Truck Performance Basics for TTX

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December 5, 2008

FORWARD THINKING.

Background

- TTX is owned by 9 major railroads.
- Manage various national railcar pools
- Goal: Provide safe, reliable cars at the lowest cost
- Owns about 140,000+ rail cars

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TTX Background

1,698 Employees:

- 280 Headquarters
- 689 Field Maintenance
- 729 Maintenance Divisions

TTX Intermodal Fleet

- Largest TTX fleet
- Consists of:
  - All-Purpose
  - TOFC
  - COFC
  - Double-Stack

TTX Automotive Fleet

- Second largest TTX fleet
- Consists of:
  - Uni-Level
  - Bi-Level
  - Tri-Level
  - Autoframe
- TTX operates North American Reload Project

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TTX General Purpose Fleet

- Box Cars
- Centerbeams
- Other Bulkhead
- Chain Tie-Down
- Gondola

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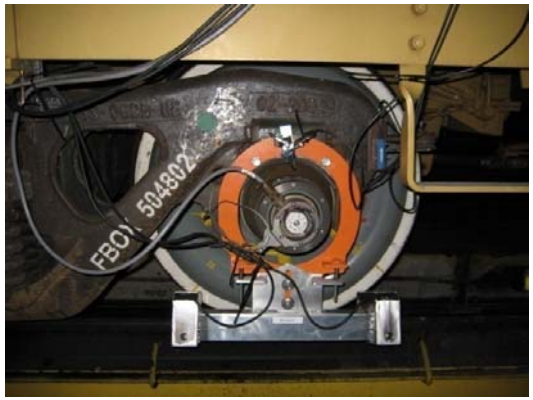
TTX Engineering & Research Dept

- Achieve goals of Safety, Reliability and Low Cost

- Three Main areas:
  - MME: Maintenance and Modification Engineering for existing equipment
  - New Products: New cars and equipment
  - Research & Development

TTX R&D Department



- 4 Employees
  - All BSME
- 2 Research Cars
- Track tests at TTCI
- Lab in Joliet, IL
- Office in Chicago HQ

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Examples of TTX R&D investments with positive return

- Autorack 65 year life
- S2-HD M-976 truck
- Walkway vibration studies
- Long travel side bearings
- Longer maintenance cycles

Railroads efficiently move freight

Transportation Mode	Approximate Hp/Ton
Boeing 747-400 Freighter	3000
Corvette	350
Dodge Minivan 3.3L	80
Mack Truck w/460 engine	16
Freight Train	1
Shenzhen Container Ship	0.85

Low hp/ton is cost-effective

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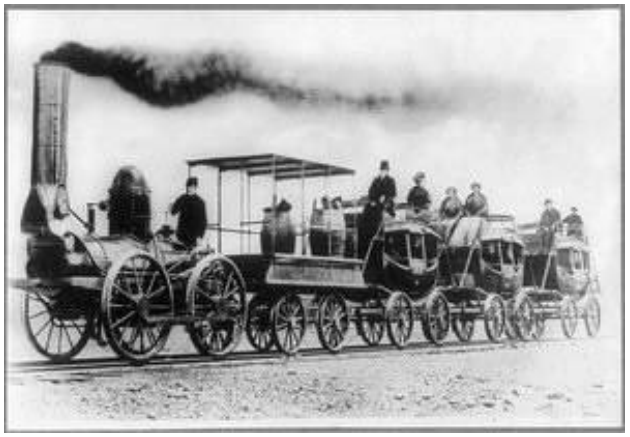
But…

- To get the low hp/ton benefit, cars must perform reliably
  - Trackworthiness, or Service-worthiness
  - Steering
  - Truck performance
  - Ride quality
    - Vertical damping
    - High speed stability

Trucks



- Early cars were short, had 4 wheels and tended to stay on the track
- As rolling stock grew longer and heavier, equipment tended to derail. (Wheelbase limit ~10m)
- Some genius invented a very short, small “car” called a truck or bogie, and used it to support cars and locomotives. Once again, these short cars tended to follow the track

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Basic 3-piece Truck

Simple design: Truck Bolster with two Side Frames
Large, stiff castings, loosely connected
Low 1st costs, good load equalization, flexible
Friction damping and tendency to warp are major weaknesses

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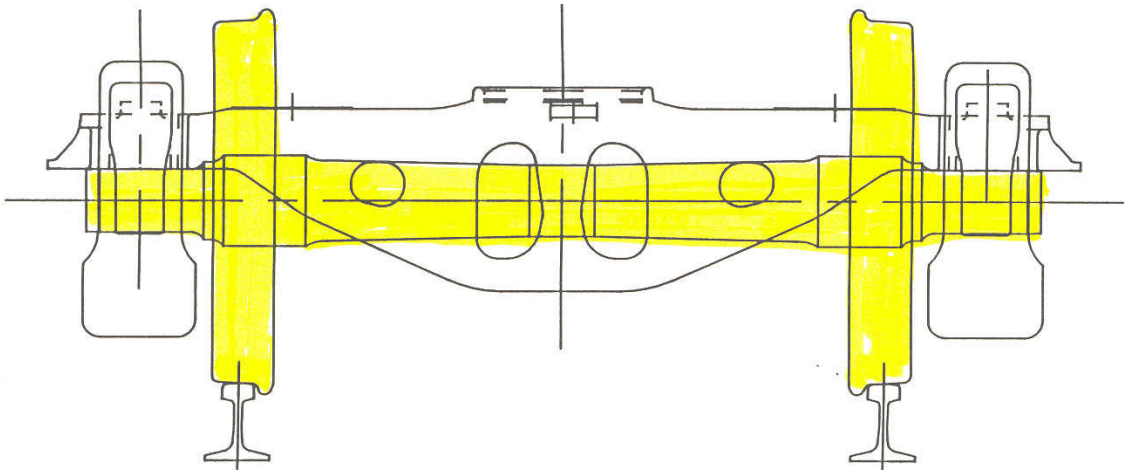
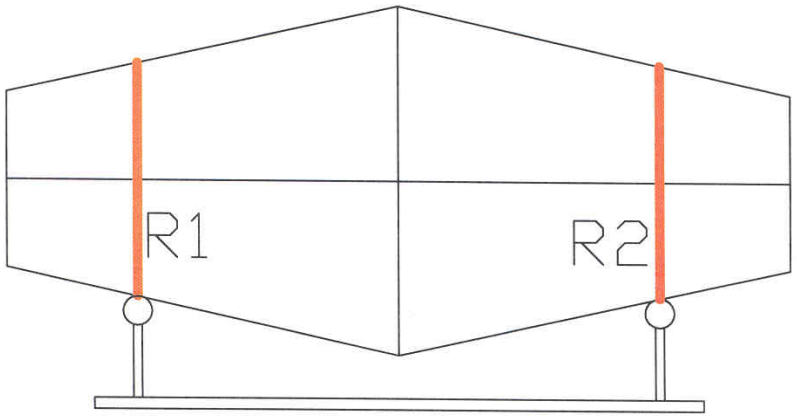
Steering



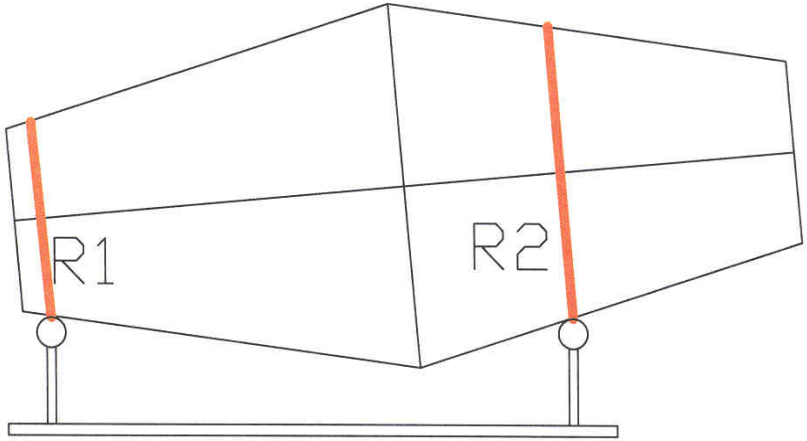
Passive steering
Solid axle with pressed on wheels
Flanged wheels with 1:20 taper

Steering: Simplified Wheel



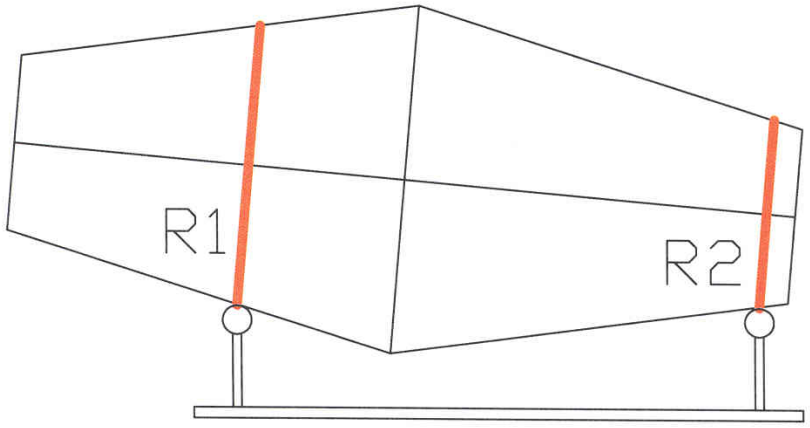
Rolling radius R1 equals radius R2, wheel will roll in a straight line. Rolling-Radius-Difference (RRD) =0

Steering: Simplified Wheel



Rolling radius R1 does not equals radius R2, wheel rolls in a curve to the left . Rolling-Radius-Difference (RRD) ≠0

Steering: Simplified Wheel



Rolling radius R1 does not equals radius R2, wheel rolls in a curve to the right . Rolling-Radius-Difference (RRD) ≠0

Steering: 1 of 4 things can happen:

- 1. RRD = curvature of track
  - For tangent track RRD=0
  - In curves, wheels follow the radius of curvature. For new wheels with 1:20 taper, this works up to about 4.5 degree curves. Worn wheels have more RRD and can curve up to about 7 degrees.
  - Ideal situation

Steering: 1 of 4 things can happen

- 2. RRD less than curvature: Wheel flange contacts rail on high, outside rail and lateral force on rail increases. Less than ideal.

RRD less than curvature (12-deg curve)

High Rail

Low rail

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Steering: 1 of 4 things can happen

- 3. RRD is greater than curvature: Wheelsets “hunt” for track centerline. On average, RRD = 0, but not at any given instant. Suspension and car may resonate due to the lateral input from the wheels hunting, this can get severe.

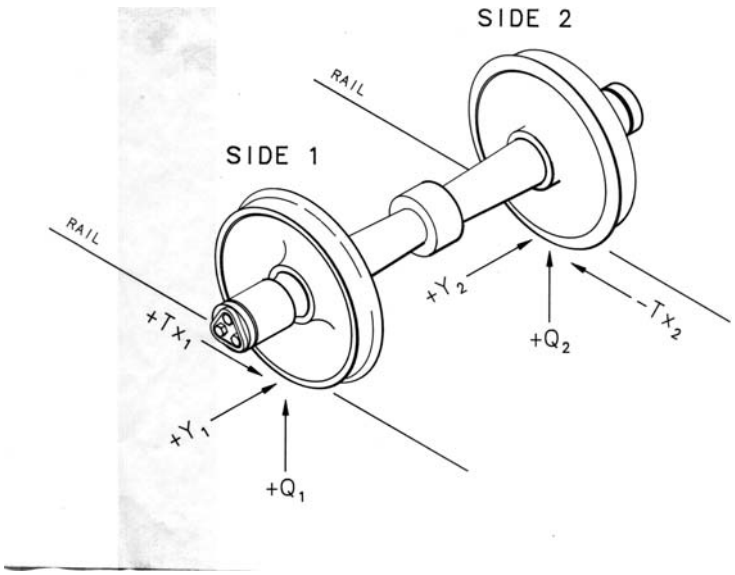
See High Speed Stability Video

Steering: 1 of 4 things can happen

- 4. Reverse steering: warped truck, wide gauge, worn wheels
  - Always bad and fortunately, rare

R&D Tools

- 16 Instrumented wheelsets
  - 4 each wheel size
- Measure forces at rail contact point



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R&D Tools

- AAR Chapter XI
- Accelerometers, displacement transducers, roll gyros, lasers, load cells, and so on
- Track test at TTCI

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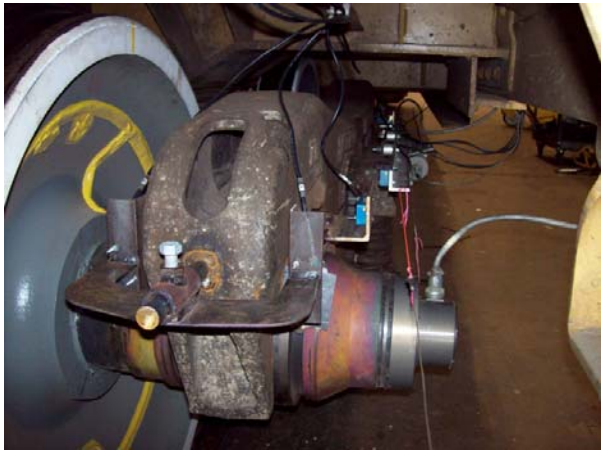
TTX Truck Testing



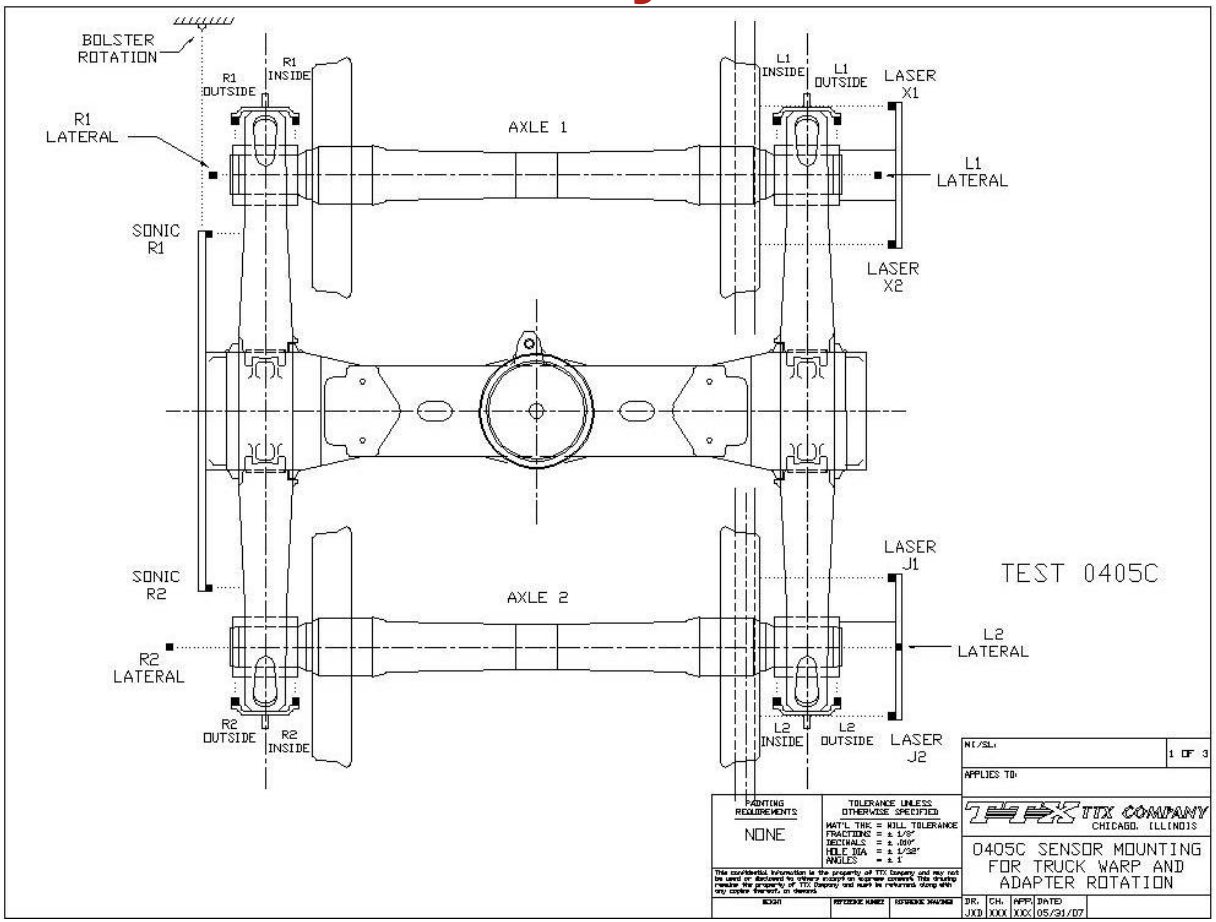
Sources: TTX Test 0405

TTX FORWARD THINKING.

M-976:
Adapter pads added to fleet

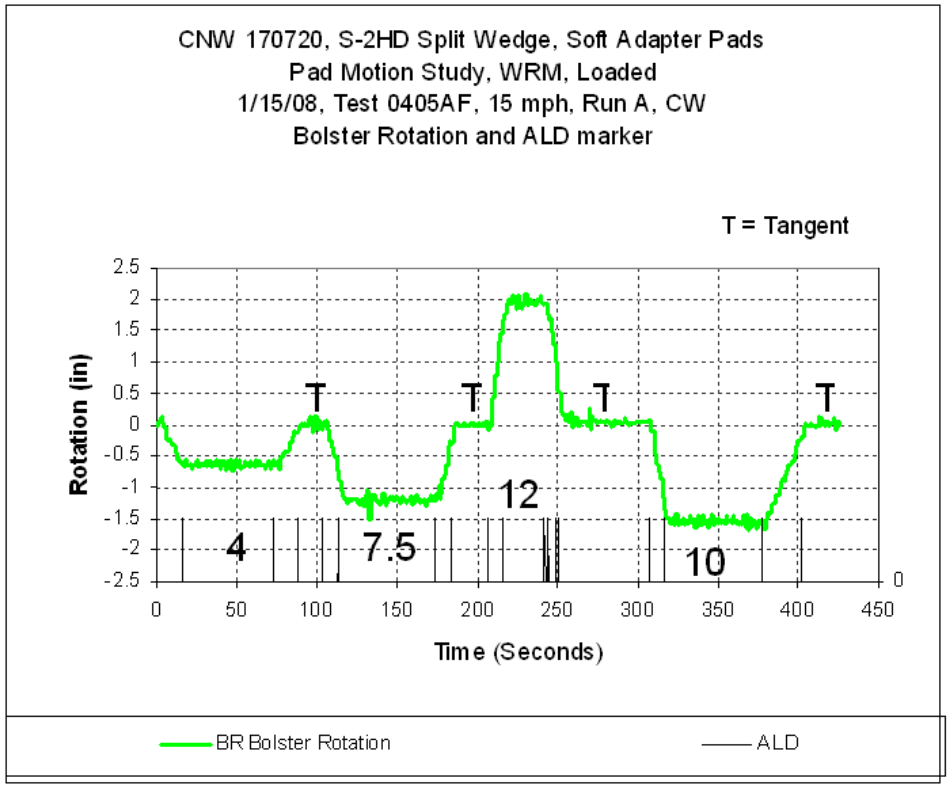
- M-976 truck types and side bearing types are familiar to TTX, but this is the first widespread use of adapter pads since 1986-1992 Articulated Doublestack cars
- Concern over how little we know about the function of adapter pads
- Adapter pads are a key performance component
- Pads are on our cars, we should know what they are doing

Instrumentation Layout



Sources: TTX Test 0405

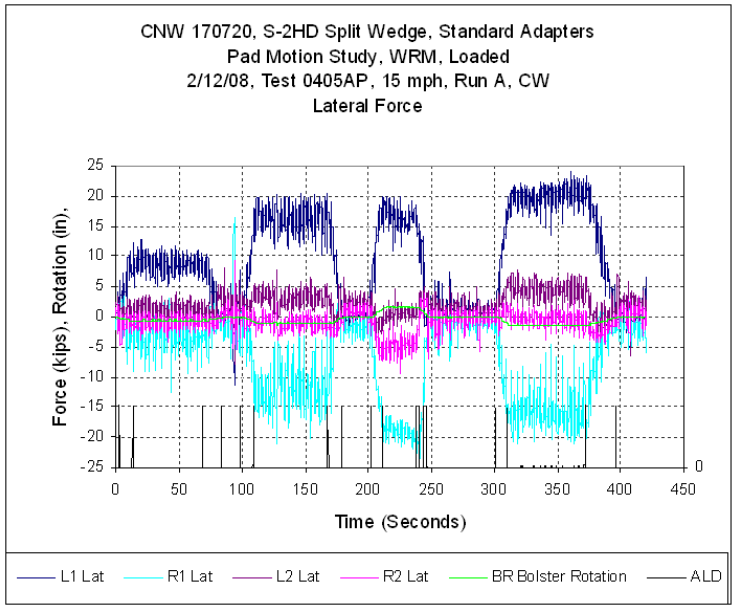
Test Track and Markers



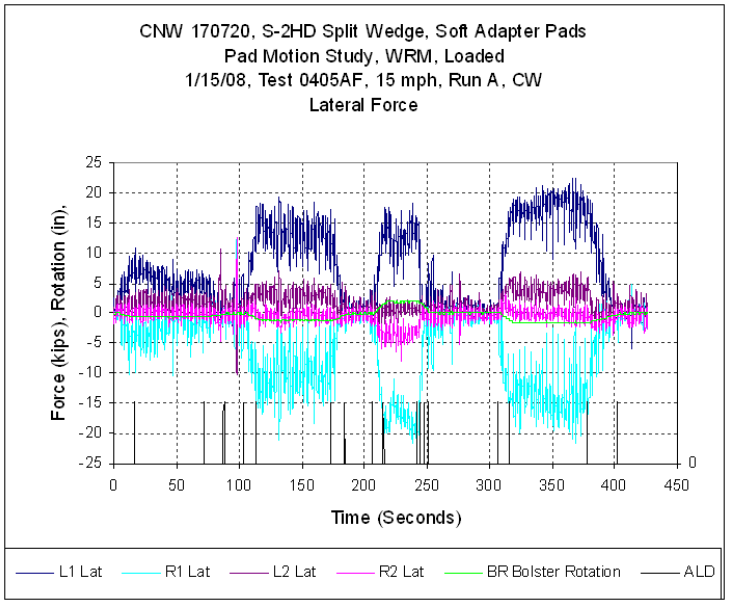
Sources: TTX Test 0405

FORWARD THINKING.

Lateral Wheel Forces



Standard Adapters

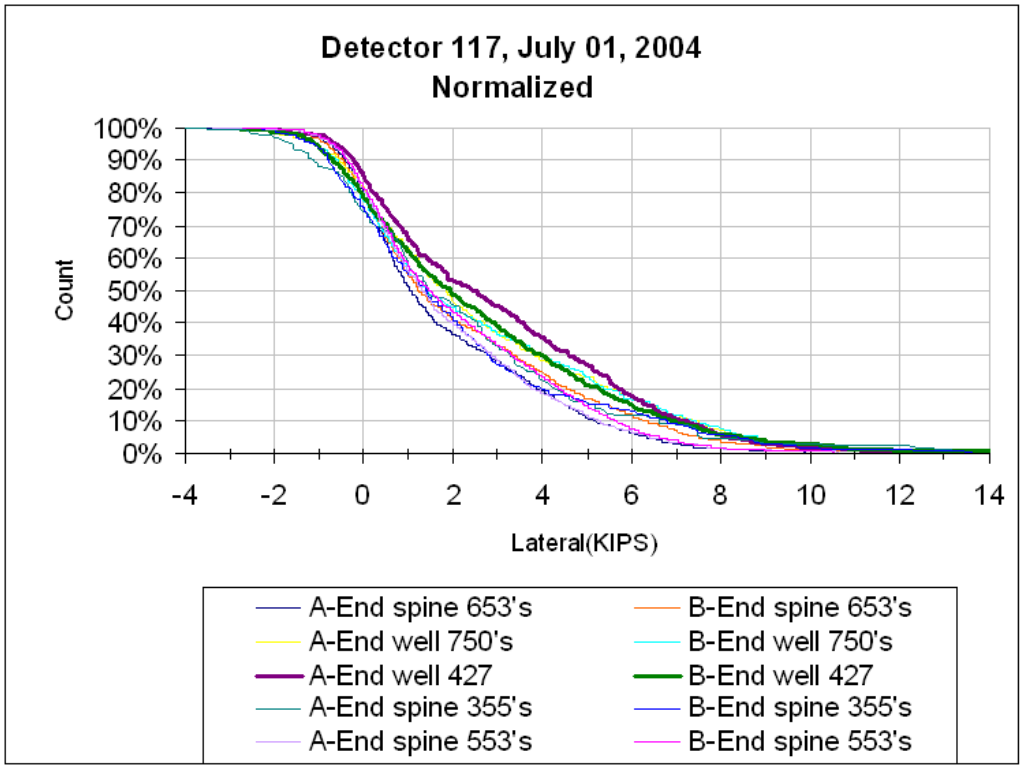


Adapter Pads

Sources: TTX Test 0405

FORWARD THINKING.

Lateral Forces from Wayside data

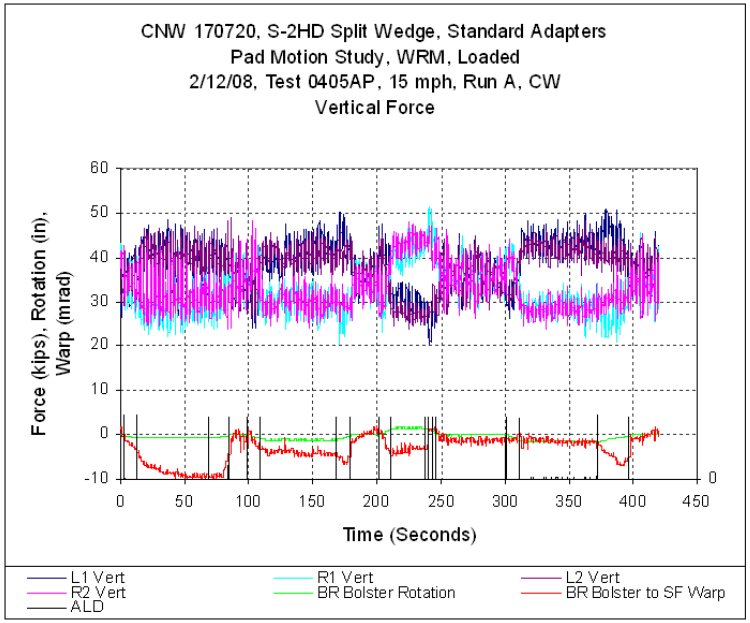


Mix of Conventional and Premium truck types (not M-976) give similar lateral force distributions

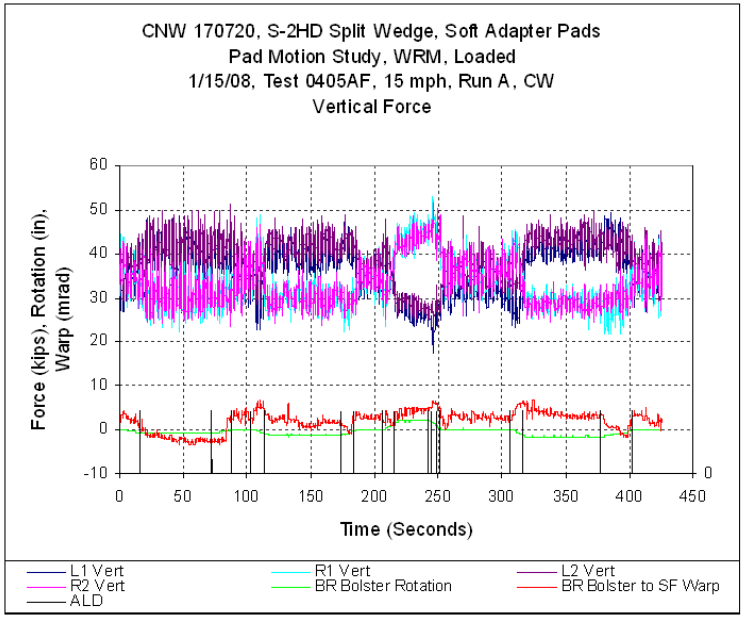
Sources: TTX Wayside Lateral Force Study

FORWARD THINKING.

Vertical Wheel Forces



Standard Adapters



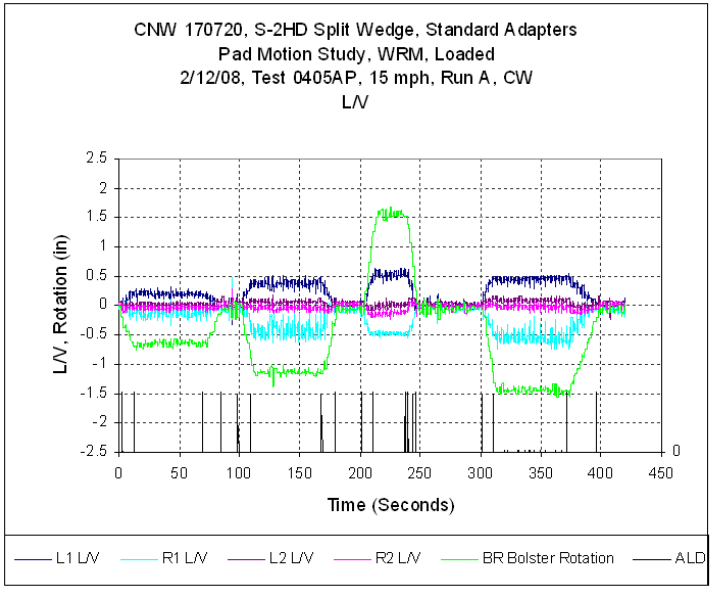
Adapter Pads

Sources: TTX Test 0405

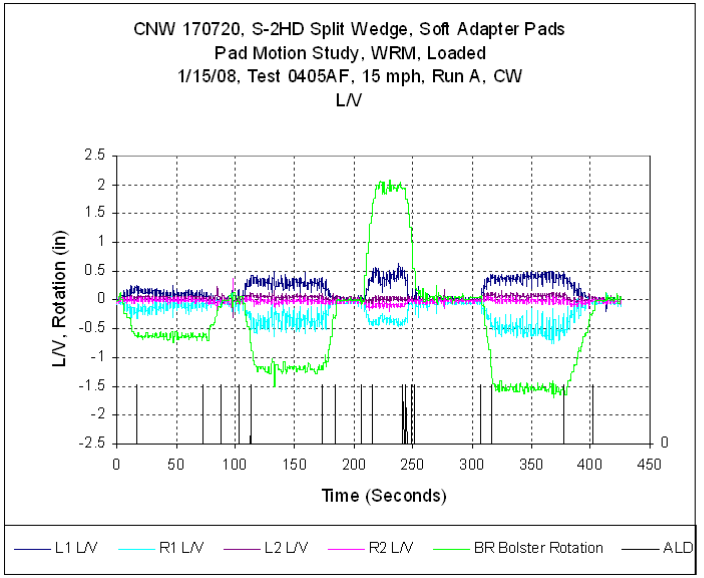
FORWARD THINKING.

Single Wheel L/V Ratio

Both configurations performed very well



Standard Adapters

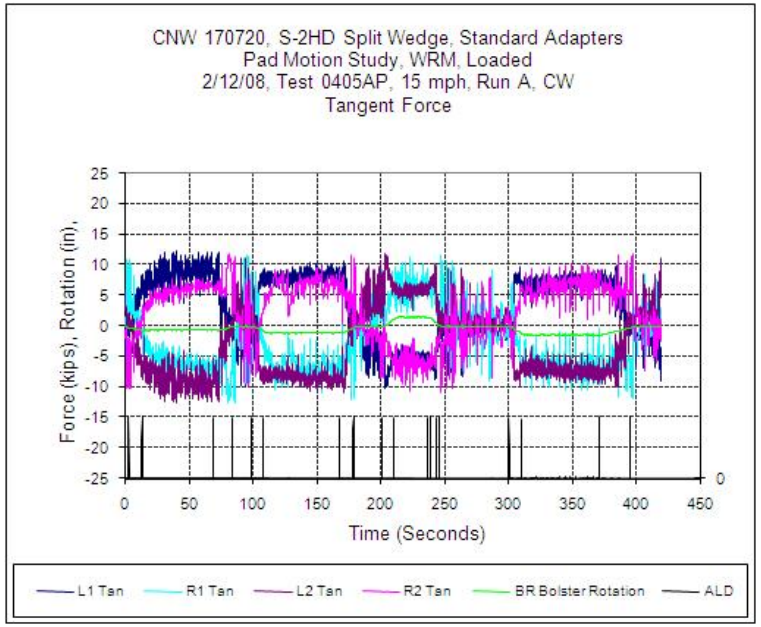


Adapter Pads

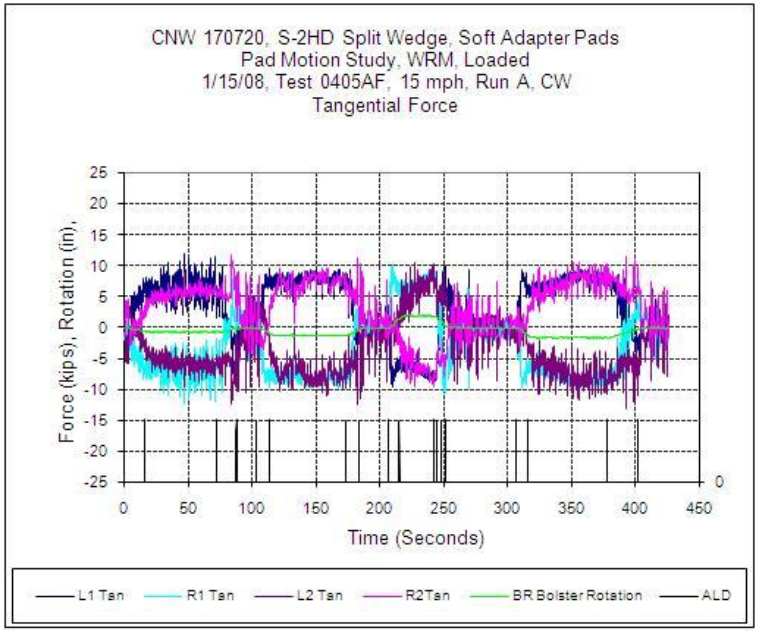
Sources: TTX Test 0405

FORWARD THINKING.

Tangential Wheel Force



Standard Adapters

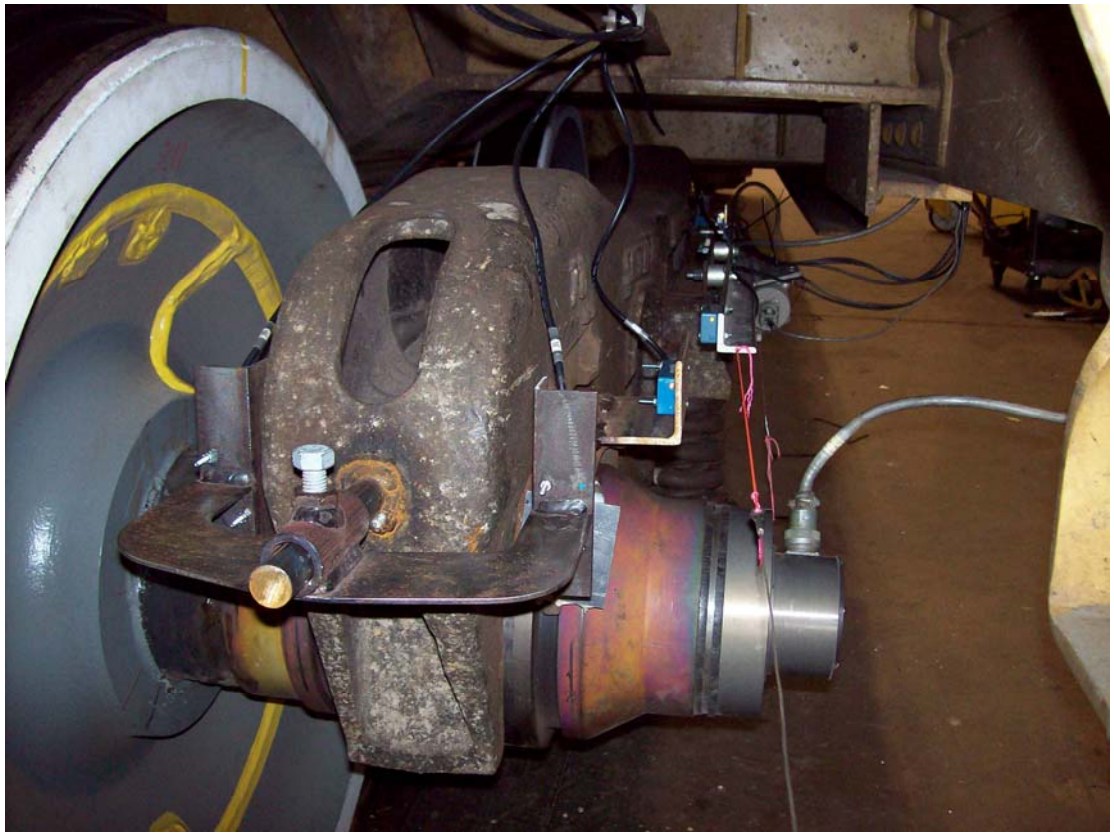


Adapter Pads

Sources: TTX Test 0405

FORWARD THINKING.

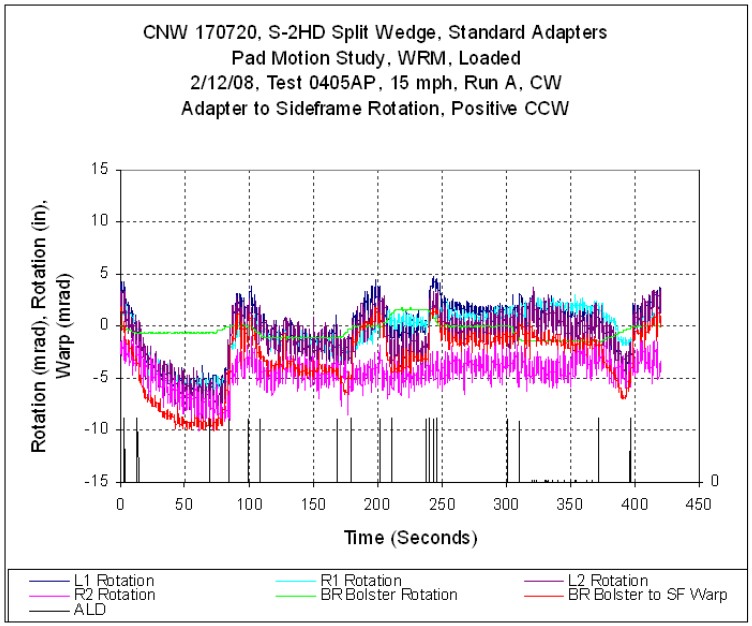
Adapter Rotation Measurements



Sources: TTX Test 0405

FORWARD THINKING.

Adapter Rotation relative to Side Frame



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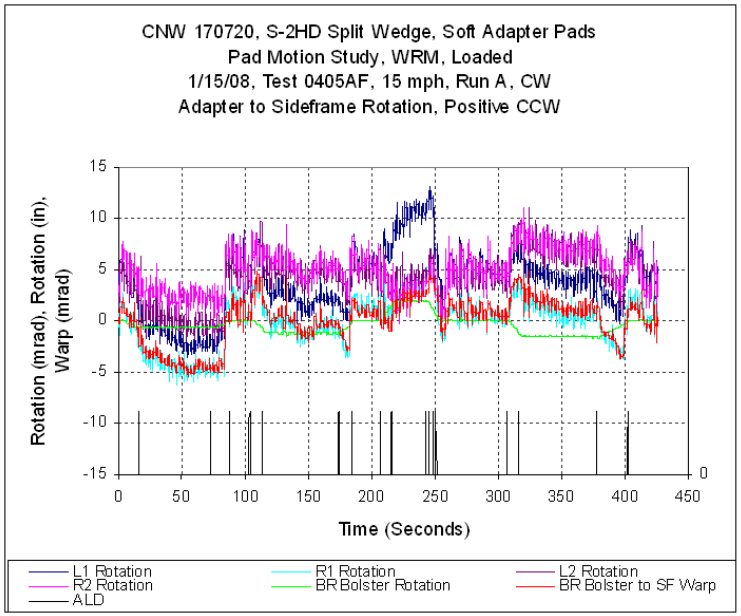


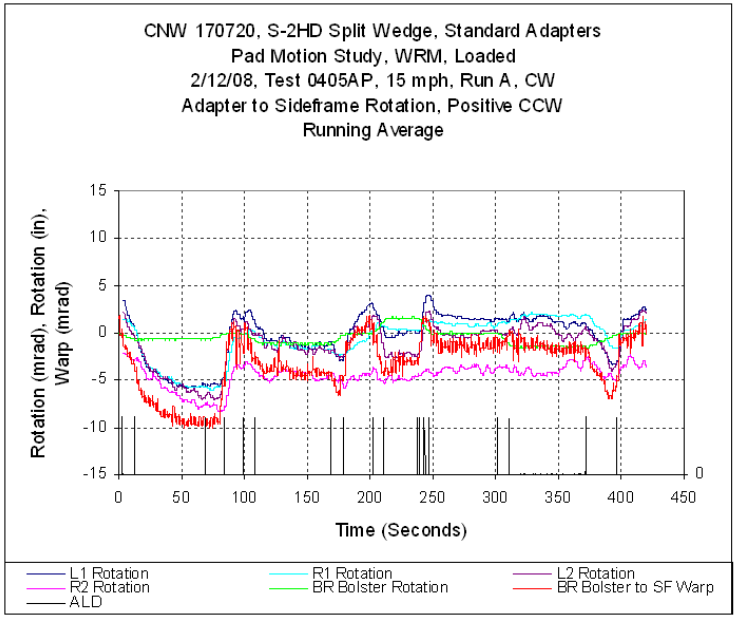
Adapter Pads

Sources: TTX Test 0405

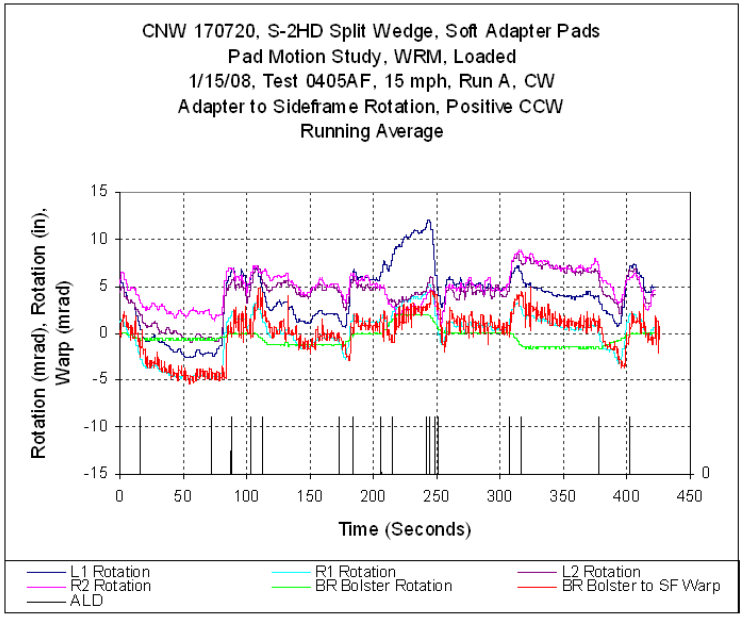
FORWARD THINKING.

Adapter Rotation (v2) relative to Side Frame

Standard Adapters



Adapter Pads

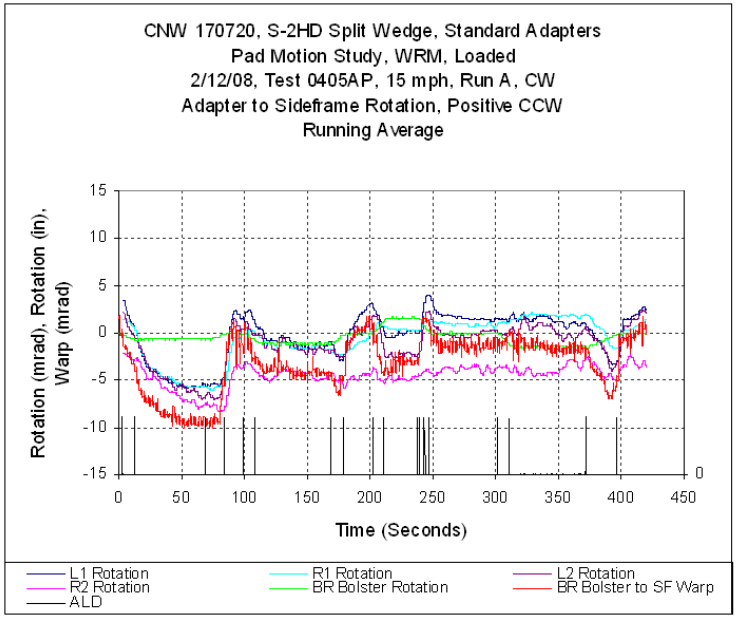


Sources: TTX Test 0405

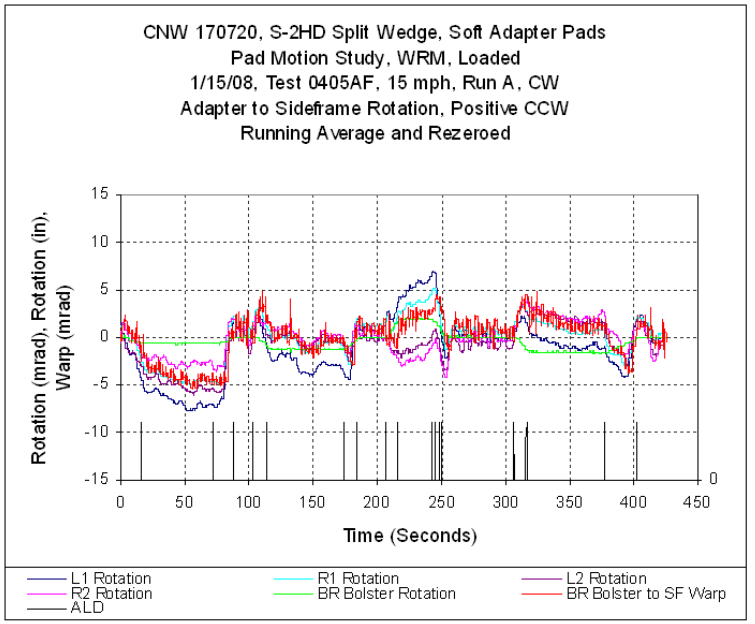
FORWARD THINKING.

Adapter Rotation (v3) relative to Side Frame (re-zero of displacement transducers)

Standard Adapters



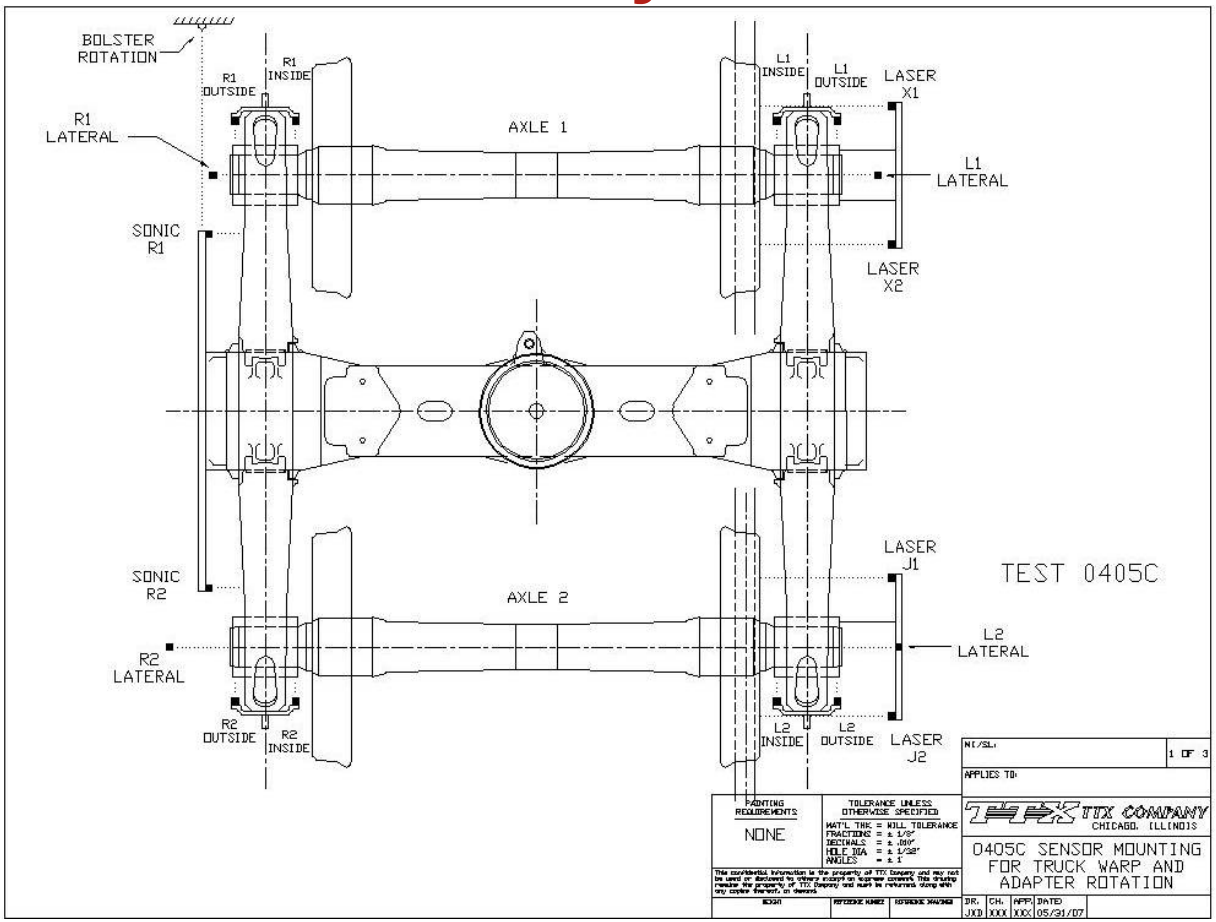
Adapter Pads



Sources: TTX Test 0405

FORWARD THINKING.

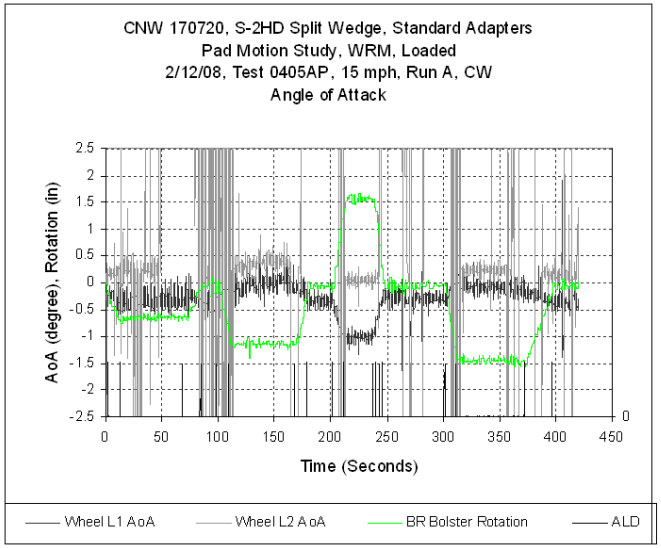
Instrumentation Layout



Sources: TTX Test 0405

FORWARD THINKING.

Wheelset AoA



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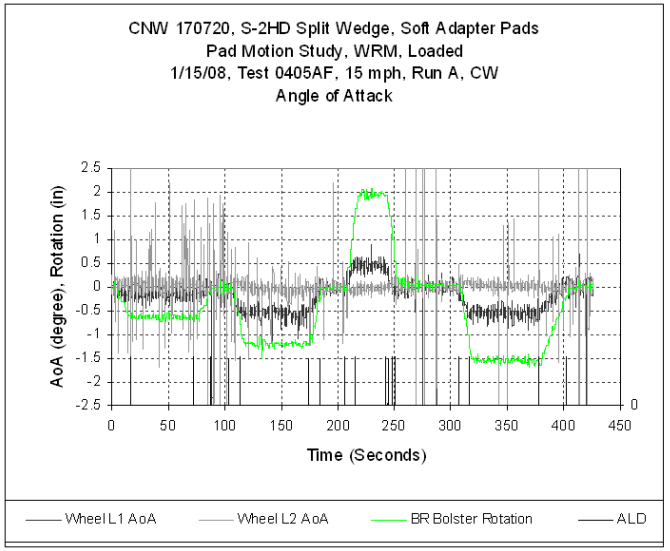
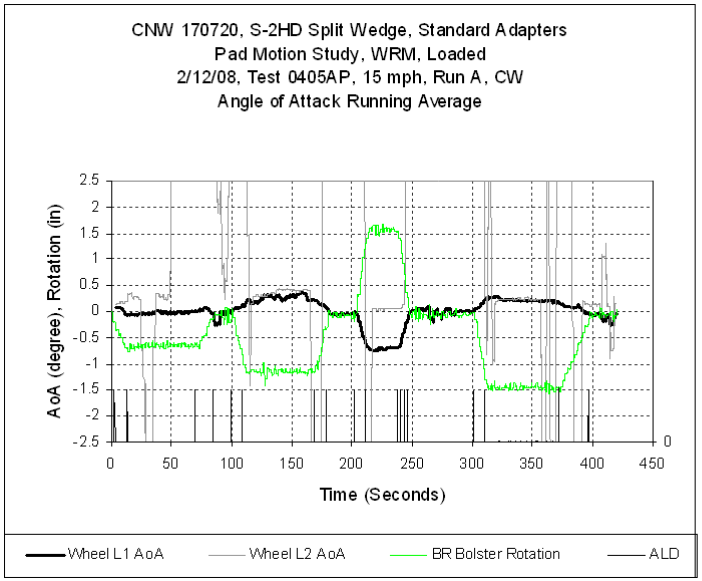


Adapter Pads

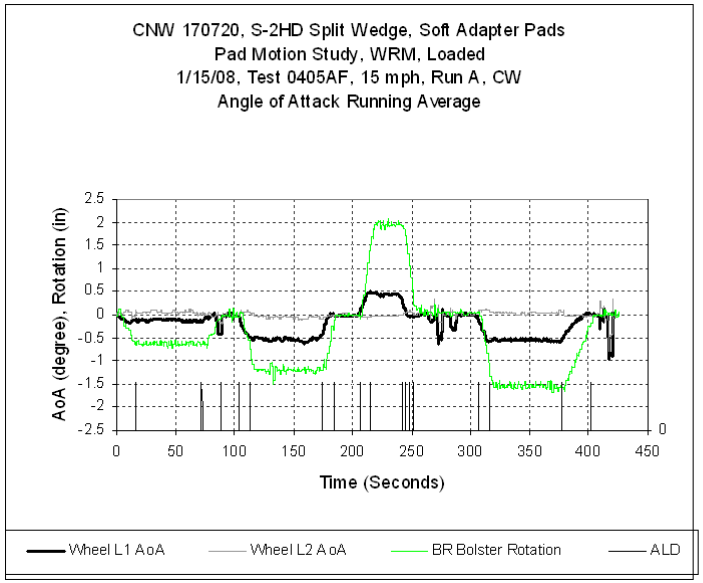
Sources: TTX Test 0405

FORWARD THINKING.

Wheelset AoA (v2)



Standard Adapters



Adapter Pads

Sources: TTX Test 0405

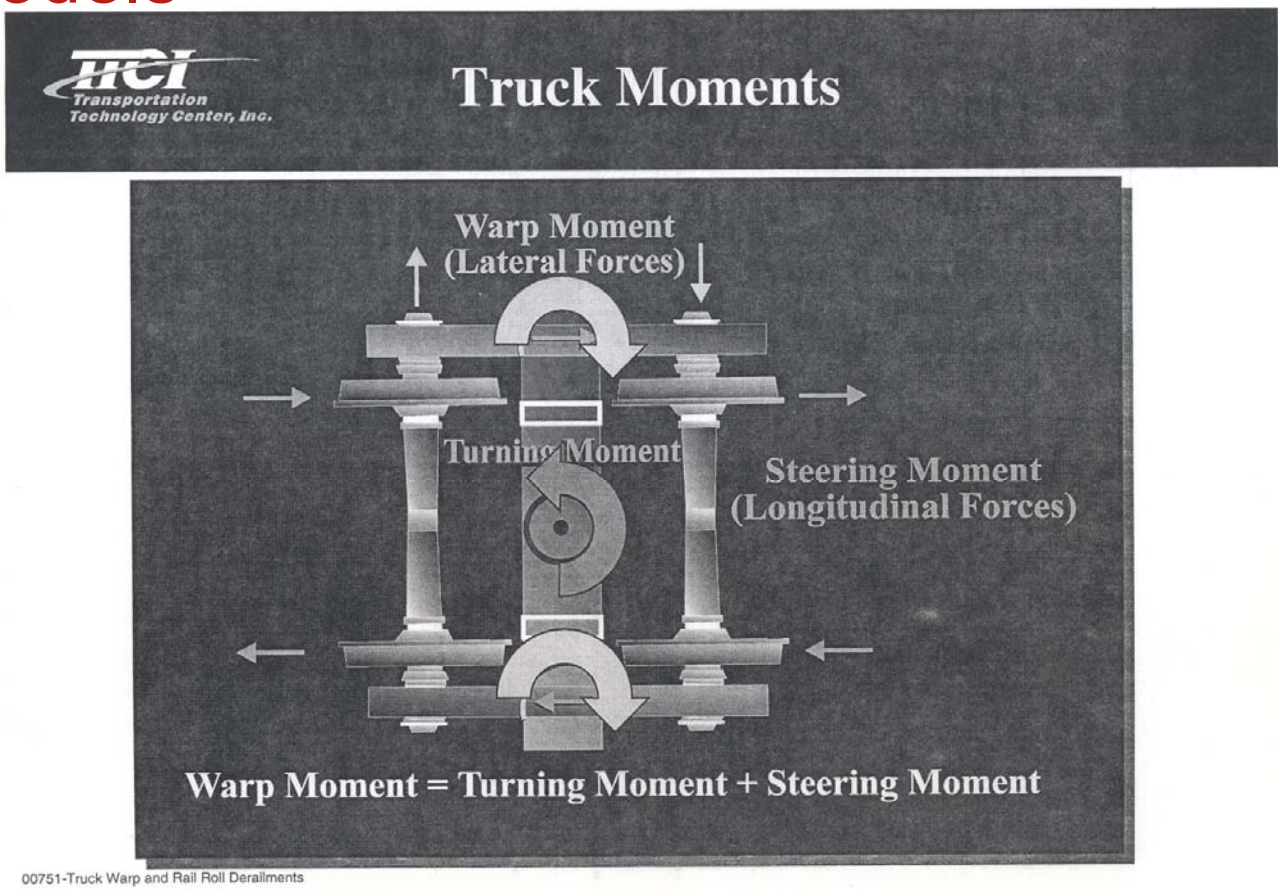
FORWARD THINKING.

M-976 Testing

Phase 2 Work

- Get trail AoA with Standard Adapters (new lasers)
- Study results from balance and over balance speeds
- Pad influence on Rolling Resistance test
- Truck Warp in Curving with High Rail Lube
- High Speed Stability Study

Models



00751-Truck Warp and Rail Roll Derailments

Models and Moments

Bowl Lube vs. rail lube

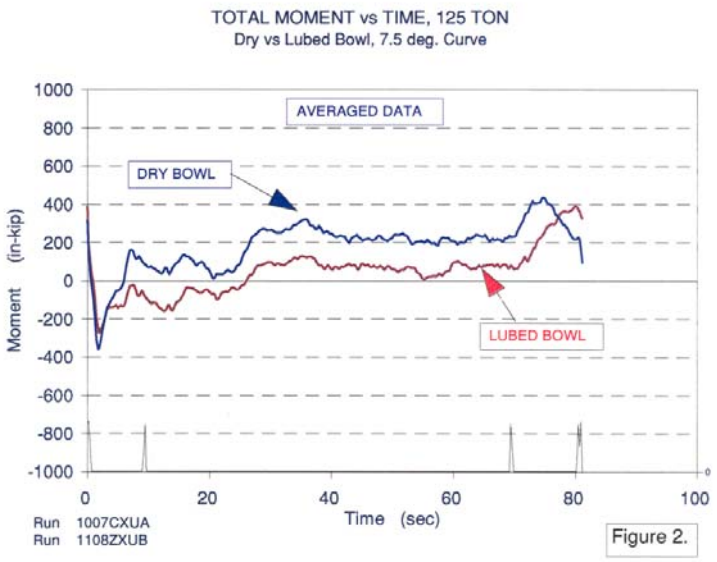


Figure 2.

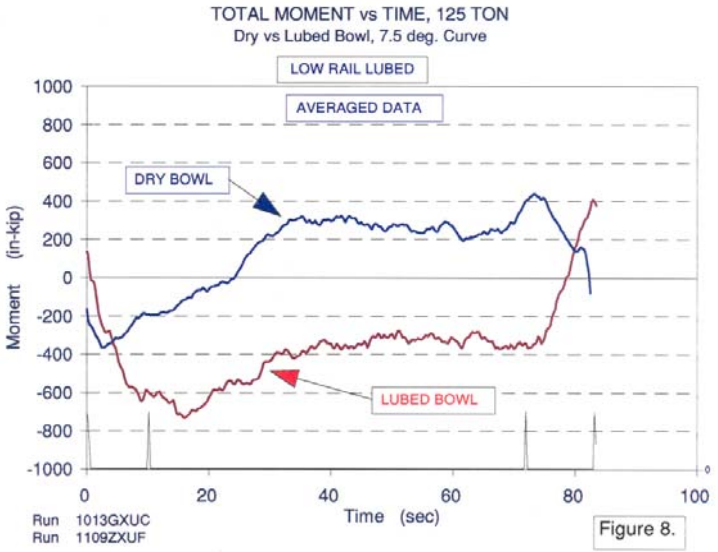


Figure 8.

TTX FORWARD THINKING.

Models and Moments

Bowl Lube vs. rail lube

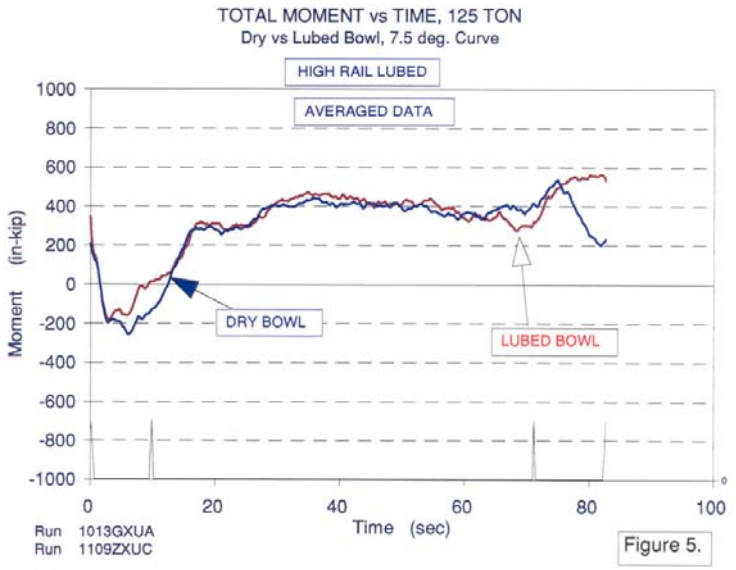


Figure 5.

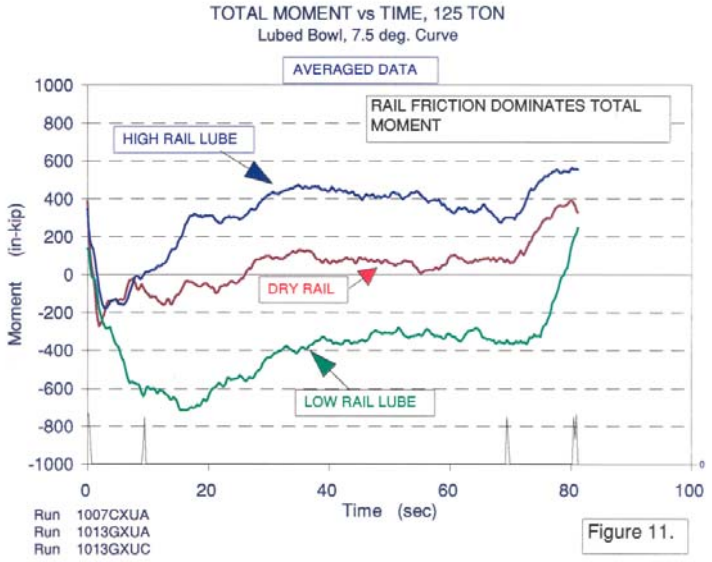


Figure 11.

FORWARD THINKING.

Bowl Torque