AAR/ARCI Freight Car Fatigue Task Force II

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John Coulborn, Trinity Industries, Inc.
David Cackovic, AAR/TTCI
Background

- The railroad environment is a moving target
- The birth of railcar design requirements centered mostly around Impact and Tensile Loads
  - 1,250,000 pound impact
  - 1,000,000 pound squeeze
  - Vertical bounce
- The goal was to avoid sudden catastrophic failures
- The solution was: Make it Heavier
- GRL’s have steadily increased
  - 100K to 200K to 220K to 250K to 263K to 268K to 286K (Some 315K)
- The need for more efficient designs (lighter cars) also increased
- About the late 60’s to early 70’s the industry awoke to the need to design for fatigue
- Guidelines for fatigue design were put in place with the understanding that would need to be kept up-to-date
Today’s Presentation:

- Why Updating is Needed (Coulborn)
- How we are updating the Fatigue Guidelines and Prioritizing Car Types (Coulborn)
- Test Program Funding and Execution (Cackovic)
Why Updating is Needed

Current Guidelines Based on:
- Old Environment
  - Different roadbed today
    - Continuous welded rail
    - Concrete ties
    - Better ballast systems
  - Longer, heavier trains today
  - Higher tractive effort and high adhesion locomotives
  - Vibration was not addressed
Why Updating is Needed

- Current Guidelines Based on:
  - 1970’s and Older Car designs
  - Cars used for tests all out of production
  - 263K GRL and lighter vs. today’s 286K GRL
  - Today’s tare weights are often lower
  - Materials today are higher strength
  - Today use of aluminum is common
Why Updating is Needed

- Fatigue is the number one structural problem
  - Draft systems on steel gondolas
  - Side sills of well cars
  - Top chords of coal cars
  - Container supports of well cars
  - Center sills of spine cars
  - Shear plate on stub sill cars
  - Center beams
  - And more
Why Updating is Needed

- **Fatigue failures are a safety issue**
  - Pull aparts
  - Collapsed cars
  - Lost loads
  - Improper or poor quality repairs

- **Stress state issues**
  - AAR Standard S-286 requires fatigue analysis
  - Defective wheels damage the car as well as the rail
A Little More Background:

- The original Fatigue Task Force began work in the mid-70’s as an ARCI endeavor.
- Later the ARCI joined forces with the AAR and the work progressed under the Track Train Dynamics program.
- Road testing began in 1984.
Why Updating is Needed

- The pathway to lighter, better cars requires accurate fatigue analysis
- Without new tools development stops or we go down the wrong pathway
- The industry has chosen the right pathway for improving the fatigue analysis tools by ...............
Reforming the FCFTF

Freight Car Fatigue Task Force II reformed September 29, 2004

- John Coulborn – Trinity Rail Group – Co-Chairman
- Shaun Richmond – Trinity Rail Group – Co-Chairman
- Members included: UP, CSX, BNSF, NS, FCA, Gunderson, NSC, Union Tank Car, Sims Engineering, FRA, Sharma and Associates, TTX, Columbus Steel Castings, and ASF-Keystone
- David Cackovic and Kevin Koch – AAR/TTCI

Work Together: Jointly work to update the specification requirements and to gather the new fatigue load environment data.
Approach Taken / This Task Force’s Goals

❖ Today’s Presentation:
  ❖ Why Updating is Needed (Coulborn)
  ❖ Updating the Fatigue Guidelines and Prioritizing Car Types (Coulborn)
  ❖ Test Program Funding and Execution (Cackovic)

7.1.2 Analysis Requirements
7.1.2.1 Mileage Criteria for Analysis
The following minimum mileage criteria are to be used to determine the acceptability of fatigue life estimates (unless the purchaser has defined alternative criteria—only higher mileage criteria are allowed for equipment in North American interchange service):

<table>
<thead>
<tr>
<th>Category</th>
<th>Mileage Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit train and high utilization cars</td>
<td>3,000,000 miles</td>
</tr>
<tr>
<td>General interchange</td>
<td>1,000,000 miles</td>
</tr>
</tbody>
</table>
Revised AAR Specification M-1001 Chapter VII

- Fatigue Analysis Calculation Method
  - Method by original 1970’s Task Force retained
  - Updated Empty-Load Ratios
  - Retained Miner’s Rule
  - Added Section 7.7: Guidelines for FEA
  - Retained original joint configurations
  - Identified new joint configurations to add later
  - Retained original REPOS until updates are done

For this example,

$$\beta_{EMP} = 354.661 \times \frac{0.93}{1.93} = 170.899 \text{ empty cycles/mile}$$

$$\frac{N_T}{\beta_{EMP}} = \frac{85,183,706,000}{170.899} = 498,445,000 \text{ miles}$$

7.2.4.1.3.5 Calculate total life (loaded and empty):

Total life = \(\frac{1}{\text{Life}_{LD} + \text{Life}_{EMP}}\)

Total life = \(\frac{1}{\frac{1}{2,206,000} + \frac{1}{498,445,000}}\) = 2,197,000 miles
Revised Chapter VII

- Over-the-road testing
  - Established authority of EEC over tests
  - Updated test methods and parameters
  - Updated the format for data reduction
  - Established the initial list of car types to be tested
  - Established the initial priority of the tests
    - Coal, Tank and Intermodal first
    - Others to follow
    - Specific cars selected for testing are approved by the AAR Equipment Engineering Committee and the Task Force. Cars will be obtained for testing through donation agreements.
Update Fatigue Guidelines

- Revised Chapter VII Recently Implemented
  - MSRP Section C, Volume 2 was Released May 7, 2007 by the AAR and the Equipment Engineering Committee via AAR Circular Letter C-10493.
  - Includes Chapter VII.
Today’s Presentation:

- Why Updating is Needed (Coulborn)
- Updating the Fatigue Guidelines and Prioritizing Car Types (Coulborn)
- Test Program Funding and Execution (Cackovic)
Test Program

Fatigue Test Requirements for Updating Freight Car REPOS (Road Environment Percent Occurrence Spectra)

- In the late 70’s and 80’s the basic test methodology was developed and implemented. The resulting output was test data required for railcar fatigue analysis and the specification “Chapter 7 - Fatigue Design of New Freight Cars.”

- Load spectra for the following cars were published:
  - High side 263K GRL coal gondola in unit train service
  - 263K GRL open top hopper
  - 263K GRL stub sill tank car
  - 70-Ton boxcar
  - 5-unit articulated TOFC spine car for 65K trailers
Test Program

- These tests are funded by the AAR Strategic Research Program and the RSI/ARCI Car Builders.
- This cooperative testing is tentatively planned for future years, until the need for current design spectra has been met.

As a side note, the FRA has joined the AAR and RSI/ARCI Car Builders in funding “sister” tests to obtain data for tank cars.
Test Program

Test Car Selection and Loading

- Only loaded testing is to be conducted. Experience has shown that empty car operation has a minimal effect on fatigue life.

- Coal, Tank and Intermodal first.
Test Program

Test Route Selection

- The test route for each car type will be determined by the Task Force and approved by the Equipment Engineering Committee. Routes selected will be the most appropriate service and train makeup for the car type.

Train Makeup

- The test conductor will work to ensure that the car is located in the middle third of the train consists, as much as is reasonably possible.
Test Program

- Data Acquisition System -- Unattended
  - A relatively small, self contained system
  - 16 channels of data, 256 digital samples per second, and low-pass filtered at 30 Hz
  - Data storage size sufficient to need only two downloads in 10,000 miles.

- Calibration of Transducers
- System Check-out in Controlled Environment
Upon review and approval by the Freight Car Fatigue Task Force and the EEC, the new load spectra data will be added to Section 7.3 ("Environment Load Spectra") of Chapter VII, either as an augmentation of existing data or as a replacement of existing data.
Test Program – Coal Car

- FCFTF coal car testing became part of AAR Strategic Research Initiative 14D “In Service Load Monitoring” Program
  - Monitor the stress state in railroad service
  - Build database for 286K GRL coal service
Test Program – Coal Car

- **SRI 14D Instrumentation**
  - 2 Force measuring wheels
  - 2 Axles to measure strain
  - Accelerations on body both ends
    - One brake valve
  - Brake beam strains
  - Top chord strains

- **FCFTF Instrumentation**
  - Bolster strains and forces
  - Side bearing loads
  - Coupler Force
  - Side frame loads
  - Top chord strains
# Test Program – Coal Car

<table>
<thead>
<tr>
<th>MEASUREMENT</th>
<th>Transducer Type, Comment</th>
<th>Data Type, Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Plate Vertical Load</td>
<td>Strain Gage, calibrated in load frame</td>
<td>Time History, Rainflow Cycle Counting Post Test Processing</td>
</tr>
<tr>
<td>Side Bearing Load Bridge</td>
<td>Instrumented Coupler</td>
<td></td>
</tr>
<tr>
<td>Longitudinal Coupler Load</td>
<td>Instrumented Coupler</td>
<td></td>
</tr>
<tr>
<td><strong>SYSTEM MEASUREMENTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>System</td>
<td>Time History</td>
</tr>
<tr>
<td>GPS Train Speed</td>
<td>GPS</td>
<td>Time History</td>
</tr>
<tr>
<td>GPS Train Location</td>
<td>GPS</td>
<td>Time History</td>
</tr>
<tr>
<td><strong>CAR BODY STRUCTURAL MEASUREMENTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car Body Strain Locations (Key locations, twist, etc.)</td>
<td>Strain gage, locations based on car type (history, analysis)</td>
<td>Time History, Rainflow Post Processing</td>
</tr>
<tr>
<td><strong>BOLSTER AND SIDEFRAME LOAD SPECTRA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolster Load</td>
<td>Strain Gage, calibrated in load frame</td>
<td>Time History, Rainflow Post Processing</td>
</tr>
<tr>
<td>SF Vertical Load</td>
<td>Strain Gage, calibrated in load frame</td>
<td>Time History, Rainflow Post Processing</td>
</tr>
<tr>
<td>SF Lateral Load</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Test Program – Coal Car
Test Program – Coal Car

- Phase I Tests, with instrumentation coach, conducted in 2006
  - Western and Eastern RR
  - 3,200 miles of loaded car data
    - Wyoming to NY on UP / CSX
    - Wyoming to Georgia on BNSF / NS
  - Aluminum coal cars in front of coal train

- Phase II Tests, unattended
  - Most measurements obtained 4,900 loaded miles of data, some measurements obtained 5,200 miles.
Test Program – Coal Car

- Top chord strains
  - Approached buckling limit in body bounce motions
  - Bending strains not as significant
  - Highest stress at speeds above 45 mph
  - Will evaluate coupler force link to high strains
## Test Program – Coal Car

Large top chord stresses were recorded

**Top Chord**

<table>
<thead>
<tr>
<th>Location on Route</th>
<th>Test Speed (mph)</th>
<th>Compressive Axial Stress</th>
<th>Bending Stress</th>
<th>Vertical Wheel Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinton Sub., MP 148.13, Right Switch</td>
<td>51.8</td>
<td>20,820</td>
<td>2,320</td>
<td>76,710</td>
</tr>
<tr>
<td>Columbus Sub., MP 86.49, Bridge</td>
<td>49.5</td>
<td>18,210</td>
<td>2,190</td>
<td>73,460</td>
</tr>
<tr>
<td>Columbus Sub., MP 88.23, Culvert</td>
<td>50.0</td>
<td>17,520</td>
<td>2,030</td>
<td>68,230</td>
</tr>
<tr>
<td>South Morrill Sub., MP 62.89, Road Crossing</td>
<td>50.0</td>
<td>16,270</td>
<td>1,680</td>
<td>56,560</td>
</tr>
<tr>
<td>Clinton Sub, MP 159.31 - culvert</td>
<td>43.1</td>
<td>15,960</td>
<td>2,150</td>
<td>65,450</td>
</tr>
</tbody>
</table>

Calculated Critical Compressive Stress for Buckling – 22,300 psi.

Maximum compressive stress 93% of calculated limit
Test Program – Coal Car

Events per Mile vs. LCF P-P Kips

- 3600 Miles 2006 Data
- 5625 Miles 83’-85’ Data
Test Program – Coal Car

- Bolster and side frame loads have been useful for AAR Coupling System & Truck Castings Committee (CS&TCC) efforts
**Test Program – Coal Car**

![Image of test program]

*Coupler loads have been useful for AAR CS&TCC efforts*

Proposed Draft M-216 Specification
Knuckle Fatigue Test Load Cycles Proposed

<table>
<thead>
<tr>
<th>Segment</th>
<th>Number of Cycles (Sinusoidal form)</th>
<th>Total Elapsed Cycles</th>
<th>Cycle Load Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>4</td>
<td>10 – 300 kips</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>6</td>
<td>10 – 280 kips</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>13</td>
<td>10 – 260 kips</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>23</td>
<td>10 – 240 kips</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>54</td>
<td>10 – 220 kips</td>
</tr>
<tr>
<td>6</td>
<td>77</td>
<td>131</td>
<td>10 – 200 kips</td>
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<tr>
<td>7</td>
<td>65</td>
<td>196</td>
<td>10 – 180 kips</td>
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<tr>
<td>8</td>
<td>73</td>
<td>269</td>
<td>10 – 160 kips</td>
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<td>9</td>
<td>89</td>
<td>358</td>
<td>10 – 140 kips</td>
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<tr>
<td>10</td>
<td>105</td>
<td>463</td>
<td>10 – 120 kips</td>
</tr>
<tr>
<td>11</td>
<td>129</td>
<td>592</td>
<td>10 – 100 kips</td>
</tr>
<tr>
<td>12</td>
<td>187</td>
<td>779</td>
<td>10 – 80 kips</td>
</tr>
<tr>
<td>13</td>
<td>279</td>
<td>1058</td>
<td>10 – 60 kips</td>
</tr>
</tbody>
</table>

Thanks to NS for significant effort on this test plan development!
Test Program – Intermodal Car

- Instrumentation installed
  - Truck (100-ton)
    - Truck bolster load
    - Side Bearing (brackets)
    - Centerbowl load
  - Car body strain measurements selected by FCFTF members
  - Additional measurements for TTX use:
    - 70-ton truck dynamics
    - Dynamic forces beneath 20 foot containers
- Began over-the-road testing December 3, 2007
- Placement target is rear two-thirds of the train consists, in Chicago to west cost
- Approximately 8,900 – 12,000 miles of data has been collected, depending on measurement reliability
Test Program – Intermodal Car

Test Load

◆ The B end unit held two 40 ft. containers loaded to 62,000 lb. each (total load 124,000 lb.).

◆ The adjacent C unit held two 20 ft. boxes each loaded to 53,000 lb. and one 16,000 lb. 40 ft. container stacked on top of the 20 ft. containers. The 40 ft. container held 16,000 lb. bringing the total in the C unit to 124,000 lb. This provided a higher vertical center of gravity for the C unit load.

◆ The other three units held one 40 ft. container each, loaded to 40,000 to 60,000 lb.
Data Validation

◆ Sims Professional Engineers is reviewing fatigue analyzes from builders using various joint designs, unit stresses & test regimes

◆ The analysis/presentation is a first cut at understanding the influences of the variables involved

◆ Chapter 7 techniques were employed unless otherwise noted
Figure 1: Coal Hopper Coupler Fatigue

Fatigue Life (mileage)

Data Set

- REPOS Table 7.23 Hopper
- REPOS Table 7.24 Hopper, Extreme
- 2006 Coal Hopper - Manned
- 2006 Coal Hopper - Unmanned

Note: Analysis performed per Ref. A
Figure 3: Coal Hopper Bolster Fatigue

<table>
<thead>
<tr>
<th>Fatigue Life (mileage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>5,000,000</td>
</tr>
<tr>
<td>10,000,000</td>
</tr>
<tr>
<td>15,000,000</td>
</tr>
<tr>
<td>20,000,000</td>
</tr>
<tr>
<td>25,000,000</td>
</tr>
</tbody>
</table>

Data Set

- REPOS Table 7.21 Hopper
- 2006 Coal Hopper - Manned
- 2006 Coal Hopper - Unmanned

Note: Analysis performed per Ref. A
Preliminary Conclusions: Coal Hopper

◆ The coupler REPOS from the new manned test is more severe than the unmanned & more severe than existing Ch. 7 similar REPOS.

◆ However, for vertical loads on the bolster, the new manned data is about the same as existing REPOS but the unmanned is not nearly as severe.
An AAR Technical Digest report is being compiled summarizing the results of the testing to accumulate coupler force data for this coal hopper. The report will show comparisons of the with the “standard” and “severe environment” data currently in Chapter 7, Section C, Part II, Volume 1 of the MSRP.

FCFTF analysts will meet Friday, September 26, to begin final determination on publishing the coal car results in the AAR MSRP.
Status: Intermodal Car

- Testing now complete.
- FCFTF analysts will meet Friday, September 26, to begin final determination on publishing the Intermodal car results.
AAR/ARCI
Freight Car
Fatigue Task Force II

QUESTIONS?

(TIME PERMITTING)