ABSTRACT

A prototype continuous mainline rail turnout for low speed and low volume diverging traffic has been developed with the team of Burlington Northern Santa Fe Railway (BNSF) and Progress Rail Services. The prototype was evaluated under 39-ton axle load traffic at the Facility for Accelerated Service Testing (FAST). After this short test at FAST, the same turnout has been installed in revenue service.

The switch configuration differs from conventional design by having both fixed stock rails on the mainline route. Thus, the name “continuous mainline rail turnout” has been applied to this design. The moveable switch points are both on the diverging route. One switch point is located on the gage side of the left stock rail, while the other is located on the field side of the right stock rail.
This design is also called a “vertical switch” because it functions by lifting wheels over the mainline rails, instead of providing a gap in the mainline rail for wheel flanges to pass through. This switch is the functional counterpart of the lift frog design that has been successfully implemented by North American freight railways. This design strongly favors the mainline in terms of ride quality and allowable speeds. This type of switch has potential applications for set-out tracks and industrial sidings accessed from the mainline.

A series of tests were conducted at FAST to evaluate the prototype design. These tests consisted of mainline and diverging operations, track strength measurements, and running surface wear measurements. The paper reports the findings of these tests, including dynamic performance of heavy axle load trains, component wear, and recommendations for design improvements.

INTRODUCTION

Progress Rail Services, Burlington Northern Santa Fe Railway (BNSF), and Transportation Technology Center, Inc. (TTCI) have developed a prototype continuous mainline rail turnout for low speed and low volume diverging traffic. The prototype was evaluated under 39-ton axle load traffic at the Facility for Accelerated Service Testing (FAST). After a short test and some minor modifications, the same turnout has been installed in revenue service. The turnout is performing well, serving an aggregate shipper located near Clifton, TX.

The design of the switch configuration differs from conventional design by having both fixed stock rails on the mainline route, thus the name “continuous mainline rail turnout.” The moveable switch points are both on the diverging route. Figure 1 shows the continuous mainline switch configuration. Note that one switch point is located on the gage side of the left stock rail, whereas the other one is located on the field side of the right stock rail.
Because the new design functions by lifting wheels over the mainline rails, instead of providing a gap in the mainline rail for wheel flanges to pass through, it is also called a vertical switch. This switch is the functional counterpart of the lift frog design that has been successfully implemented by North American freight railways. This design strongly favors the mainline in terms of ride quality and allowable speeds. This type of switch has potential applications for set-out tracks and industrial sidings accessed from the mainline.

Conventional switches have one fixed stock rail and one moveable switch point on each route. The term “split switch” is applied to this design. Figure 2 shows a conventional split switch. Both routes have running surface discontinuities on one rail. Wheels transition from stock rail to switch point on one rail of each route.
The continuous mainline rail concept described here was developed to address the common failure modes of a split switch. These failure modes are related to the thin section switch point design used (1). During the project literature search, several vertical switch concepts were reviewed to develop the basis for the heavy axle load service concept presented here. A feasibility study was conducted, using vehicle/track dynamic modeling (1). Promising results from the simulations led to the development of a prototype by BNSF and Progress Rail Services.

**TESTS AT FAST**

The development team conducted a series of tests at FAST to evaluate the prototype design. These tests consisted of mainline and diverging operations, track strength measurements, and running surface wear measurements.

Operations consisted of 40 mph mainline trains of 315,000-pound cars. Approximately 20 million gross tons (MGT) was accumulated. Diverging operations consisted of spotting loaded and empty cars in the 350-foot set-out track. These operations were made at speeds ranging from 2 mph to 10 mph. Approximately 0.06 MGT (275 cars and locomotives) were operated over the switch.

The prototype performed very well in most aspects. The dynamic forces, measured using strain-gaged wheelsets, for mainline moves were quite low, similar to what is normally measured on open track. Maximum dynamic forces on diverging moves, as Table 1 shows, were similar to those seen in conventional turnouts. A comparison was made with a nearby split switch turnout. Even though the split switch turnout is larger (No. 20 vs. No. 11), the lateral forces were comparable. Remember, the prototype is intended for low volume, low speed diverging route moves. Maximum vertical loads are somewhat higher (about 15 percent) for the vertical switch because of the ramping in the switch, where wheels are raised above the stock rails (see Figure...
3). Also, the wheel climbs a step as it encounters the end of the switch point (which rests on the surface of the stock rail).

The measured diverging forces agree well with the modeled forces from the feasibility study.

**Table 1. Comparison of Measured Wheel/rail Forces for Diverging Moves in the Prototype and Conventional Switches**

<table>
<thead>
<tr>
<th>Test Route</th>
<th>Speed (mph)</th>
<th>Maximum Lateral Force (kips)</th>
<th>Maximum Vertical Force (kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype Facing Point, Diverging</td>
<td>2</td>
<td>15</td>
<td>56</td>
</tr>
<tr>
<td>Prototype Trailing Point, Diverging</td>
<td>5</td>
<td>20</td>
<td>58</td>
</tr>
<tr>
<td>No. 20 Split Switch Facing Point, Diverging</td>
<td>2</td>
<td>14</td>
<td>49</td>
</tr>
<tr>
<td>No. 20 Split Switch Trailing Point, Diverging</td>
<td>5</td>
<td>20</td>
<td>50</td>
</tr>
</tbody>
</table>

**Figure 3. Vertical Ramping in Prototype Switch Points**

Table 2 lists the measured maximum dynamic loads for mainline moves through the two turnouts. The data here is split between the switch and the frog on each turnout. Note that in each location, the continuous rail turnout produced lower maximum lateral forces. There were similar drops in average lateral forces, as well. The changes in running surface in the conventional switch and frog generate lateral forces above those seen in open track. Maximum vertical forces at higher speeds should be similar to open track with continuous welded rail. Previous tests of a lift frog at FAST showed 95-percent vertical forces of 47 and 76 kips for lift and railbound manganese frogs (RBM), respectively, at 40 mph (2).
Track strength tests were conducted on the diverging route of the prototype turnout. In conventional split switches, the switch points are supported laterally by the stock rails and the field side braces. In most cases, this provides a track that resists gage widening. In the prototype, one switch point is on the field side of the stock rail. Thus, switch rods are required to hold gage and provide rotation resistance for the switch point.

Gage strength tests were conducted using the TTCI’s Track Loading Vehicle (TLV). The TLV was operated at walking speed through the switch with vertical and lateral loads of 33 and 18 kips applied using a single split axle wheelset. These test runs, intended to simulate a damaged or poorly steering truck, revealed a weakness in the prototype between the last switch rod and the fixed heel joint. This location, in the middle of an 8-tie span of laterally unsupported switch point length was too flexible for the loading applied. In conventional split switches, this laterally weak switch point would be a fixed position stock rail. Figure 4 shows the location from a longitudinal and a profile view of the switch. The proposed remedy is to add an additional switch rod in the middle of the span.

Wear of the stock rails and switch points was also measured. The switch points, with their nonconformal shapes and short vertical ramps, wore at a much higher rate (per MGT) than the stock rails. Table 3 shows wear rates for each of the four running rails in the prototype.
switch. The switch point wear rates are 2 to 3 orders of magnitude higher. Note, however, that the initial wear in the first measurement interval of 0.22 MGT was about 50 and 90 percent of the total wear of the gage- and field-side points, respectively. The wear rate is expected to continue decreasing as the points reach shapes that are conformal to wheels. Also note that the stock rail wear rates are similar to tangent track rail wear rates. Thus, if the wear life of the stock rails is expected to be 2,000 to 4,000 MGT, the wear life of the switch points will be at least 20 to 40 MGT. At the revenue service test site, the projected wear lives of the mainline stock rails will be 30 to 60 years and the projected wear lives of the switch points will be 30 to 100 years at the current wear and traffic rates. Figures 5 and 6 show the switch point wear versus location for three accumulated tonnages.

Table 3. Comparison of Wear on Vertical Switch Points and Stock Rails

<table>
<thead>
<tr>
<th>Component</th>
<th>Average Wear Rate (sq in/MGT)</th>
<th>Maximum Wear Rate (sq in/MGT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gage Side Switch Point</td>
<td>0.333</td>
<td>2.275</td>
</tr>
<tr>
<td>Matching Stock Rail</td>
<td>0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Field Side Switch Point</td>
<td>1.123</td>
<td>2.177</td>
</tr>
<tr>
<td>Matching Stock Rail</td>
<td>0.002</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Figure 5. Gage Side Switch Point Wear vs. Distance
Note the similarities and differences in wear of the two switch points. In both cases, the locations of highest wear rate are at the point ends. This is where the wheel impacts the end of the point as it rolls in a facing point move. Somewhat higher wear is also noted at the top of the point ramps. The effect of running surface profile may explain the higher wear rate (reported as cross section area loss) on the field-side point. Both points started with the same rectangular shape. The running surface available to the wheel on the field-side point is much smaller and perhaps less conformal, as well. In addition, the field-side point is a composite structure consisting of three pieces. Shifting of the pieces relative to each other may cause some of the reported wear for this switch point. Since the profiles are aligned using the non-wearing surface of the point guard, any relative movement of the tread bearing portion will be interpreted as wear.

**REVENUE SERVICE PERFORMANCE**

The prototype turnout was modified by Progress Rail and BNSF to address the issues found during the tests at FAST. It was then installed in revenue service on BNSF near Clifton, TX, in March 2013. The Fort Worth subdivision carries about 65 MGT annually. The turnout serves an aggregate shipper that loads about 30 cars per week. Mainline speeds are 75 mph for passenger trains and 55 mph for freight. Figures 7 and 8 show the turnout on BNSF.
The design team engineers have been monitoring the performance of the turnout in service. In general, it has performed well. Local switching crews have learned its operating characteristics and are satisfied with its performance on diverging moves. The mainline
Operating performance has been very good, with favorable comments from operating and track maintenance personnel.

Running surface profiles of the switch points and stock rails were measured in May 2013 to determine the wear performance of these components in revenue service. A total of 32 running surface cross section profiles were taken at the same locations as previous measurements done during testing at TTC. Thus, the initial wear rates in revenue service were calculated and compared to wear rates under 315,000-pound car traffic at FAST. The results show some changes in wear rate and worn shapes from revenue service traffic. The wear rate has decreased under 286,000-pound cars as compared to 315,000-pound car traffic at FAST. Figure 9 shows a series of switch point profiles taken at 12 inches from the point of switch on the gage-side point. The profiles show the switch point running surface when new, after approximately 0.02, 0.04, and 0.06 MGT (275 cars weighing 315,000 pounds) and after another 0.04 MGT (240 cars weighing 286,000 pounds loaded and 60,000 pounds empty). From Figure 9, one can also see that the switch point continues to deform to become more conformal in shape to the wheels running over it. There is metal loss above the gage corner with metal flow down the vertical face of the point near the gage corner. There is also some metal flow on the laterally unsupported field edge of the point.

![Figure 9. Time Series of Gage Side Switch Point Profiles (12 inches from point of switch)](image)
CONCLUSIONS

The continuous mainline rail turnout has undergone testing at FAST. The prototype has performed successfully in low speed diverging operations with loaded and empty 315,000-pound capacity cars. In mainline operations, train dynamic performance is significantly better than with conventional split switch turnouts.

From the initial operations, the project team will be making several design improvements, including:

- Lateral stiffening of the field-side point to prevent gage widening. Reconfiguration of the switch heels to reduce switch throw effort. For the prototype, cutting the switch rails at the heel made them much easier to throw for the diverging route. For future turnouts, adding switch point rollers may be sufficient to reduce the required throw effort.
- Reconfiguration of the point guard to enhance safety and simplify construction. Moving the guard, currently located on the field-side point, to the gage-side point will allow the guard to contact more of the wheel surface. It will also eliminate the wheel/rail contact issues inherent with field-side point guards.
- Use of more conformal running profiles on the points. An initial shape closer to a rail will reduce the high initial wear rates.

The continuous mainline rail turnout was modified to incorporate some of the suggested improvements before revenue service installation on BNSF in 2013.

Acknowledgements

John Bosshart, former Director of Track Standards – BNSF Railway and Russ Hein, Technical Director – Progress Rail Services were instrumental in developing the continuous mainline rail turnout concept into a working prototype. TTCI employees Joseph LoPresti, and Xinggao Shu contributed to this article.

REFERENCES

Design and Performance Evaluation of a Continuous Mainline Rail Turnout

David D. Davis
Senior Scientist
Transportation Technology Center, Inc.
**Continuous Mainline Rail Switch**

- 2012 BNSF Prototype built by Progress Rail Services
- Conventional Split Switch (1 point and 1 stock rail on each route)

**AAR Special Trackwork Research**

- Proof of Concept: Dynamic Simulation
- Feasibility study complete
- Vehicle-track modeling suggests:
  - Diverging route vertical loads are 20% higher at switch
  - Mainline route vertical loads should be lower
  - Lateral loads are <2 kips at point of switch
AAR Special Trackwork Research

Proof of Concept: vertical switch designs
- Stock rail in test at FAST
- Stock rail with a field side cut proved durable under 315K
- Running surface profile developed flow

AAR Special Trackwork Research

Progress Rail Services vertical switch point design proof-of-concept test at FAST
- Point is over stock rail
- Track gage is proper for each route
- Switch point tips sufficiently durable for application

Continuous Mainline Rail Switch

- Purpose of Continuous Mainline Rail Turnout

Continuous Mainline Rail Switch

- Continuous Mainline Rail Turnout - Facing Point Diverging Move

Continuous Mainline Rail Switch

- TLV test, Facing Point Diverging (Right Rail)

Continuous Mainline Rail Switch

- Train Operations, Facing Point Diverging
Continuous Mainline Rail Switch

FAST Proof Test Results

- Mainline route:
  - Lateral forces: significant reductions at switch and frog
  - Vertical forces: reduction at frog
- Diverging route:
  - Lateral forces: similar to conventional turnouts
  - Vertical forces: somewhat higher at switch due to ramp

<table>
<thead>
<tr>
<th>Route</th>
<th>Speed (mph)</th>
<th>Maximum Lateral Force (kips)</th>
<th>Maximum Vertical Force (kips)</th>
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<tr>
<td>Vertical Switch</td>
<td>- 5</td>
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<td>#20 Split Switch</td>
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<tr>
<td>Trailing, Main</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Key findings:
- Track strength testing at FAST revealed a weak spot
- Low gage widening strength between last rod and fixed heel - No lateral support of rail for 7 ties

Continuous Mainline Rail Switch

- Improvements from FAST Proof Test
  - RELOCATE GUARD (TO GAGE SIDE POINT)
  - RECONFIGURE POINTS
  - IMPROVE HEEL FLEXIBILITY
  - STRENGTHEN LATERAL SUPPORT
  - REMOVE TRIP HAZARD

Component Average Wear Rate (sq in/MGT) Maximum Wear Rate (sq in/MGT)

- Gage Side Switch Point: 0.333 2.275
- Matching Stock Rail: 0.001 0.002
- Field Side Switch Point: 1.123 2.177
- Matching Stock Rail: 0.002 0.003

Switch Points show Higher Wear Rates than Stock Rails
- End discontinuities
- Ramps
- Non-conformal profiles
- Should provide service lives of years for intended use

Time Series of Cross Section Profiles Showing Wear on Gage Side Point (12 inches from p.o.s.)
Continuous Mainline Rail Switch

♦ Train Operations, Trailing Point Main - BNSF

Summary:
♦ Concept is technically feasible
♦ Prototype built and tested under 315,000 lb. traffic
  - Performance measured was slightly better than modelling predicted
  - Turnout was modified for revenue service
♦ Installed in Revenue Service in April 2013
  - Successful operation to date
  - Performance is being measured

Acknowledgements:
♦ Co-authors:
  ♦ Rafael Jimenez, Senior Engineer, TTCI
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  ♦ Beatrice Rael, Data Analyst, TTCI
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  ♦ Progress Rail Services - Russ Hein, Director Engineering