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Causes of Locomotive Wheel Climb at Switch Point Protectors

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Summary

Transportation Technology Center, Inc. (TTCI) is conducting an investigation into locomotive wheel climb at switch point protectors (SPP) under the Association of American Railroads (AAR) Strategic Research Initiatives Program. The major causes of the wheel climb at SPPs are:

- The worn plane on the SPP entry flare can serve as a ramp.
- Large chamfers on locomotive wheelsets produced from wheel truing increase the potential contact area with the worn plane of the SPP and can form sharp transitions between the chamfer and front rim face that can dig into the SPP and provide extra grip.

As a short-term way to reduce risk, best practices regarding lateral positioning of the locomotive wheel true cutter head should be reviewed, and the importance of proper lateral alignment of this cutter should be stressed to locomotive wheel truing machine operators. Potential longer term solutions to prevent locomotive wheel climb at SPPs need to be evaluated. They include:

- Minimizing locomotive wheel chamfer size and eliminating sharp transitions through:
 - Industry wide standardization of locomotive wheel widths and locomotive wheel truing profiles, including the possibility of using a radius instead of a chamfer
 - Changes to the locomotive wheel truing process to improve the lateral alignment of the cutter heads
- The addition of a guardrail to assist with facing point moves at locations where the SPP is situated on the outer rail of a curve
- Geometry changes to the SPP flare
- Increased SPP maintenance to limit the wear plane angle

TTCI personnel visited locomotive maintenance shops of four railroads to observe the truing procedure and measure profiles on 96 locomotive wheels. Locomotive wheel width varied from 5.512 inches to 5.748 inches. The two wheel truing templates obtained by TTCI were designed for 5.5625 and 5.625-inch wide wheels. Wider wheels produce larger chamfers when truing and increase the potential for wheel climb. In some cases, a convex shape is formed with a sharp corner at the chamfer and front rim face transition, which has potential to “bite” into the SPP and result in a wheel climb. Lateral misalignment of the wheel cutter head with the wheel can exacerbate these issues.



INTRODUCTION

TTCI is conducting an investigation into locomotive wheel climb at field side SPP. Railroads that have reported such derailments have generally described large chamfers that exceed the AAR limit of 0.4375 inch (greater than 0.8 inch in at least one case) between the tread and the front rim face on the derailed wheels. Figure 1 shows one such example. Figure 2 shows a SPP developing some wear from wheel contact. A previous study of wheel climb at SPPs concluded that a large wheel chamfer increases the wheel climb risk as it contacts with worn switch point protectors.¹



Figure 1. Locomotive Wheel Climbing a Field Side SPP



Figure 2. SPP Developing a NonVertical Wear Plane

Since 2008, AAR has limited the size of the chamfer on locomotive wheels to 0.4375 inch measured along the length of the chamfer.² However, locomotives are exchanged between railroads via run-through agreements, not interchanged the same way as freight cars. Therefore, AAR rules have limited applicability in the case of locomotives.

SPPs are a sacrificial wear component installed at low speed yard turnouts to reduce diverging route switch point wear, and are especially useful in turnouts positioned in curves or adjacent to curves. SPPs function by pushing the wheels toward the track center to keep them from striking or picking the tip of the diverging route switch point.

CAUSES OF WHEEL CLIMB AT SPPs

One commonly used SPP is installed with 3.9375 inches between the face of the protector and the gage face of the nearest rail. The top surface of the SPP is 1.25 inches above the railhead. Figure 3 shows a condition of ideal contact between vertical surfaces of the SPP and the wheel. This ideal condition can only occur if the wear surface of the SPP is vertical and there is zero angle-of-attack between the wheelset and the SPP. As a practical matter, this ideal contact rarely occurs. Even if the wheelset has zero angle-of-attack with

respect to the track, the flare angle (see Figure 2) of the SPP creates an angle-of-attack with the wheelset. An angle-of-attack moves the contact between the wheel rim and the SPP ahead (in the direction of travel) of the contact patch between the wheel tread and rail. This effectively creates a non-vertical contact between the rim of the wheel and the SPP. Figure 4 illustrates these contact conditions.

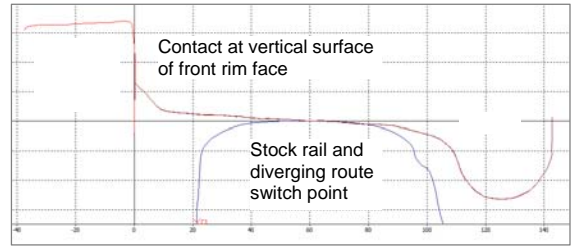


Figure 3. Ideal Contact Condition of SPP

The SPP pushes wheels away from flange contact, reducing the rolling radius difference required for wheelset curving. Note that the rolling radius on wheels is further reduced due to the contact of the chamfer with the SPP, resulting in large negative angle-of-attack and increasing the risk of wheel climb.

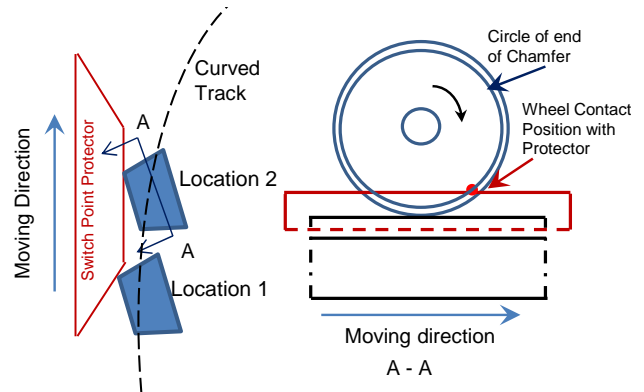


Figure 4. Contact Positions of Wheel with SPP

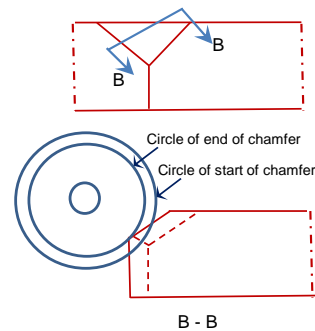


Figure 5. Illustration of Wheel Climbing Worn SPP

Over time, the surface of the protector may wear into a plane with a lower angle, especially at the entry location where the flare and the center section of the SPP connect (marked with a yellow circle in Figure 2 and illustrated in Figure 5). When the wheel is at location 1 in Figure 4, this plane may serve as a ramp to assist wheel climb, as Figure 5 shows. With a large 45-degree wheel chamfer from wheel truing, and a

large wheelset angle-of-attack, this plane can provide undesired stable support for wheel climb. Larger chamfers give larger potential contact area with the worn plane of the protector, increase the rolling radius difference, and increase the risk of wheel climb. Location 1 in Figure 4 (transition between the flare and the center portion of the SPP) is the most likely position for wheel climb.

In addition to a large chamfer, some freshly trued locomotive wheels have a convex shape ending in a sharp discontinuity at the transition between the chamfer and the front rim face. Wear plates of SPPs are typically constructed of manganese steel, a material that is relatively soft immediately after manufacture, but work hardens during service. The sharp corner at the wheel chamfer/rim transition may have a tendency to “bite” into newer, softer SPPs and promote wheel climb. Figure 6 shows photos of one such wheel that derailed at a SPP.

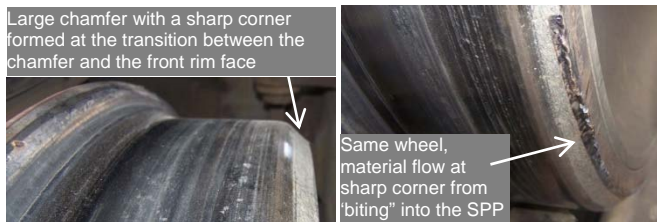


Figure 6. Photos of a Locomotive Wheel that Climbed a SPP

The other factors for wheel climb on SPPs include:

- Low switch point gage face angle in the case of trailing point moves with the switch lined in the reverse direction³
- Wheel profiles that do not promote beneficial steering forces⁴
- Wheel lateral-to-vertical (L/V) force ratio
- Speed and associated vehicle dynamic performance

Locomotive Wheel Truing Machines

Instances of locomotive wheel climb at SPPs occur mainly on recently trued wheels. Worn locomotive wheels generally have a smaller chamfer size due to wear and a more rounded tread end shape without a sharp transition between the chamfer and front rim face. This rounding at the corner of the chamfer and front rim face likely occurs due to contact with SPPs.

Most locomotive wheelsets are trued using a milling-type machine with a head that cuts a fixed profile. Figure 7 illustrates the cutting head, on which the arrangement of small circular cutters forms the wheel profile. The transition from the tread surface to the front rim face is made at a 45 degree chamfer. The size of the chamfer is a function of three variables: cutter head design, wheel width, and lateral alignment of the cutter head. The chamfer is not produced on freight car wheelsets due to the use of truing lathes with much higher wheelset rotational speed that can quickly cut a profile from a single cutting tool. Thus, truing lathes for freight car wheelsets can cut a radius (rather than a chamfer) at the

appropriate location for each wheel regardless of where that particular wheel falls within the wheel width tolerance.

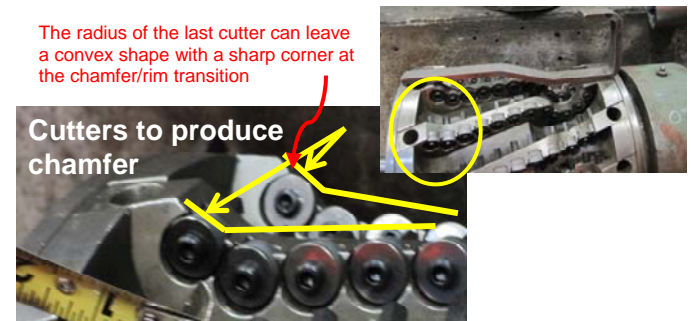


Figure 7. Cutting Head of Locomotive Truing Machine

FINDINGS – Wheel Width and Cutter Design

TTCI visited the locomotive wheel truing machines in four railroad locomotive maintenance shops. The objective of the visits was to investigate the relationship of wheel chamfer size with the truing machines and procedures. Profiles were measured from 96 locomotive wheels in a variety of conditions: new, worn wheels before and after truing, and worn wheels not yet in need of truing. The design wheel profile templates for the cutters of two of these machines were also collected. One template was designed for a wheel width of 5.5625 inches, and the other template was designed for a wheel width of 5.625 inches.

The measured locomotive wheel widths had a range of 0.236 inch, from a minimum of 5.512 inches to a maximum of 5.748 inches. Figure 8 shows a histogram of wheel widths measured at the wheel shops of two different railroads. Interestingly, all 22 of the wheels with width greater than 5.70 were grouped together in four locomotive trucks. As a reference, standard freight car wheel width is specified at 5.7188 ±0.125 inch.

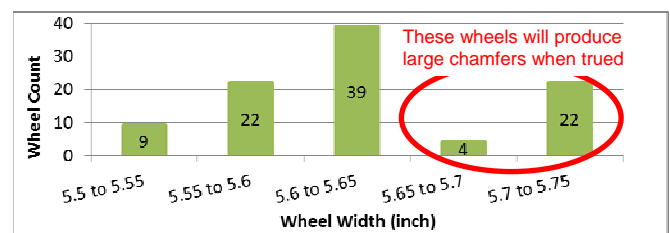


Figure 8. Histogram of Locomotive Wheel Width Measured at Two Different Wheel Shops

Figure 9 shows profiles from new wheels installed in new locomotive trucks. If the wheel width does not exceed the design cutting width limit and the cutter head is correctly positioned, the chamfer size would be as shown on the template (about 0.275 inch). Larger wheel tread chamfers are produced when truing wheels that are wider than the designed cutting width limit. Figure 10 shows the result of truing wheels having a width of 5.75 inch with a cutting head designed for a wheel width of 5.5625 inch: chamfer size of 0.62 to 0.66 inch and a sharp corner at the end of the chamfer.

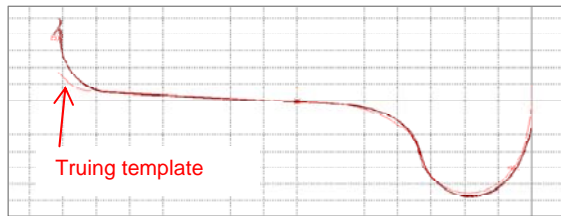


Figure 9. Profiles of New Wheels that are Close to the Designed Cutting Width of 5.5625 inch

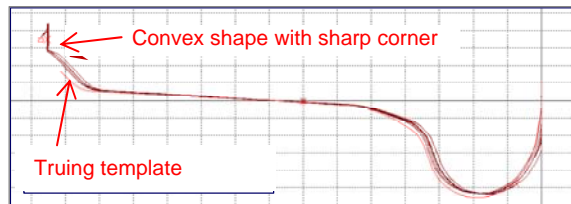


Figure 10. Measured Wheel Profiles after Wheel Truing

FINDINGS – Effect of Cutting Head Position

The lateral alignment of the cutting head influences the wheel chamfer size. A cutting head positioned too far to the front side of the wheel will produce an undesirable discontinuity on the back of the flange. On the other hand, a cutting head positioned too far to the back side of the wheel will produce a chamfer that is larger than necessary with a sharp corner at the chamfer/rim transition. Figure 11 illustrates the effect of cutter head lateral position.

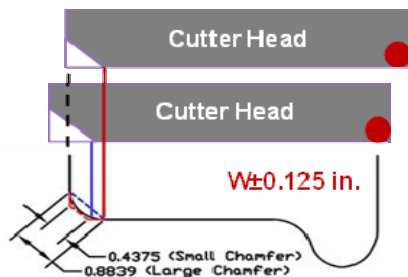


Figure 11. Lateral Position of Cutter Head Position Affects Chamfer Size

Figure 10 shows several instances where the cutting head was positioned toward the back of the wheel. In comparison to the template (in red color), the flanges of the trued wheels are shifted toward the back side of the wheels. In addition to a large chamfer, a small convex shape can be observed at the end of the chamfer on some of these wheels. This shape indicates that the last cutting tool engaged beyond its designed location.

Figure 12 shows photos of the back side of the wheel flanges of two wheels after truing. The cutting head was positioned too far to the back side of the wheel in the photo on the left, as evidenced by almost no flange back contact with the cutters. The photo on the right of Figure 12 shows clear cutter contact with the flange back and is the result of positioning the cutter head toward the front of the wheel.



Figure 12. Indications of Variation in Cutter Head Position

CONCLUSIONS

- The worn plane on the SPP entry flare can serve as a ramp to assist wheel climb.
- Large chamfers that exceed AAR standards and sharp transitions between the chamfer and front rim face of locomotive wheels are wheel climb contributors.
- Some locomotive wheels exceed the design wheel width of at least some locomotive wheel cutter heads. This leads to undesirable large chamfers with sharp transitions between the chamfer and front rim face.
- Correct lateral position of the cutter head on locomotive wheel truing machines is essential for minimizing chamfer size and creating a proper chamfer/rim transition shape.

RECOMMENDATIONS AND FUTURE WORK

Additional training regarding optimal locomotive wheel cutter head lateral positioning and its importance should be considered as a short-term means to help reduce risk of locomotive wheel climb at SPPs.

TTCI will evaluate the feasibility of a number of longer term potential solutions to the problem of wheel climb at SPPs including:

- Industry wide standardization of locomotive wheel widths and locomotive wheel truing profiles, including the possibility of using a radius instead of a chamfer
- Improve the lateral alignment method of the cutter heads to minimize the chamfer size, and eliminate the sharp corners
- The addition of a guardrail to assist with facing point moves at locations where the SPP is situated on the outer rail of a curve
- Geometry changes to the SPP flare
- Increased SPP maintenance to limit the wear plane angle

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