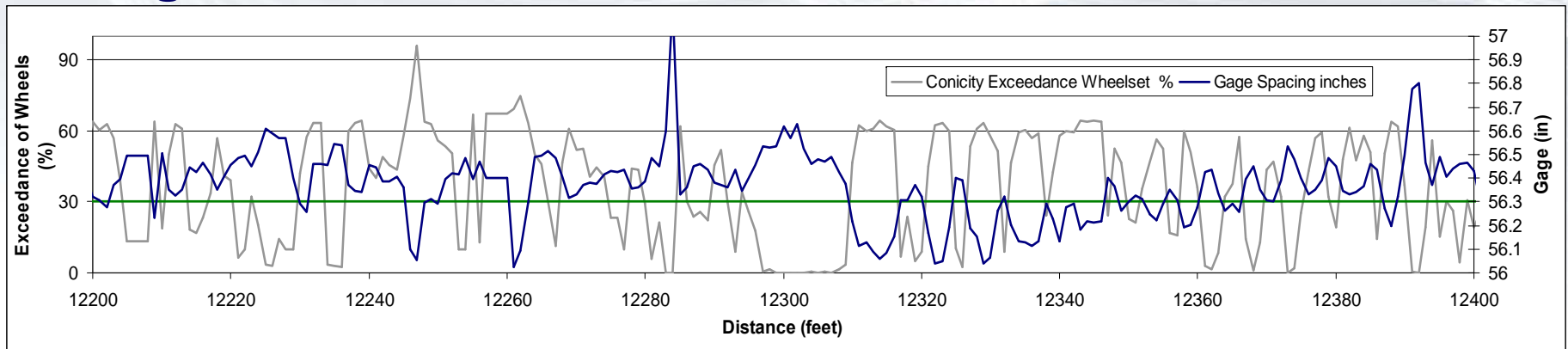
Tangent Track W/R Conicity Summary

- ◆ 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.)

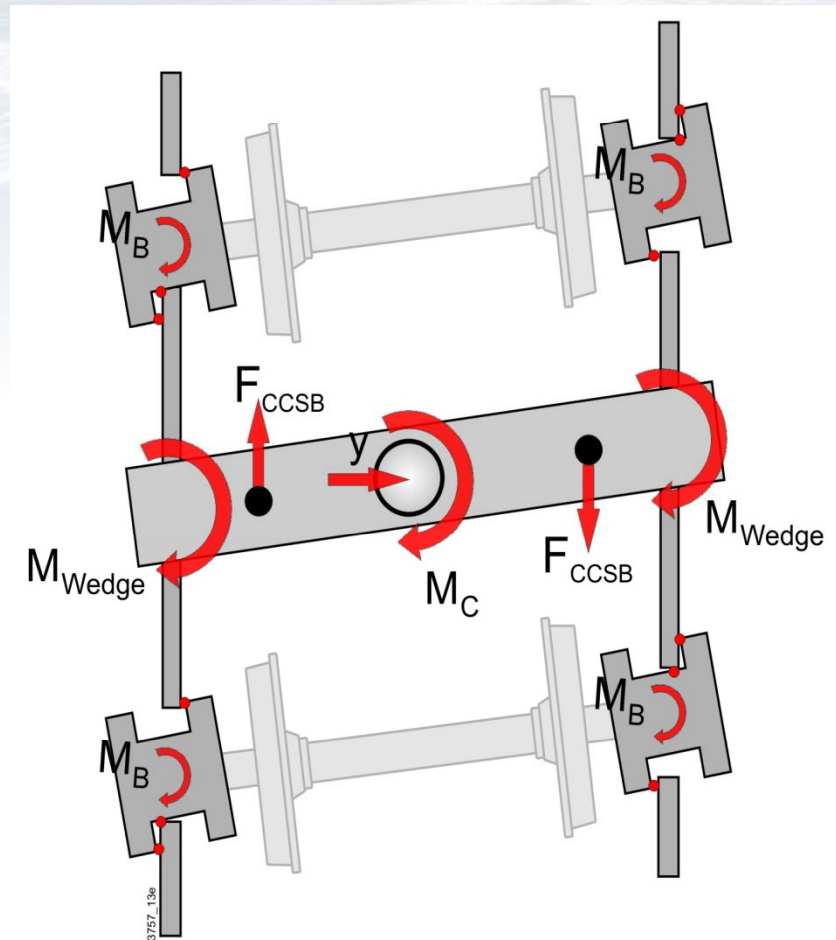
- ◆ **Tight gauge is highly correlated to high conicity in tangent track**



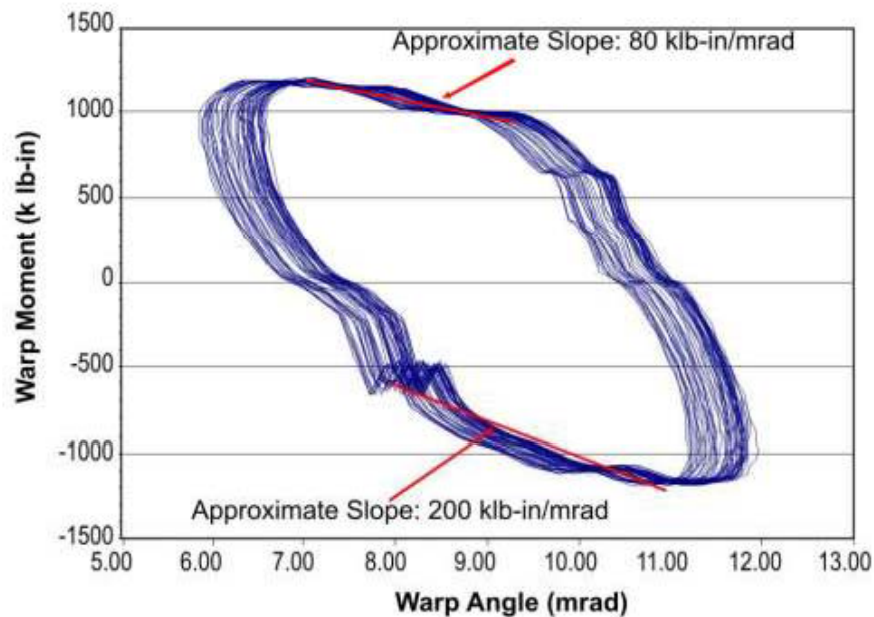
- ◆ **High conicity was found on only 10% of track**
- ◆ **Rail grinding to relieve reduce flattened rails, relieve the gauge corner and remove metal flow in the gauge corner could reduce conicity**
- ◆ **A more conformal new wheel profile could change the rapid initial wear pattern of new wheels**

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

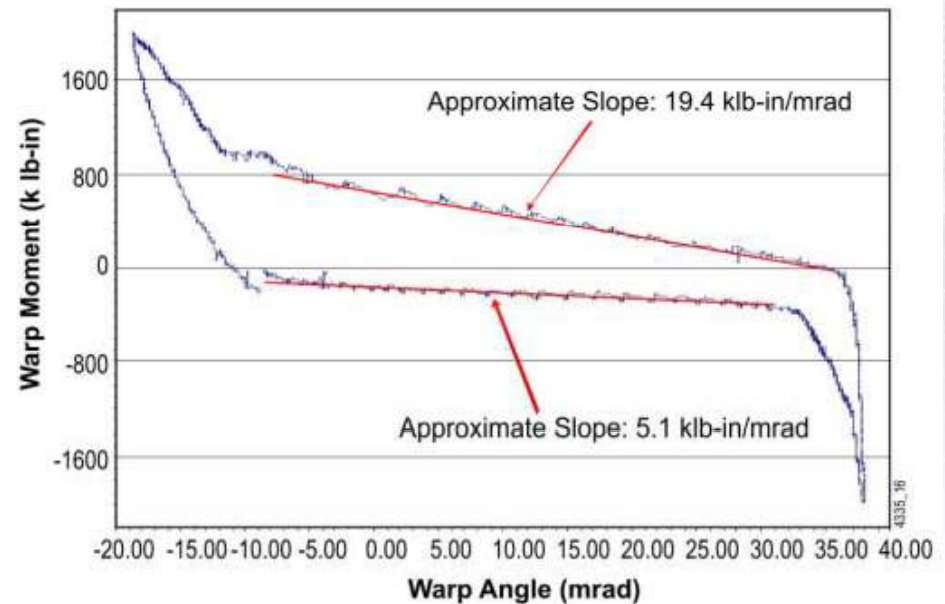


Truck Warp Test Results



Avg. stiffness = 140 klb-in/mrad

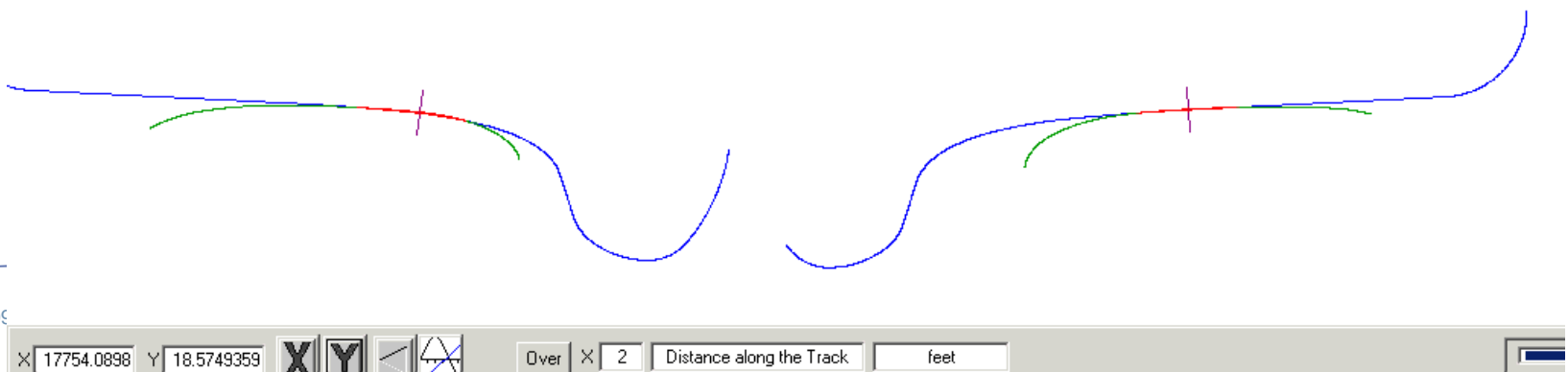
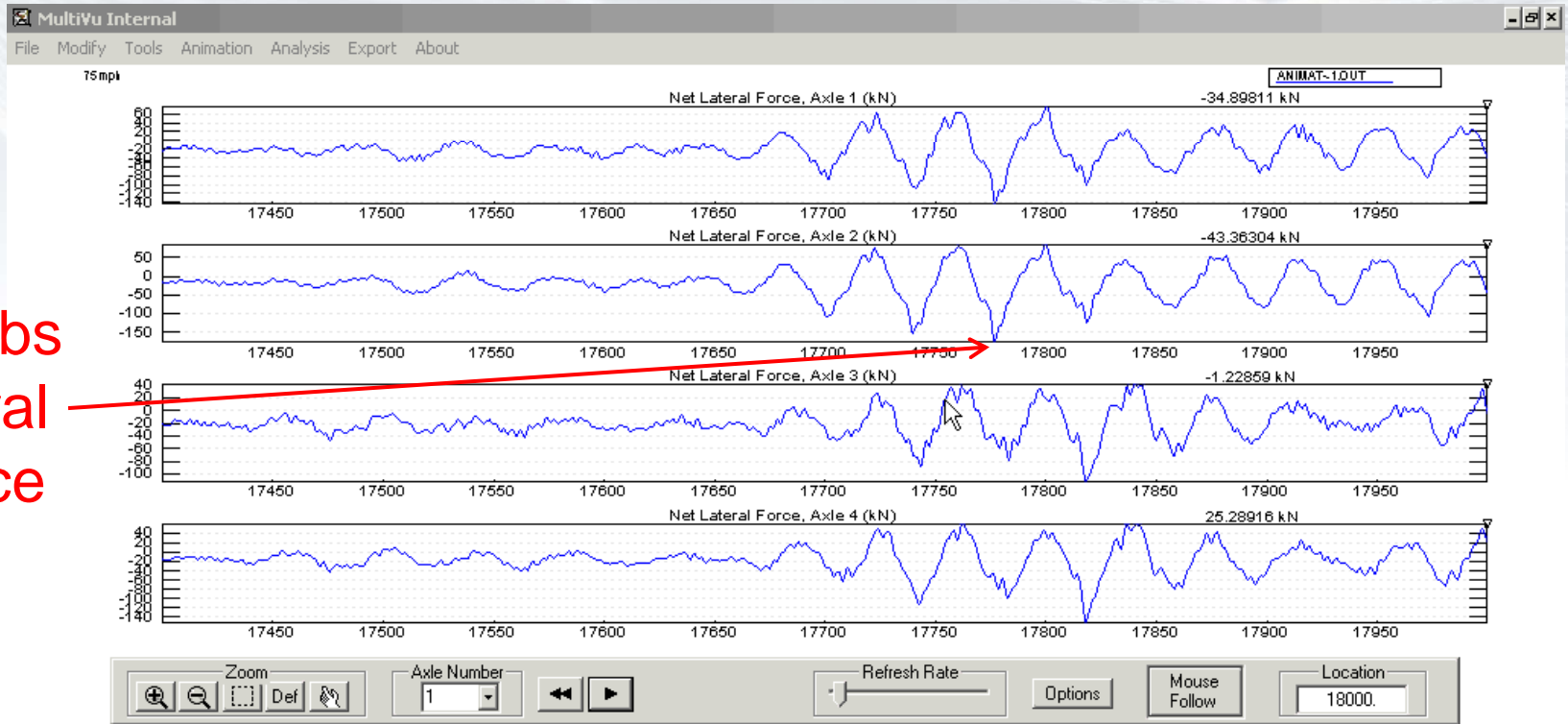
**High warp restraint
similar to previous tests
of the same truck type
when friction wedges
have little motion**



Avg. stiffness = 12.5 klb-in/mrad

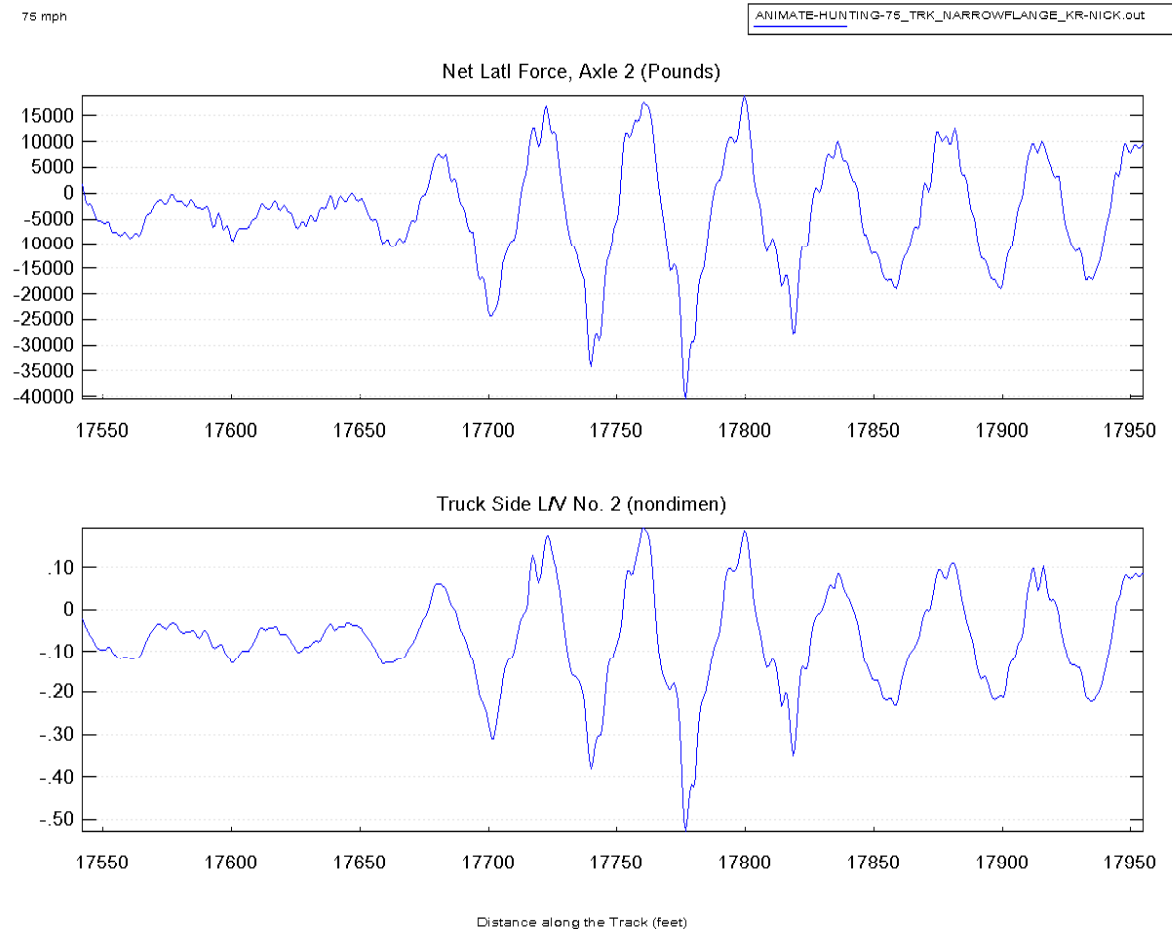
**Warp stiffness reduced
by factor of about 11 due
to friction saturation
with large wedge motions
from combined body
vertical/lateral motions**

NUCARS[®] simulations to evaluate W/R forces and effects of Carbody and Suspension Parameters



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)

Loaded Car Hunting: Conclusions (cont.)

- ◆ **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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