Switch Point Inspection Gauges to prevent Wheel Climb Derailments

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Introduction

- Wheel climb derailments in switches remains a major derailment category for both freight and passenger rail operations in the US.
  - Switch Point related derailments are the major subset in this category
  - Most wheel climb derailments are a combination of a poor or degraded switch point and/or worn or degraded wheel profile.
- IDEA Project addressed the development, evaluation and field validation of a series of hand held measurement gauges to address the problem of wheel climb at switch points.
  - Examine international switch inspection practices that address wheel climb in the switch point area
- Specific focus was on switch point conditions not currently fully addressed by FRA, AREMA or railroad practices
  - Contribute to wheel climb derailments in switches.
Switch point derailments – how big a problem?

Industry switch point derailments* in 2013

- FRA-reportable: 68

Estimated reportable + non-reportable: >1000

* FRA cause codes T311, T314, T319
FRA Turnout Derailments (2013)
All Cause Codes

Derailment causes at turnouts in 2013

- Other: 18%
- Switch Point Gap: 13%
- Frog: 4%
- Switch Point: 39%
- Switch Adjust: 15%
- Switch Mechanism: 8%
- Stock Rail: 3%
§ 213.135 Switches
(h) Unusually chipped or worn switch points shall be repaired or replaced. Metal flow shall be removed to insure proper closure.

Subjective standard with no specific measurements or defined parameters.
IDEA PROJECT: Development and Validation of Inspection Gauges for Wheel Climb Safety at Switch Points

– Focus on Switch Point Inspection Techniques
  • European Practice
  • Adapt to North American (AREMA) conditions
  • Address different mechanisms
– TRB IDEAS program
– Phase I (S-23) examined current standards of switch point wear as they effect on wheel/rail interface
  • Develop set of four prototype gauges
– Phase II (S-28) performed a series of field validations leading to the finalization of gauge designs
Phase I Overview

• Phase I (IDEA S-23) addressed the development of a series of hand held measurement gauges to address the problem of wheel climb at switch points.
• These gauges were developed based on wheel/rail contact at switchpoint, European practice, US conditions and practices.
• These gauges were designed, fabricated and then field tested on three series of yard tests looking at switches in various conditions.
• The specific focus was on switch point conditions not currently fully addressed by FRA, AREMA or railroad practices but which have been shown to contribute to wheel climb derailments in switches.
Review of International Practices- Network Rail (UK) and SBB (Swiss)

Network Rail used a series of hand gauges that addressed the following switch related conditions:

- Improper flange contact between the wheel flange and the switch rail point
- Excessive or unusual wear of the switch rail (point) and of the stock rail
- Excessive switch rail damage
- Improper switch rail profile.

- SBB (Swiss railways) used a series of hand gauges that addressed the following switch related conditions
- Improper flange contact between the wheel flange and the switch rail point
- Excessive switch rail damage
- Excessive switch point gauge face wear
Switch Point Issues

- The study team identified four potential wheel climb mechanisms that are of particular concern to US railways. They included:
  - Chipped or damaged switch points.
  - Poor wheel/rail contact through the point for new or moderately worn wheel profile
  - Excessive gauge face wear of the switch point
  - Severely worn wheel-related climb.
- For each of these four mechanisms, a series of hand gauges designed specifically for North American conditions were developed, fabricated, and field-tested in yards of a major Class 1 railroad.
- Norfolk Southern Railroad Research and Test department fabricated the gauges used in these field tests.
Phase I Results

- Following a series of field tests, four gauges were found to be potentially to be useful, and eligible for follow up testing (Phase II)
  - Chipped Point Gauge:
    - This gauge addressed chipped or damaged switch points.
    - Modified version of NR Gauge 2, based on US wheel and switch designs.
  - AA1B Wheel Contact Gauge:
    - Gauge addresses improper wheel/rail contact at switch point
    - US version of the Network Rail TGP8 gauge, using an AAR 1B new wheel profile.
    - Switch point contact below the 60° mark appears to be an undesirable condition.
  - Severely Worn Wheel Profile Gauge:
    - This is the third generation severely worn profile gauge that gives an indication of the potential for wheel climb derailment for a severely worn wheel.
    - The 70° gauge version of the SP Gauge developed by the study team was judged to be most useful, to be used in the Phase II field evaluations.
  - Gage-face Wear Angle Gauge
    - Based on SBB gauge with a 32° gauge face angle:
    - Check on gage face angle and the potential for wheel climb, particularly for high L/V conditions.
Switch Point Inspection Gauges

1. Chipped point gauge
2. AAR 1B wheel contact gauge
3. Severely worn wheel profile gauge
4. Gage-face wear angle gauge

Four gauges mounted on two measurement bars
G1 - Chipped point gauge

If the bottom edge of gauge (edge A) is over the top of the switch point, Fail
Apply this gauge where the point is worn or broken. If contact with the switch point is...

- above the 60° mark, **Pass**
- below the 60° mark, **Fail**
Apply this gauge to the first inch of the point, where head-on contact with a worn flange is most likely. Start with the 70° slider on top of the stock rail, then slowly shift the slider until it slides off the stock rail.

- If the slider slides down the gage face of the switch point, **pass**
- If the corner of the slider lands on top of the switch point, **fail**

This gauge can be used to identify gapping points, broken points and points that are exposed due to a worn stock rail.
4. Gage-face wear angle gauge

If the switch point’s gage-face angle is…

- Less than $32^\circ$ ($>58^\circ$), **pass**
- Greater than $32^\circ$ ($<58^\circ$), **fail**

This gauge protects against a wheel climbing the gage face of the point.
Phase II: IDEA Project S-28 Field Implementation

- IDEA S-28 was the field implementation phase
  - Participating railroads include:
    - NS, Amtrak, LIRR, CN, BNSF, CP, TTCI and Gary Wolf (consultant)
  - One set of gauges provided to each railroad
  - Initial field assessment looked at 272 switches
  - Gauges modified based on comments
  - Second field assessment looked at additional 74 switches
Task 2: Field Evaluation

- A comprehensive initial field evaluation was conducted during the period from Oct 2015 to Feb 2016.
- Measurements were taken by four railways plus an independent consultant who looked at a total of 285 switch points of different design configurations and conditions using the four study gauges.
  - 13 measurements rejected because of inadequate data
  - 272 measurements analyzed in initial field assessment
- The tests were taken in more than 20 yards.

<table>
<thead>
<tr>
<th>RR A</th>
<th>RR B</th>
<th>RR C</th>
<th>Consultant D</th>
<th>RR E</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>45</td>
<td>135</td>
<td>41</td>
<td>42</td>
<td>285</td>
</tr>
</tbody>
</table>

Switches inspected
**Field Inspection Form**

### Field Validation of Switch Point Inspection Gauges: IDEA Safety - 28

1. **Inspector’s Name**
2. **Date**
3. **Railroad**

### Switch Point Information (one form per switch point)

4. **Yard Name/Location**
5. **OR**
6. **Mile Post/Track No.**
7. **Switch ID/Name**
8. **Rail size**
9. **Turnout size**
10. **Switch point length**
11. **Switch point side**
    - Straight
    - Diverging (Curved)
12. **Switch point type**
    - Samson/Undercut
    - Plain
13. **Turnout**
    - Left hand
    - Right hand
    - Equilateral
14. **Prevailing traffic**
    - Facing
    - Trailing
    - Balanced
15. **Is the turnout on or at end of curve?**
    - No
    - Yes; Degree
16. **Inspector Assessment of Switch Point Condition (prior to measurement with gauges)**
    - Good
    - Marginal
    - Poor
    - Failed

#### Gauge 1: Chipped point gauge

- **Pass**
- **Fail**
- **Can’t determine (reason)**

#### Gauge 2: AAR 1B wheel contact gauge

- **Pass**
- **Fail**
- **Can’t determine (reason)**

#### Gauge 3: Severely worn wheel profile gauge

- **Pass**
- **Fail**
- **Can’t determine (reason)**

#### Gauge 4: Gage-face wear angle gauge

- **Pass**
- **Fail**
- **Can’t determine (reason)**

### Comments

- Attached digital photo of switch point and send form and photos digitally to Dr. Allan Zarembski; <dramz@udel.edu>
## Summary: Correlation Analysis

### 1st Field Evaluation

<table>
<thead>
<tr>
<th>Case/Railroad</th>
<th>Number of inspections</th>
<th>% Agreement</th>
<th>% Disagreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>All inspections</td>
<td>272</td>
<td>58%</td>
<td>42%</td>
</tr>
<tr>
<td>RR C only</td>
<td>135</td>
<td>49%</td>
<td>51%</td>
</tr>
<tr>
<td>All others</td>
<td>137</td>
<td>66%</td>
<td>34%</td>
</tr>
<tr>
<td>4A: RR E</td>
<td>41</td>
<td>44%</td>
<td>56%</td>
</tr>
<tr>
<td>4B: RR B</td>
<td>45</td>
<td>84%</td>
<td>16%</td>
</tr>
<tr>
<td>4C: RR A</td>
<td>16</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>4D: Consultant D</td>
<td>35</td>
<td>77%</td>
<td>23%</td>
</tr>
</tbody>
</table>
Summary Correlation Analysis - Observations

- There is a wide range of agreement with the gauges, ranging from under 50% to almost 85%.
- This suggests several issues:
  - There is a range of inspection standards between railroads. For example, RR B is a passenger carrying railroad and as such is less tolerant of marginal switch point condition that can lead to a derailment.
  - There is a range of experience among the inspectors. For example, RR D is a very experienced derailment inspector with an extensive range of derailment investigation experience. As such, he may be more sensitive to identifying switches that are at or near derailment potential.
  - Different inspectors may be familiar with different types of derailments and switch conditions and not familiar with others. Preliminary analysis of the data suggests that some of the railroad inspectors may not be familiar with certain derailments categories for which specific gauges are intended, such as wheel climb (Gauge 2 or Gauge 3) and worn gauge face wear (Gauge 4). This is an area that requires more detailed investigation at the individual gauge level.
Summary: Gauge Analysis Observations

• Gauges 1 and 3 generated the greatest number of failures.
• Of particular interest is the fact that RR C had 60% of their failures with Gauge 1 (Chipped Point gauge) while all the others appeared to have the greatest number of failures with Gauge 3 (Severely worn wheel gauge).
• This would suggest a different method of inspection and replacement by the inspectors, based on railroad policy or practice, with a RR C perhaps having a lesser emphasis on broken points.
• The unfamiliarity with inspectors for the severely worn wheel condition would lead to a high percentage of “failures” for this gauge.
Decision Tree Analysis

• The next set of analyses performed on the data made use of a statistical decision tree analysis approach.
• Decision tree analysis is a “data mining” technique that has gained traction in the statistical data analysis field. It uses a “divide-and-conquer” approach to the problem of learning from a set of independent data events, which are in this case switch points inspections.
• The specific analysis approach used here made use of WEKA Data Mining Software] and specifically the J48 Algorithm.
• The J48 algorithm chooses one attribute of the data that most effectively splits its set of samples into subsets enriched in one class or the other. As a result, the J48 will choose a “sufficient” gauge in the top of the tree followed by gauges that are less “sufficient” further down the decision tree. The algorithm excludes gauges that are not based on the data and assumptions of each case.
Decision Tree (Case 1A all data)
## Comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chipped point gauge</td>
<td>Not relevant</td>
<td>Not relevant</td>
<td>Most sufficient</td>
<td>Not relevant</td>
</tr>
<tr>
<td>AAR 1B wheel contact gauge</td>
<td>Least sufficient</td>
<td>Not relevant</td>
<td>Not relevant</td>
<td>Most sufficient</td>
</tr>
<tr>
<td>Severely worn wheel profile gauge</td>
<td>Most sufficient</td>
<td>Less sufficient</td>
<td>Not relevant</td>
<td>Less sufficient</td>
</tr>
<tr>
<td>Gage-face wear angle gauge</td>
<td>Less sufficient</td>
<td>Most sufficient</td>
<td>Not relevant</td>
<td>Not relevant</td>
</tr>
</tbody>
</table>
Gauge specifications (final)

G1. Chipped point - paddle depth 0.75”, paddle angle 70°

G2. AAR 1B – uses the profile of a new AAR 1B wheel; hash mark at 60°

G3. Severely worn wheel profile - sliding gauge simulates 70° wheel flange angle

G4. Gage-face wear angle, 30°(60°)- (depth of paddle not important)
Second Field Assessment

- Modified gauges were fabricated and distributed to the participants in early September 2016.
  - Field evaluation was performed in September-October 2016
  - 74 switches were inspected
- The participating railways/consultants for Stage 2 field evaluation (Task 3) were as follows:
  - BNSF
  - CP
  - Long Island Rail Road
  - Norfolk Southern
  - TTCI
  - Gary Wolf
## Results of Second Set of Field Evaluations

<table>
<thead>
<tr>
<th>Case/Railroad</th>
<th>Number of inspections</th>
<th>% Agreement</th>
<th>% Disagreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>All inspections</td>
<td>74</td>
<td>82%</td>
<td>18%</td>
</tr>
<tr>
<td>RR E</td>
<td>19</td>
<td>74%</td>
<td>26%</td>
</tr>
<tr>
<td>RR B</td>
<td>19</td>
<td>95%</td>
<td>5%</td>
</tr>
<tr>
<td>RR A</td>
<td>10</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>RR F</td>
<td>7</td>
<td>43%</td>
<td>57%</td>
</tr>
<tr>
<td>Consultant D</td>
<td>15</td>
<td>93%</td>
<td>7%</td>
</tr>
<tr>
<td>Consultant G</td>
<td>4</td>
<td>75%</td>
<td>25%</td>
</tr>
</tbody>
</table>
RR Comments

- Comments from the railroad inspectors.
- RR F: “…. the use of these gauges have the potential to help reduce switch point derailments, and also help maintenance forces prioritize switch point replacement. The gauges provide a consistent means of evaluating switch points, and reduces the subjective opinion as to what constitutes a switch point in need of replacement. …”
- RR A: “With the everyday methods of inspecting a turnout combined with the concepts of the Switch Point Inspection Gauge (SWIG) a more detailed inspection is performed. The SPIG was a great tool for me in learning what to look for when inspecting a point. It increased my awareness on how the wheel actually interacted with the point. … This gauge caused to me to ask the proper questions during inspections, and helped my judgment with determining if a switch point is in correspondence.”
- RR G: “We have used the gages on a variety of switches, … We are impressed that the gauges seem “about right” as compared to our visual ratings.”
Probabilistic simulation analysis was performed using an analysis logic based on Monte Carlo Simulation.

<table>
<thead>
<tr>
<th>Gauge</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>86%</td>
<td>91.8%</td>
<td>83.2%</td>
<td>85.1%</td>
<td>83.2%</td>
</tr>
<tr>
<td>Min</td>
<td>83.9%</td>
<td>90.1%</td>
<td>80.8%</td>
<td>82.9%</td>
<td>80.8%</td>
</tr>
<tr>
<td>Chance of Success (Agreement)</td>
<td>85%</td>
<td>91%</td>
<td>82%</td>
<td>84%</td>
<td>82%</td>
</tr>
</tbody>
</table>

- Each of the gauges had “agreement” of no less than 82%
  - Some gauges having agreement as high as 92%.
- Overall agreement of 82% consistent with correlation results
- Supports validity of gauges in evaluating switch point condition.
All four switch point gauges have been assembled on one bar.

The two “gauge” ends (of the two original bars) are shown attached to each other, rotated 90°. The two “dummy” ends are no longer needed.
Summary

- Goal was to provide railroads with a set of practical and directly useable gauges for track inspectors to evaluate condition of switch points.

- A set of four inspection gauges were developed, each addressing a different failure mechanism and potential derailment condition.

- During the two sets of field assessments, approximately 350 switches on 7 railroads/consultant organizations were inspected and evaluated.
  - Evaluations included direct correlation between inspector and gauges, statistical analyses and decision tree analyses all looking at the effectiveness of the gauges in identifying switch points which are in a condition that can contribute to or result in a derailment.

- Results of two field inspections showed extremely good agreement, with overall ratings of 80+%; in line with the statistical analysis.
  - In several cases agreement was over 90% (and in one case 100%).
  - Particularly good agreement with experienced inspectors.
  - Other railroad inspectors may not be familiar with certain derailments categories for which specific gauges are intended.

- Feedback from the railroads and inspectors was very favorable.
  - Noted that gauges addressed several conditions which are often overlooked, such as excessive gauge face wear (Gauge 4).
  - In general made for a more detailed inspection of the switch point.
  - Gauges will help train inexperienced inspectors and refine their judgement in this area.

- New design allows all four gauges to fit on one bar.
Acknowledgements

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  – Jo Allen Gause, Charles Taylor, Harvey Berlin

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  ➢ Brad Kerchof (NS)- Chairman
  ➢ Bob Kollmar (AAR) Joe Smak (Amtrak), Tony Bahara (SEPTA), Yifeng Mao (LIRR), Steve Abramopoulos (LIRR)

• Ali Alsahli, graduate student, University of Delaware (Phase II), analysis of field validation data

• Samet Ozturn, graduate student, University of Delaware (Phase I), analysis of wheel/rail contact

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• Railroads/Consultants who participated in the field validation and provided invaluable feedback:
  ➢ BNSF, CN, CP, LIRR, NS, Gary Wolf & TTCI