Basics of Vehicle Truck and Suspension Systems and Fundamentals of Vehicle Steering and Stability

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Course Agenda

- Truck Nomenclature
- Wheel/rail influences
- Truck Dynamics
  - Physics
- Truck Types
- AAR M-976

- Truck Maintenance
Truck Nomenclature (Bogie)

3-piece truck

- Friction Wedge or Shoe
- Wheel
- Adapter
- Control Springs
- CCSB
- Spring Group
- Load Springs
- Bearing
- Axle
- Sideframe
- Adapter Pad
- Bolster
Suspension Nomenclature

- Friction Wedge or Shoe
- Pocket Wear Plate
- Column Wear Plate
- Load Springs
- Control Springs
- Bolster
- Side Frame
North American Freight Car Systems

<table>
<thead>
<tr>
<th>Capacity Tons</th>
<th>GRL Lbs.</th>
<th>Bearing Size</th>
<th>Wheel Diameter Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>220,000</td>
<td>Class E</td>
<td>33</td>
</tr>
<tr>
<td>100</td>
<td>263,000</td>
<td>Class F</td>
<td>36</td>
</tr>
<tr>
<td>110</td>
<td>286,000</td>
<td>Class K</td>
<td>36</td>
</tr>
<tr>
<td>125</td>
<td>315,000</td>
<td>Class G</td>
<td>38</td>
</tr>
</tbody>
</table>
Contact Patch area

Comparison of Wheel/Rail contact area of AAR-1B-WF

- **-loaded 286k (32.4mt)**
- **-loaded 263k (29.8mt)**
- **-empty 40k(6.8mt)**

Lateral position in mm

Area in mm$^2$
Dynamic Influences

- Speed
- Wheel to Rail Contact
- Track Input
- Mass/Inertias (Car Body, Truck Components)
- Friction
- Spring Suspension
- Suspension Dampening
Multimode Dynamics Software

Bounce and Pitch

\[ F_1 = c(\ddot{z} - L\dot{\Theta}) + K(z - L\Theta) \]
\[ F_2 = c(\ddot{z} + L\dot{\Theta}) + K(z + L\Theta) \]
\[ M_1 = c(\dot{z} - L\dot{\Theta})L + K(z - L\Theta)L \]
\[ M_2 = c(\dot{z} + L\dot{\Theta})L + K(z - L\Theta)L \]

\[ \dot{z}, \ddot{z}, \dot{\Theta} \]

\[ T \]

\[ m = \text{mass, Kg, slugs} \]
\[ K = \text{Stiffness, Nt/m, lb/in} \]
\[ C = \text{Damper Nt-sec/m, lb-sec/in} \]

\[ \frac{m\ddot{z}}{c} + Kz = 0 \]
\[ \dot{z} + \frac{c}{m} z + \frac{K}{m} z = 0 \]
\[ \frac{\dot{z}}{m} + \frac{c}{m} z + \frac{K}{m} z = 0 \]

Assume Solution:
\[ z = Ae^{i(w + \theta)} \]
\[ \dot{z} = Ai\omega e^{i(w + \theta)} \]
\[ \ddot{z} = Ai^2\omega^2 e^{i(w + \theta)} \]
Critical Attributes of the Wheel/Rail

1. Wheel set back-to-back dimension
2. Wheel Profile of both wheels
3. Wheel tapeline of both wheels
4. Rail Gauge (I.E. gauge point)
5. Rail Profile of both rails
6. Rail cant or inward tilt of each rail
Why do wheels have Conicity?

1:12 taper  1:6 taper  cylinder

EC = 0.083  EC = 0.167  EC = 0

*Curtis Urbin of TTCI
Wheels conicity in service

- Transit cars = 1:40
- Freight cars = 1:20
Conicity and Rolling Radius

- Slope angle at point of contact
- Rolling Radius Difference
- Effect of Wear on rail and wheel

EC = 0.050
Contact angle = 2.85°

AAR-1B-WF on AREMA A136 railhead
Hertzian Contact Patch - Creep theory

AAR-1B-WF on new 136# rail

4mm hollow wheel on TTCI ttt track

Contact Patch Issues:
- Steering Force
- Lateral Force

* Creep theory
Contact Patch in curves

TPD rail profile with “average” worn wheel

Angle of high rail contact = 6.65°
RRD = -0.11 mm

Angle of high rail contact = 42.26°
RRD = 10.74 mm
Wheelset instability
Truck Hunting

• High Speed
• Typically worse for empty cars
• Rail friction (~ 8 mph)
• Causes wheel wear and lading damage
• Measured in lateral gs rms (0.13gs)
Truck Performance Modes

- **Yaw & Sway**: Car / Suspension Specific
- **Twist & Roll**: 15–25, 50–60 mph
- **Pitch & Bounce**: 50–70 mph
- **Truck Hunting**: Truck Warp, Truck Rotation, Wheelset Movement 40+ mph

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Carbody Interaction Details

Characteristic

Truck Spacing

Center of Gravity

Stiffness

Inertia

Light Weight

Predominate Influence

Pitch / Bounce

Twist / Roll

Spiral

Hunting

Curving
Hopper Car on Pitch and Bounce track

Distance along the Track (feet) vs. Body leading end vertical acceleration (g's)
Truck Interaction Details

Warp Stiffness
The warp stiffness design is controlled by the shoe width and force.
Carbody / Truck Interaction Details

Carbody Bolster Interface
Side Bearing / Center Plate friction design accommodates these regimes and must remain consistent
Passive Steering
• Provides wheelset alignment to reduce rolling resistance
• Designed stiffness enhances performance for these regimes
Truck Interaction Details

- Friction Shoe
- Springs

Spiral
Friction shoe force limited to prevent wheel unloading

Hunting
Friction shoe force limits warp

Twist / Roll
Tuned friction shoe damping & suspension stiffness limit Roll

Pitch / Bounce
Tuned friction shoe damping & suspension stiffness limit Pitch / Bounce
Motion Control® Features M-976

- Passive Steering
  - Curving
  - Rolling Resistance
- Tuned Suspension
  - Stability
  - Vert. and Lat. Accelerations
- Lightweight Castings
  - Stability
  - Roll Control
- CCSB
  - Stability
  - Roll Control
- Wide Friction Shoe
  - Stability
  - Curving
- 36” Class C Wheel
- 6 ½ x 9 Class K Roller Bearing
- Class K Axle
- 36" Class C Wheel
- Class K Axle
M-976 Friction Shoes

- Motion Control® and SSRM
- Ridemaster
- Super Service Ride Control
- S-2-HD Split Wedge
- S-2-E
Shoe Types

ASF Shoe Design (MoCo, SSRC)

37.5° Angle
30” Slope Radii, Shaped Slope
Steel Shoe

Accommodates:

- Bolster/Side Frame Rotation Part Variation - Casting, Shoe

Provides:

- Shoe Stability - Roll and Sway
- Warp Stiffness - Edge Contact
- Smooth Action
- Long Suspension Life
Shoe Types

S2HD Shoe Design

- 32° Angle
- Split Wedge
- Iron Shoe

Pocket Side Wall Wear Plate

Split Wedge Insert

Split Wedges
Suspension Design

Constant
- ASF Ride Control
- ASF SSRC
- Buckeye XC-R
- Meridian C-1, Wedge Lock

Variable
- Motion Control
- ASF Ridemaster
- Swing Motion
- Barber S-2-HD
Secondary Truck Suspensions

** Friction Damping $\sim F \times D$

Variable damping

Constant damping
Damping Advantages

**Constant Damping:**
- Long Service Life
- Moderate Track Ride
- Light Car Truck Warp

**Variable Damping:**
- High C. of G. Approval
- Ease of Maintenance
- Rough Track Ride
- Service Life Varies by Design
Hydraulic Damping in suspensions?

Hydraulic damping:
• Good Performance
• High Speed
• Service Life?
• Maintenance
Truck Maintenance

Most wedges have built-in wear indicators.
CCSB must be “long travel”
Truck Inspection

- Shoe Rise
- Column Wear Plate Bolts
- Gibs
- Springs
Frame Braced truck

- Increases warp stiffness
- Typically added to a 3-piece truck
Swing Motion® truck
Summary

- Trucks operate as part of an overall system
- Utilize primary and secondary suspensions
- Dynamic performance is dependent on the assembled suspension parts
- Good maintenance is critical to continued performance and overall life of the system
Thank You - Questions