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# New Rail Profile Designs for Switch Points

Huimin Wu, Benjamin Madrill, and David D. Davis

## Summary

Transportation Technology Center, Inc. (TTCI) has designed two new switch point rail profiles for American Railway Engineering and Maintenance-of-Way Association (AREMA) No. 20 style switches. The new profile designs were developed to improve wheel/rail contact conditions by reducing contact stress in both normal and tangential directions. The new profile designs are expected to increase the switch point life by reducing wear and delaying the initiation of rolling contact fatigue (RCF).

TTCI conducted an investigation to determine the causes of severe RCF observed on AREMA No. 20 switches. The investigation indicated that:

- Severe RCF usually initiates in the load-carrying section of the switch point about 9 to 20 feet from the switch point tip. The rail carries most of the vertical load in this area of the switch point.
- The stock rails show fewer surface defects than the matching switch points.
- In general, the switch point surface conditions for straight and diverging routes were worse than conditions on open tangent track or in 1.5-degree curves.

Observations and wheel/rail contact pattern analysis indicate that the existing switch point profile may contribute considerably to the formation and development of RCF on the switch rail surface. The severe RCF observed on the running surface is likely the accumulated results of wheel/rail interaction forces since the switch point rail was new.

Two new rail profile designs for the No. 20 switch point have been produced. Design 1 consists of three tangential arcs and Design 2 utilizes a 1-inch radius arc at the rail gage corner. Design 2 will be tested first, because it can be produced using existing cutting tools and is easier to machine than Design 1.

TTCI is working with railways and suppliers to build and test these prototype switch points.



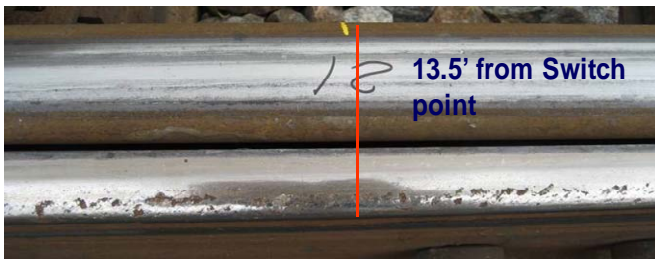
**INTRODUCTION**

RCF has been 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.

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. Switches are expensive elements in the railway infrastructure. Extending their service lives can reduce operation and maintenance costs.

With support from railroads, 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™ device, and many photographs were taken. Also, TTCI visited the machining shops of two switch suppliers and took profile measurements of new switch points.

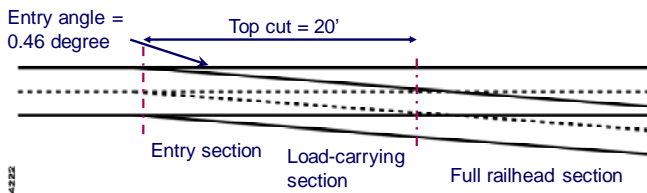
The investigation focused on the No. 20 curved point switches (AREMA style<sup>1</sup>) that are commonly used on the main lines of heavy haul service routes.



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

**OBSERVATIONS**

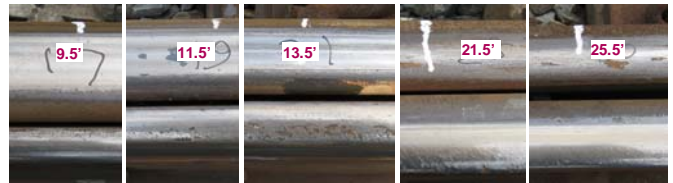
The switch point can be divided into three sections based on different wheel/rail contact features, as Figure 2 shows: (1) the entry zone where the stock rail and gage side of the switch point carry the load, (2) the load-carrying zone where the switch point carries the load, and (3) the full railhead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

- 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)**



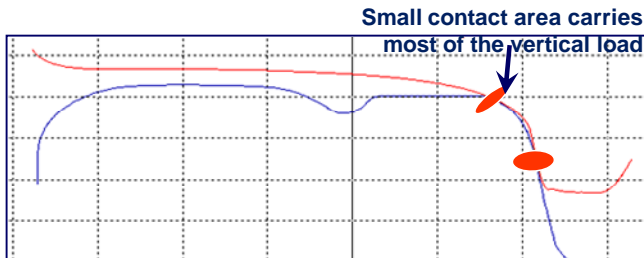
**Figure 4. Rail Surface Conditions versus Distance from the Switch Point Tip (Diverging Route)**



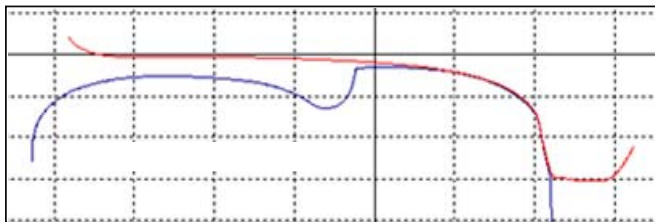
**Figure 5. Surface Condition of the Switch Rail and the Matching Stock Rail at the Same Distance from the Switch Point Tip**

**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.

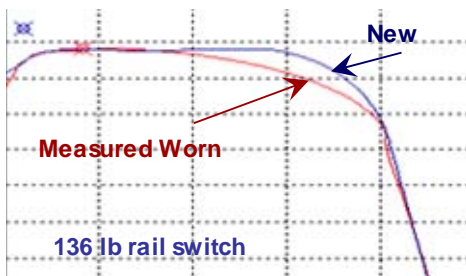


**Figure 6. Contact Pattern of a Worn Wheel in Contact with the Current Switch Point Design**



**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.



**Figure 8. Comparison of the Current Switch Point Design and the Worn Switch Point after less than 100 MGT of Service**

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.

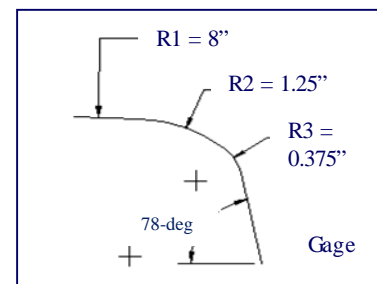
Also, with modern machining capabilities, special trackwork suppliers are now capable of producing switch points with more complicated shapes.

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:

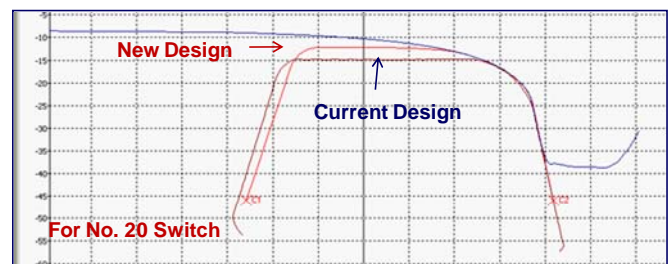
- Extending the service life of a switch point by reducing or delaying the initiation of RCF
- Reducing contact stress and shear stress by producing a larger wheel/rail contact area
- Improving wear life by avoiding concentrated wear
- Reducing variations in contact conditions by smoothly blending the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

**NEW SWITCH POINT PROFILE DESIGNS**

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**



**Figure 10. Comparison of the Current Switch Point Design and the New Switch Point Profile Design 1**

In order 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 shapes.

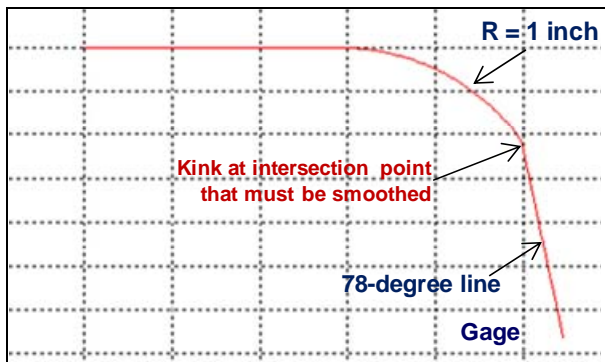


Figure 11. New Switch Point Profile Design 2

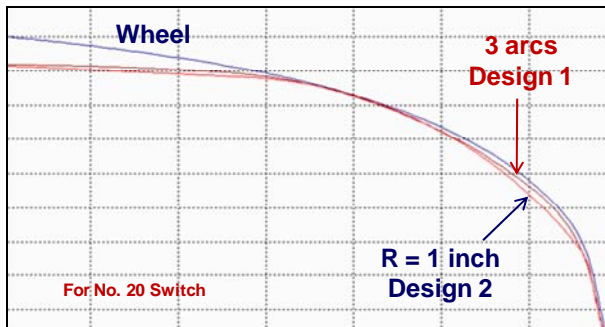


Figure 12. Comparison of the Contact Patterns for Switch Point Profile Designs 1 and 2

### 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.

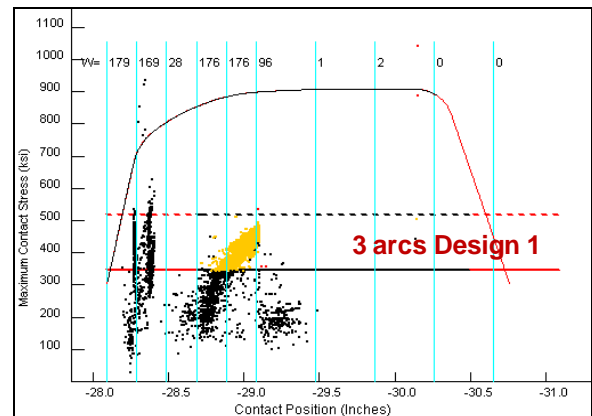
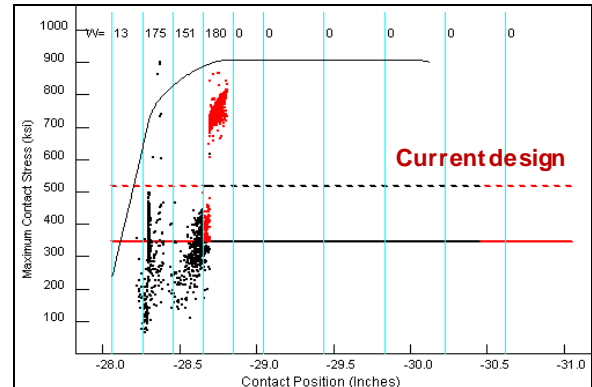


Figure 13. Contact Stress Level Comparison

### 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.

### 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 switch point rail profile designs described in this *Technology Digest* can improve wheel/rail interface conditions by producing larger contact areas when contacting with new and worn wheel profile shapes, which leads to lower contact stresses in both normal and tangential directions. The new profile designs are expected to increase switch point life by reducing wear and delaying the initiation of RCF.

TTCI is working with railways and suppliers to build and test these prototype switch point rail profile designs.

### REFERENCES

American Railway Engineering and Maintenance-of-Way Association. 2008. Plan 127-08, *Portfolio of Trackwork Plans*, Lanham, Maryland.