Abstract

Switch point fatigue is a limiting factor of the service life of turnouts. Switch point breakage (chipping), rolling contact fatigue, and metal flow are common degradation modes seen in heavy axle load service. Under Association of American Railroads’ research funding, Transportation Technology Center, Inc. designed a new running surface profile for mainline switch points. The new design is intended to reduce wheel/rail contact stresses and to locate wheel contact toward the rail top over the length of the switch point transfer zone. Working with Union Pacific Railroad, BNSF Railway Company, and switch suppliers, the switch points with the new designed profile and with the current standard profile have been tested in revenue service since December 2010. The test results up to early 2012 indicated that the new designed switch point profile prototypes, when correctly shaped, have produced better wear patterns, lower wear rate, and less rail surface damage. In addition, the prototypes have required less grinding for plastic flow and RCF maintenance.
INTRODUCTION

As rail has increased in hardness, rolling contact fatigue (RCF) has been more commonly observed on the running surface of switch points. Figure 1 shows an example of defects found on switch points that occurred after less than 100 million gross tons (MGT) of traffic. RCF is rapidly becoming a major cause for switch point replacement on heavy haul lines.

Transportation Technology Center, Inc. (TTCI) conducted an investigation to determine the causes of RCF on switch points under the Association of American Railroads’ Strategic Research Initiatives Program to develop strategies to mitigate RCF at switch points (1). Switches are expensive elements in the railway infrastructure. Extending their service lives can reduce operation and maintenance costs.

With support from Union Pacific Railroad (UP) and BNSF Railway Company (BNSF), TTCI inspected switch points on three heavy haul service routes. Several sets of No. 20 switch point profiles were measured during the inspections using the Miniprof™ (a portable electronic profile measurement device), and many photographs were taken. Also, TTCI visited the machining shops of two switch suppliers and took profile measurements of switch points.

The investigation focused on the No. 20 curved point switches (AREMA style (2)) that are commonly used on the main lines of heavy haul service routes.

Figure 1. Surface Defects on the Switch Rail of a No. 20 Switch, Straight Route, 13.5 feet from the Switch Point

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FIELD OBSERVATIONS

The switch point can be divided into three sections based on different wheel/rail contact features, as Figure 2 shows: (1) the entry zone where the stock rail and gage side of the switch point carry the load, (2) the load-carrying zone where the switch point carries the load, and (3) the full railhead zone where the switch rail is back to full section.

Figure 2. No. 20 Switch Point Layout with a Top Cut Distance of 20 feet

Observations from the inspection sites indicate the following:

- Severe RCF usually started about 9 to 10 feet from the switch point tip and reduced in severity after 21 feet. In this zone, the switch rail carries most of vertical load and the contact regions move from occurring primarily on the top of the stock and switch rail gage side to the top of the switch rail or to the gage corner of the switch rail.

- The surface condition in the full railhead zone was considerably better than that in the load-carrying zone (Figures 3 and 4).

- The stock rails showed fewer surface defects than the matching switch point (Figure 5).
In general, the switch point surface conditions for the straight and diverging routes were worse than conditions on open tangent track or in 1.5-degree curves.

Figure 3. Rail Surface Conditions versus Distance from the Switch Point Tip (Straight Route)

Figure 4. Rail Surface Conditions versus Distance from the Switch Point Tip (Diverging Route)

Figure 5. Surface Condition of the Switch Rail and the Matching Stock Rail at the Same Distance from the Switch Point Tip
CONTACT AND WEAR PATTERN ANALYSIS

Figure 6 shows the typical contact pattern of a common worn wheel contacting a new switch point profile of the current design. Very high contact stress and shear stress can be induced at the switch point gage corner due to the small contact area. This condition can only be improved when the sharp corner is worn into the shape shown in Figure 7.

Figure 6. Contact Pattern of a Worn Wheel in Contact with the Current Switch Point Design

Figure 7. Contact Pattern of a Worn Wheel in Contact with a Worn Switch Point

Figure 8, which compares a typical worn switch rail profile with a new switch rail shape for the current design, shows the concentrated wear that occurs at the switch rail gage corner.
Field observations and the results from contact and wear pattern analysis indicate that the current design of the switch point profile may contribute considerably to the formation and development of RCF on the switch point running surface. The surface defects shown in Figures 1, 3, 4, and 5 are likely the accumulated result of wheel/rail interaction forces since the switch point was new.

NEW SWITCH POINT RAIL PROFILE DESIGN

Traditionally, switch points were made by planing a full section rail. Thus, the designs involved simple straight side and top cuts. A 5/8-inch radius arc connected the top and side cuts. This design resulted in the typical wheel/rail contact pattern shown in Figure 6. While this design was acceptable in the past when softer rail steels would quickly deform or wear into conformal shapes with passing wheels, with today’s head hardened rails, nonconformal switch points are prone to develop RCF before they deform or wear into conformal shapes with passing wheels.

Also, with modern machining capabilities, special trackwork suppliers are now capable of producing switch points with more complicated shapes.
TTCI has designed two new switch point profiles for No. 20 switches to improve wheel/rail contact conditions on the switch point running surface. The objectives of the new designs include:

- Extending the service life of a switch point by reducing or delaying the initiation of RCF
- Reducing contact stress and shear stress by producing a larger wheel/rail contact area
- Improving wear life by avoiding concentrated wear
- Reducing variations in contact conditions by smoothly blending the switch point section into the full railhead section
- Ensuring no negative performance issues result compared to the current switch point design

Figure 9 shows the switch point profile Design 1 that contains three tangential arcs with a straight gage side cut of 78 degrees. Figure 10 shows a comparison of the current design and the new Design 1. The new Design 1 switch point profile provides a large wheel/rail contact area to carry the vertical load and tangential force and will more quickly wear into the conformal shape shown in Figure 7.

![Figure 9. New Switch Point Profile Design 1](image)
To simplify the machining process and use an existing cutting tool, an alternative switch point profile design (Design 2) has been developed. This switch point profile has a 1-inch radius at the switch point gage corner. It maintains the 78-degree gage side cut and has a flat top (or 1:20 slope) cut that is tangential to the 1-inch radius arc, as Figure 11 shows.

Design 2 maintains the desired contact features (Figure 12) produced using Design 1. Because the 1-inch radius arc is not tangential to the 78-degree line, it creates a small kink at the intersection point of the two segments that must be smoothed during production. This switch point should quickly wear into a conformal shape with the commonly worn wheel profile shape.
CONTACT STRESS ANALYSIS

The new switch point profile designs were analyzed for contact stresses using typical worn wheel profiles. Figure 13 shows the contact stress distribution for 180 measured worn wheel profiles contacting the current and the new Design 1 switch point profiles. The analysis suggests that the maximum contact stresses produced by the new Design 1 may be 30 to 40 percent lower than those produced using the current design. Also, the analysis suggests that the contact positions are spread over a wider range for the new Design 1 compared to the current design, which concentrates contact in a narrow range. These improvements in contact stress and contact patterns should result in a lower rate of wear and a lower risk of RCF.
SWITCH POINT TOP CUT MODIFICATIONS

As Figure 10 shows, to increase the size of the wheel/rail contact area, the switch point top of the new design is slightly higher than the current design in the load-carrying zone from 9 to 19 feet from the switch point tip. The top cut slopes for the first and second cuts, and the length of the second cut have been adjusted to keep the switch point tip elevation the same as in the current design.

PROTOTYPE TESTS

Prototype switch points involved in revenue service testing on BNSF and UP lines were built by two separate switch suppliers.

The BNSF test consists of a No. 20 crossover at East Marceline, Missouri. One turnout has prototype switch points, while the other has AREMA style profile switch points. Figure 14 shows the Marceline test site.

Traffic at Marceline consists of intermodal, mixed freight, unit grain, and passenger trains. Traffic levels are approximately 60 MGT/yr on each track.

The UP test consists of four No. 20 turnouts at Bonner Springs, Kansas, and Linn, Kansas. These are installed in three crossovers. One crossover, at Linn, has two turnouts: one with
prototype and one with AREMA style profile switch points. A second turnout with prototype switch points is installed near Bonner Springs. The second turnout with AREMA style profile points is installed at the control point west of Linn. All four turnouts are within a 10-mile segment of line that carries considerable heavy axle load traffic. Figure 15 shows the turnout at Bonner Springs. Traffic at Bonner Springs consists of unit coal, intermodal, unit grain, and mixed freight trains. Traffic levels are approximately 80 MGT/yr per track.

![Figure 15. No. 20 Turnout with Prototype Switch Points on UP at Bonner Springs](image)

**Actually Tested Prototype Switch Point Profiles**

The tested switch points were manufactured by two switch suppliers. The concept drawing as shown in Figure 11 was interpreted differently by each supplier. Thus, the prototype points were made with somewhat different shapes.

Figure 16 compares the manufactured switch point profiles with the recommended shape (Figure 11). The prototype switch points (Prototype 1, Figure 16a) at Marceline, were produced simply using a cutter with 1-inch radius to tangentially connect the two straight sections at the rail top and the gage side respectively. Compared to the intended profile, too much metal was removed at the rail gage corner resulting in strong two-point contact. The prototype switch point profile (Prototype 2, Figure 16b) installed at Bonner Springs, although not in complete agreement with the
recommended shape, was reasonably close to the intended profile. The performance results for these two prototype switch profiles show some differences.

![Graph showing comparison of manufactured prototype switch point profiles to the recommended simplified design.](image)

**Figure 16. Comparison of Manufactured Prototype Switch Point Profiles to the Recommended Simplified Design**

**Performance Measurements**

The performance of the switch points is being quantified by measuring the running surface cross section at various locations over time. The profiles are overlaid to determine the amount of wear and metal flow. Profiles are taken from a few feet in front of the point of switch to the location where the switch point is a full railhead section again. Figure 15 shows a running surface profile being taken. Thirty profiles of each switch point were taken.

Additionally, qualitative assessments of surface conditions by visual inspection and records of running surface maintenance grinding are being used to determine the effect of the profiles on RCF occurrence.

The railways involved in the test have provided tonnage estimates for each track and route through the turnouts on these multitrack lines. The rail grindings to remove plastic flow at the gage corner and running surface fatigue defects have been conducted by the local track maintenance personnel on the test switch points. The metal removal amount resulting from rail grinding was not
always measured, because of logistical issues. This paper discusses the performance trends of the standard switch point and the two types of prototype switch profiles described in Figure 16.

Trends of Performance Results

Standard Switch Points

The standard switch points from two switch suppliers at the two test sites produced similar wear patterns as in the previous survey (Figure 8).

Figure 17 shows the switch point profiles at the two test sites, measured at 14 feet from the point of switch after about 7 months and after 18 months since the switch points were installed, overlaid with the new profile. Following are two main observations:

- The high rate wear occurred in the first 7 months
- The wear was concentrated at the rail gage corner

![Graph showing standard switch point wear patterns over time](image)

(a) Marceline, Standard, Straight (left), Diverging (right)

(b) Bonner Springs, Standard Main 1- mostly empty trains, Straight (left), Diverging (right)

Figure 17. Standard Switch Point Wear Pattern
Figure 18 is a photo of the standard switch point taken 7 months after the installation at Marceline, which shows the surface damage at the rail gage corner. Rail grinding (using a hand grinder) was conducted a few days before for the purpose of removing the plastic flow at the gage corner.

![Image of standard switch point](image)

**Figure 18. Standard, Straight, about 14 feet (measurement position 22) from the Point of Switch, Grinding had been Conducted to Remove the Gage Flow – April 2011**

*Prototype Switch Points*

Figure 19 shows the wear patterns for two variations of the prototype switch point profile at a similar distance from the switch point as that shown in Figure 17 and during the same time.

Compared to the standard switch point profile, performance results from the prototype profiles show the following features:

- Both versions of the prototype profile did not show the concentrated wear at the rail gage corner as seen on the standard profile. The wear was mainly spread at the rail top, indicating a larger wheel/rail contact area.

- The wear at this location during the same service period was lower than that on the standard profile.
Figure 20 is a photo of the prototype switch point taken at 7 months after the installation at Marceline. Compared to Figure 18, the rail surface condition was much better and the contact band was located on the top of the rail, which agreed with the measured profiles.

(a) Marceline, Prototype 1, Straight (left), Diverging (right)

(b) Bonner Springs, Prototype 2, Main 2 – mostly loaded trains, Straight (left), Diverging (right)

Figure 19. Prototypes (a) BNSF—Straight, Diverging (b) UP—Straight, Diverging — April 2011

Figure 20. Prototype, Straight, about 15 feet (measurement position 23) from the Point of the Switch – April 2011

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From the measured profiles, it has been noticed that Prototype 1 tends to have more gage face wear in the switch entry section and in the beginning of load carrying section, especially for the diverging route. Figure 21 shows an example. This wear pattern is likely due to the orientation of the 1-inch radius cut at the rail gage illustrated in Figure 16(a), which caused a small contact area at the gage face and a strong two-point wheel/rail contact condition that has a negative effect on curving. This gage face wear pattern did not occur on the Prototype 2 switch point, because the gage corner was oriented to be more conformal to wheel flange root – tread profiles. This recommended shape provides a larger wheel/rail gage face contact area.

![Figure 21. Prototype 1, Diverging, 8 feet from the Point of Switch](image)

**CONCLUSION**

The current switch point rail profile design tends to experience a high rate of wear and severe RCF due to high contact stress and concentrated contact at the rail gage corner.

The new design switch point rail profiles described in this paper can improve wheel/rail interface conditions by producing larger contact areas with new and worn wheel profile shapes, which lead to lower contact stresses.
The track tests conducted on revenue service lines again confirmed the previous observations on the current standard switch point profile, showing it produces concentrated wear and causes surface damage in the early stages of service life.

The track test also indicated that the contact positions for both prototypes of switch point profiles moved away from the rail gage corner. An indication of the robustness of the design was inadvertently obtained when two variants of the design profile were made. While both provided significant improvement over the currently used profile, the prototype that was closer to the recommended shape produced better wear patterns, lower wear rates, and less rail surface damage.

Therefore, the new designed switch point profiles are expected to increase switch point life by reducing wear and delaying the initiation of RCF.

WAY FORWARD

The prototype switch points have provided benefits in terms of decreased wear and running surface maintenance in two heavy haul revenue service tests. Further monitoring of the prototypes will establish the life-cycle cost improvements likely to be derived. With no adverse effects noted in the prototype tests, a wider scale implementation is warranted. Additional effort is needed to perfect the manufacturing processes for the simplified point design. Also, a determination of the likely payback from using the more complex 3-arc profile will be made.

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SWITCH POINT PROFILE DESIGN
AND REVENUE SERVICE
PROTOTYPE EVALUATION

David Davis and Huimin Wu
Transportation Technology Center, Inc.

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NEW SWITCH POINT PROFILE DESIGN AND TESTING

Findings
- Point profiles play significant role in formation of rolling contact fatigue (RCF)
- Point wear concentrated at the gage corner
- Severe RCF defects generally first formed within the top cut section at gage corner
- Switch points show greater RCF than the matching stock rails

Entry angle = 0.46 degree
Top cut = 20 feet
Entry section
Load carrying section
Full railhead section

AREMA No. 20 Switch

13.5 feet from switch point
Less than 100 MGT

Measured worn less than 100 MGT

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New Switch Point Profile Design and Testing

• Tests
  – Two switch point profiles redesigned to improve contact conditions with anticipated reduced
    • Surface damage
    • Wear
    • Plastic flow at rail gage
  – TTCI, railroads, & one supplier to build & test prototype switch point rail profile designs
    • Prototype & base to be located on same line to assure similar traffic environments for comparison
    • Currently BNSF and UP are planning tests

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New Switch Point Profile Design

- Prototypes built to 1” radius design
- Prototype 1 smoothed to gage line
- Prototype 2 closely matched the design
New Switch Point Profile Design

Switch Point Running Surface Profile

• Prototype Tests
  – BNSF — Marceline, MO
  – UPRR — Kansas Sub

First prototype for BNSF at Progress Rail
Prototype Switch Points in Revenue Service

Union Pacific – Bonner Springs, KS
• #20 RH Turnout with prototype points
• Installed November - December 2010
  – Traffic types: coal, intermodal, mixed freight
  – Traffic rates: ~190 MGT/yr on two tracks
• 2 prototypes, 2 standard turnouts

BNSF - Marceline, MO
• #24 LH Turnout with prototype points
• #24 LH Turnout with standard points
• Installed October 2010
  – Traffic types: Intermodal, mixed freight, coal
  – Traffic rates: ~130 MGT/yr on two tracks
Prototype Switch Points in Revenue Service

BNSF – Marceline, MO

Union Pacific – Bonner Springs, KS
New Switch Point Profile Design and Testing

Initial Findings (first year in service)

- Simplified profile working as intended
  - Contact higher on point rail
  - Wider contact band
  - Metal flow noted (profiles are not conformal)
- Prototypes have 50 to 70% less wear
  - Less RCF forming
    - Prototypes closer to design performing better
    - Prototype 1 has two point contact with wheels
Comparison of New and Worn Switch Point Rail Profiles
BNSF at Marceline, MO
Straight, @ 13 ft from p.o.s.

Standard measured on 09/09/2010
Prototype measured on 04/05/2011

Prototype, new measured on 09/09/2010
Standard, measured on 04/05/2011

Wear (inch^2)

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Comparison of New and Worn Switch Point Rail Profile
UP, Bonner Springs, KS
Straight points @ 13 feet from p.o.s.

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<th>Wear (inch^2)</th>
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<td>Standard</td>
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MP20.6 measured on 04/05/2011
MP28.19 measured at Nortrak
141lb rail

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Key Findings: Initial performance of Prototype Switch Point Profiles looks promising.

- Standard Straight Point
- Prototype Straight Point

- Contact on gage corner
- Contact centered

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Current Findings (two years in service)

• Simplified profile working as intended
  – Contact higher (more centered) on point rails
  – Wider contact band

• Prototypes have 50 to 70% less wear
  – Wear rates becoming similar as profiles wear to conformal
  – Less RCF forming
    • Prototypes closer to design performing better
    • Prototypes require less grinding
Both points carrying roughly the same traffic.
Running Surface Appearance Standard and Prototype Switch Points at Marceline, MO
Straight, @ 14 and 15 ft from p.o.s.

Standard point – RCF present

Prototype point – no RCF
Running Surface Appearance Standard and Prototype Switch Points at Marceline, MO
Diverging points @ 14 ft from p.o.s.

- Same diverging traffic – turnouts in a cross-over
Running Surface Appearance Standard and Prototype
Switch Points at Bonner Springs, KS
Straight points @ 14 ft from p.o.s.

- Prototype point carries ~4x more traffic
Running Surface Appearance Standard and Prototype Switch Points at Bonner Springs, KS
Diverging points @ 14 ft from p.o.s.

- Same diverging traffic – turnouts in a cross-over

Standard point

Prototype point
Conclusions

- Simplified profile working as intended
  - Care should be taken to orient 1 inch radius to match canted rail
  - Significant reduction in wear (>50%)
  - Less RCF forming
    - Prototypes closer to design performing better
- Study whether 3 radius design is feasible
New Switch Point Profile Design and Testing

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