Truck Performance Basics for TTX

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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
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
TTX General Purpose Fleet

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

<table>
<thead>
<tr>
<th>Transportation</th>
<th>Approximate Hp/Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing 747-400 Freighter</td>
<td>3000</td>
</tr>
<tr>
<td>Corvette</td>
<td>350</td>
</tr>
<tr>
<td>Dodge Minivan 3.3L</td>
<td>80</td>
</tr>
<tr>
<td>Mack Truck w/460 engine</td>
<td>16</td>
</tr>
<tr>
<td>Freight Train</td>
<td>1</td>
</tr>
<tr>
<td>Shenzhen Container Ship</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Low hp/ton is cost-effective
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
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
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 $R_1$ does not equals radius $R_2$, wheel rolls in a curve to the left. Rolling-Radius-Difference (RRD) $\neq 0$
Steering: Simplified Wheel

Rolling radius $R_1$ does not equal radius $R_2$, wheel rolls in a curve to the right. Rolling-Radius-Difference (RRD) $\neq 0$
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
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
R&D Tools

• AAR Chapter XI
• Accelerometers, displacement transducers, roll gyros, lasers, load cells, and so on
• Track test at TTCI
TTX Truck Testing

Sources: TTX Test 0405
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

CNW 170720, S-2HD Split Wedge, Soft Adapter Pads
Pad Motion Study, WRM, Loaded
1/15/08, Test 0405AF, 15 mph, Run A, CW
Bolster Rotation and ALD marker

T = Tangent

Sources: TTX Test 0405
Lateral Wheel Forces

Sources: TTX Test 0405
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
Vertical Wheel Forces

Sources: TTX Test 0405
Single Wheel L/V Ratio

Both configurations performed very well

Sources: TTX Test 0405
Tangential Wheel Force

Standard Adapters

Adapter Pads

Sources: TTX Test 0405
Adapter Rotation Measurements

Sources: TTX Test 0405
Adapter Rotation relative to Side Frame

Sources: TTX Test 0405
Adapter Rotation (v2) relative to Side Frame

Standard Adapters

Adapter Pads

Sources: TTX Test 0405
Adapter Rotation (v3) relative to Side Frame (re-zero of displacement transducers)

Sources: TTX Test 0405
Instrumentation Layout

Sources: TTX Test 0405
Wheelset AoA

Standard Adapters

Adapter Pads

Sources: TTX Test 0405
Wheelset AoA (v2)

Sources: TTX Test 0405
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

Truck Moments

Warp Moment (Lateral Forces) ↑

Turning Moment

Steering Moment (Longitudinal Forces) ↓

Warp Moment = Turning Moment + Steering Moment

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Models and Moments

Bowl Lube vs. rail lube

Figure 2.

Figure 8.
Models and Moments

Bowl Lube vs. rail lube

**Figure 5.**

**Figure 11.**
Bowl Torque