AAR Research Update

by

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Wheel/Rail Lubrication

Problem: Potential benefits of wheel/rail lubrication are not fully realized due to problems with:

- Mobility and durability of lubricants
- Consistency of lubrication
- Effectiveness of lubrication delivery systems
- Effective management of lubrication programs
- Effects on wheel/rail interaction

Wheel/Rail Lubrication

Approach and End Products:

- Support management of rail lubrication
  - Prototype high-speed tribometers
- Monitor lubrication concepts & procedures
  - Prototype top-of-rail lubrication systems
- Optimize friction at wheel/rail interface
  - Performance guidelines for lubrication control
Wheel/Rail Asset Life Extension

Wheel/Rail Lubrication

Findings
- TOR can be applied under controlled train operating conditions
  - Energy savings: 10%-13% curved
  - 3%-4% tangent
- TOR likely to need gage face lubrication to achieve optimum rail wear and energy savings
- TOR does reduce lateral loads
- TOR may cause some high angle of attack performance on worn trucks
- No significant wheel slip or adverse effects on train handling when end of train target friction is 0.3
- TOR reactivity and implementation issues still remain to be resolved

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Vehicle/Track Performance

Approach and End Products:
- Quantify load carrying ability of track
  - TLV track strength measurement system
- Optimize track strength retention
  - Post maintenance slow-order guidelines
- Assess track quality via vehicle response
  - Improve performance of track geometry cars
  - Performance-based track geometry guidelines
- Determine root causes of geometry caused derailments
  - Guidelines and remedies to reduce derailments

Problem: Track and vehicle maintenance policies are not always optimized to minimize total vehicle and track costs.
- Derailments cost railroads time and money
- Relationship between track geometry & track strength
- Effects of maintenance on track strength
- Effectiveness of dynamic track stabilizers
- Performance-based prioritization of maintenance
- System view on vehicle design and track strength

Vertical Track Deflection

TLV & Tank Car Consist

Load - Deflection Curve at Point Along Track

large variations in Contact Stiffness indicate subgrade support problem

variations in Sealing Stiffness indicate tie-ballast support problem
TLV Vertical Track Strength Measurement Test Consist

Background:
- Track geometry-involved accidents are a major concern to member railroads
- The accident trend is downward over the last five years
- Gauge widening, alignment and cross level are primary concerns
- Train delays due to derailments and geometry-related slow orders affect network reliability

Covered hopper findings
- Multiple surface, crosslevel, or alignment perturbations can produce higher vehicle/track loads than single perturbations
- Combinations of different track deviations can produce higher vehicle/track loads than either deviation alone
- Neural networks can predict 0.1 mile wheel force statistics given track geometry alone.
- Several Neural networks should be trained to predict various regimes of vehicle response
- Predictions of large wheel lateral forces are most reliable
**Heavy Axle Load Implementation**

**Problem:** The impact of heavy axle loads on track needs to be minimized.
- Safety and economics of HAL operations
- Track maintenance penalty
- Fatigue life reduction of bridges
- Performance of premium track materials
- Utility of improved suspension trucks
- Justification of operating cost savings

**HAL Research Program**

**Purpose**
- Determine the effect of 39-ton axle loads on track performance and degradation
- Develop safe and economical methods for the operation of heavy axle load cars

**Earlier Phases**
- Phase I 1988-1990: 160 MGT
- Phase II 1990-1996: 300 MGT
- Phase III 1995-1996: 425 MGT, 100,000 miles

**Recently Completed**
- Phase IV: 46 MGT, Premium Track, No Lubrication

**Starting Late Summer 1999**
- Phase V: 8/00, 400 MGT
- Current design: 3-piece trucks, Premium Track, New materials

**Heavy Axle Load Implementation**

**FAST/HAL Operations**

- Determine technical feasibility and enhance safety
  - Report on technical feasibility & economic impact
- Reduce costs, improve safety of train operations
  - Longer lasting track components
  - Improved trucks and optimal car designs
- Monitor revenue service effects, identify problems
  - Track component life-cycle database
- Improve industry’s ability to evaluate effects of HAL
  - HAL track analysis models, bridge costing models, network capacity analysis programs
**Heavy Axle Load Implementation**

**Significant Findings**
- Heavier axle loads decrease operating and equipment costs but increase track costs
- Increase in track maintenance and renewal costs
  - Bridges - steel bridge fatigue, timber bridges
  - Rail defects - less than 300 BHN rail
  - Marginal support conditions - soft subgrade
  - Special track work - crossing diamonds
- Increased costs due to poor curving performance of three-piece standard trucks - improved suspension trucks reduce track maintenance and fuel consumption

**Wheel/Rail Profile Optimization**

**Problem:** Current wheel/rail profiles and maintenance procedures are not always optimized.
- Hollow-worn wheels increase operating costs:
  - Impair ability of trucks to steer leading to
    - Increase in fuel costs and rail wear
    - Increase in derailment risk
    - Cause damage to special track work and low rail
  - Increase in welding efforts
  - Increase in grinding costs

**Approach and End Products:**
- Characterize distribution of hollow-worn wheels
  - Statistical description of hollow-worn wheels
- Determine effects on rolling resistance
  - Technical data for economic analysis
- Optimize wheel maintenance procedures
  - Guidelines for hollow-worn wheel removal
- Determine costs/benefits of rail grinding practices
  - Recommended guidelines for rail grinding practices

**Wheel/Rail Asset Life Extension**

**Wheel/Rail Profile Optimization**

**Objective:**
- Optimize system performance and extend wheel/rail life

**Background:**
- Wide range of worn wheel profiles in service
- Wide range of worn and ground rail profiles in service
- Unsuitable match of profiles gives poor wheel/rail interaction
  - High rolling resistance
  - Damaging stresses

**Distribution of hollow wheels in North American service, 6,757 Measured Wheels**
Wheel / Rail Asset Life Extension
Wheel / Rail Profile Optimization

Findings:
- Hollow wheel wear causes:
  - Increased rolling resistance
  - Increased derailment risk
  - Damage to special track work and low rails in curves
  - Increased tie damage
- Removal of hollow wheels is hampered by high wheelset maintenance costs

Removal at 3-mm hollow wear (0.12 inch)
Economic benefit of removing hollow-worn wheels

1-Wear Wheel Costs And Benefits

| Increased wheelset maintenance | ($115.7m) |
| Reduced rolling resistance | $46.8m |
| Reduced rolling resistance & low rail wear | $56.6m |
| Reduced lateral force & longer wheelset life | $4.8m |
| Lower wheelset stress & less grinding | 6.4 |
| Less damage to special track work | ? |
| Reduced derailment risk | ? |
| Increased wheel life | ? |
| Net benefit (per year, 1990 dollars) | $17.0m . . . |

Hollow wear increases contact stress and the probability that a hollow wheel can give high stress.

Wheel / Rail Asset Life Extension
Wheel / Rail Profile Optimization

Grinding Test Findings:
- Need for grinding is site- and rail-specific
- Current practice: high-speed, single-pass "preventive grinding"
- Low rail is increasing focus of grinding
- Hollow-worn wheels responsible for surface deterioration on low rail
- Clean premium rail in curves resist the development of internal defects
- Focus on low rail to relieve field-side
- Minor gage-corner relief to aid natural wear
- May need heavier gage corner relief on standard rail
- Avoid excessive two-point contact conditions

Problem: Certain transverse rail defects masked by shells, rail-base defects, and rail-weld defects are difficult to detect.

- Third largest ranking cause group for derailments
- Rail defects affect productivity & network efficiency
- Broken rails can pose a threat to safety
- Track buckling is 2nd highest cause group for track geometry related derailments

Form partnerships, start a development program
- Workshop proceedings and report on survey
- Identify efficacy of current practices
- Rail defect test facility
- Benchmark of current technology
- Foster development of new technologies
- Laser-based ultrasound and eddy-currents
- Investigate new technologies for track circuits
- Alternative rail-break detection systems

Track Integrity Monitoring

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Track Integrity Monitoring
Track Integrity Monitoring
Improved Rail Flaw Detection

Objective
- To improve speed, reliability and accuracy of defect detection systems

Background
- Annual cost of inspection and derailments related to rail flaws
  - $185 million
- Third largest ranking cause group for train accidents

End Products and Findings
- Benchmarking existing rail flaw detector cars
  - Consistent with recommended guidelines
- Upgrading rail defect test facility (RDTF)
  - Scheduled completion (August 1999)
- Foster the development of improved rail flaw detection systems
  - Laser UT
  - RF & LF eddy current

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Track Integrity Monitoring
Improved Rail Flaw Detection

Objectives
- Evaluate alternatives to track circuits
- Monitor performance, maintenance, reliability of prototypes at FAST

Background and findings
- Introduction of Positive Train Control systems may make track circuits for train control redundant
- Fiber optic based detection systems are technically feasible, but not economical
- Durability and ease of repair still a problem in RR environment

Problem: Turnouts and crossing diamonds represent the most costly and maintenance intensive elements of track structure.
- Spending annually $300 M on TOs and CDs
- Substantial train delay due to maintenance & repair
- Excessive wear & metal flow under dynamic loads
- Average life of main line diamond is 50-150 MGT
- Among top five causes of track related derailments
Special Track Work

- Reduce the forces applied to special track work
- Intermediate turnout designs with spring frogs
- Increase life-cycle of medium/heavy tonnage turnouts
- Specs for bainitic steel; bainitic frogs & switch pts
- Increase reliability of diamonds under HAL
- Prototype flange bearing diamond
- Reduce repair and maintenance costs
- Guidelines for frog repair, switch point grinding, surfacing and substructure design

North American Railroads are
- Spending annually $300 million on turnouts and crossing diamonds:
  - 6800 new turnout frogs installed annually
  - 1000 new crossing diamond frogs installed annually
  - Additional $400-$600 million cost of train delay at crossing diamonds and turnouts due to slow orders

- Research Demonstrates the Effects of Implementing Heavy Axle Loads
  - Turnouts: life shortened but performance can be recovered with premium materials
  - Crossing Diamonds: life shortened and cannot be recovered with premium materials

Research Objectives
- Develop and evaluate new design for heavy axle loads
- Develop advanced materials for frogs

Research has led to:
- New special track work designs and advanced materials
- Bainitic frog steel specification
- Prototype frogs and switch points for testing at FAST
- Improved Turnout maintenance practices
  - Frog welding
  - Switch point grinding
  - Surfacing and foundation designs
**Special Track Work**

**Turnouts and Crossing Diamonds**

**Goals:**
- Develop and evaluate new design crossing diamonds for heavy axle loads

Research has led to:
- Performance specification for crossing diamonds
- Development of new concepts
  - Flange bearing frog prototype tests at FAST
  - Development and testing of bainitic steel for Crossing Diamond
  - Running surface ramp concept evaluation

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**Bridges**

**Problem:** Methodologies are needed to extend the life of existing bridges while minimizing the effects of HALs
- Effects of tractive forces generated under AC locos
- Secondary bracing members most costly to repair
- Fatigue on critical bridge components under HAL
- Shear stress limits of timber bridge stringers
- Lack of methodology to determine need for strengthening railway bridges for dynamic loads

**Benefits:** Reduction in steel and timber bridge renewal and maintenance costs. Avoidance in seismic retrofit costs.

**Program Goals**
- Develop recommendations and practices for longitudinal design of steel bridges
- Develop guidelines to extend life of steel bridges and critical bridge components
- Develop methodologies to determine remaining life of timber bridges

- Minimize the effects of longitudinal forces
  - Guidelines to design, strengthen bridges
- Minimize HAL effects, optimize utilization
  - Guidelines for repair of HAL critical components
- Extend the life of timber bridges
  - Methodology to extend the life of bridges
- Minimize costs RRs will incur due to earthquakes
  - Dynamic design and evaluation methodology
Background
- 1993-1994 AAR/Caltrans/UNR tests resulted in dropping of retrofit requirements for some bridges
- AAR bearing failure test on NS bridge conducted in 1998

Objectives
- Quantify resistance of railroad bridges to dynamic loading

Findings
- NS Viaduct test results
  - Tests completed in Oct. 1998 on 5 identical 62-foot OD DPG spans
  - 3 lateral pushes and 2 longitudinal pushes
  - Results show significance resistance to earthquake ground motions

Approach and End Products
- Achieve significant improvements in wear and fatigue
  - Alloy specs for high-performance rail steels
- Improve structural integrity of thermite welds
  - Process development for EMS welds
- Improve in-track survivability of thermite welds
  - Guidelines for use of wide-gap welds
Track Components
Advanced Rail Steels

Objectives

To develop a high-hardness bainitic rail giving significant improvements in wear resistance over current premium rail

- NA railroads purchase about $250 million of rail each year
- About another $200 million is spent on installation
- Wear is a major cause of rail replacement

Findings

- Test J6 bainitic rail has higher hardness and toughness than premium rail
- The J6 rail has higher strength, which translates to better fatigue resistance
- Bainitic rails are readily joinable by flash welding
- J6 bainitic rail has marginally worse wear performance than current premium rail

Potential Increase in Advanced Rail Steel Life

<table>
<thead>
<tr>
<th>Decreasing rail grinding</th>
<th>Increasing rail wear</th>
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<tbody>
<tr>
<td>25 percent less grinding</td>
<td>+14 percent</td>
</tr>
<tr>
<td>50 percent less grinding</td>
<td>+45 percent</td>
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(based on profile measurements at ground test sites)

Bainitic Rail Service Performance:

- Small increase in wear
- Large increase in fatigue and deformation resistance
  - Reduced surface deterioration
  - Reduced need for grinding
  - Increased life in curved track

End Products

- Recommended guidelines for improved rail welding
  - Report on FAST trails of wide-gap welds
  - Specifications and recommendations for EMS thermite welding
- Survey report on thermite weld failure

Significant Findings

- Wide-gap welds showed similar properties to standard welds in lab tests.
- EMS is effective in refining the weld metal structure.
- Preliminary survey results indicate that the majority of weld defects are not related to their installation.

Thermal rails are the single most common cause of rail defects
- Repair of rail/weld defect is costly and time-consuming.
- The principal causes of thermite weld failures are yet to be identified.