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Evaluation of the Performance of a Prototype Heavy Point Frog

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Summary

Researchers at Transportation Technology Center, Inc. (TTCI) analyzed the trailing point direction for freight cars traveling through a number 24 prototype heavy point frog at various speeds. The new prototype design meets FRA Class 6 track safety standards. The results presented represent a 50 mph speed. Two sets of simulations were conducted, considering both the nominal profile of an AAR 1B wheel and the worst case of a worn wheel profile with a 0.16 inch (4 mm) hollow.

Previous work shows that it is possible for a heavy point frog to meet all requirements for track, guard, and face gage by widening the frog flangeways back to 1.875 inches in the area of the heavy point.[1] Results of the simulation of the prototype heavy point frog were compared to the Federal Railroad Administration (FRA) track safety limit, and the new design met all the requirements.

Findings from the current study reveal:

- The wider flangeway of the modified heavy point frog will make wheel transfer from point to wing occur closer to the point of the frog.
    - Dynamic loads may be larger than on the current narrowed flangeway heavy point frog due to the wider flangeway
    - The point slope should be short enough that point-to-wing transfer occurs before the point slope starts (for trailing point moves)
- New and worn wheel/frog contact paths through the frog are quite different. The frog is designed for a new wheel. There is no accommodation for a hollow worn wheel profile.
- The new frog profile condition is the worst case for hollow worn wheels. Some wear to accommodate the false flange of the wheel will likely improve the performance of the fixed point frogs modeled.

The difference in the contact generates different wear indices. The lateral contact between the worn wheel back of flange on the frog wing and the contact between the wheel rim and the stock rail cause the worn profile wheel to have a higher wear index than the new profile.

This study was conducted as part of the Association of American Railroads' (AAR) Strategic Research Initiative on special trackwork.

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INTRODUCTION

Widening the frog near the point of frog (POF) to approximately 1 inch greatly reduces frog point deformation and fatigue. The current heavy point frog design illustrated in Figure 1 widens the minimum width from 0.625 inch to 0.969 inch.

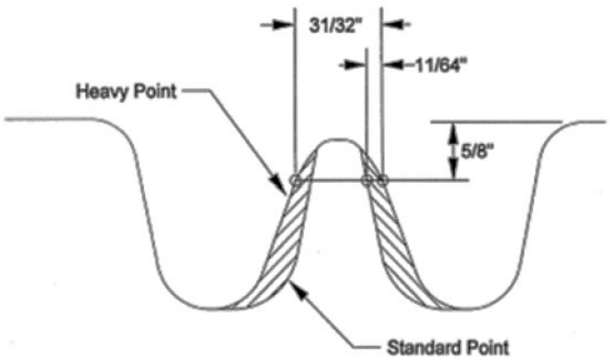

Figure 1. Cross Section of Heavy Point Frog

The benefits that are obtained with a heavy point frog include longer service life and less maintenance. However, widening the nose of the frog results in failing to meet all the FRA safety requirements for track, guard, and face gage dimension limits for class 5 and higher track illustrated in Figure 2.

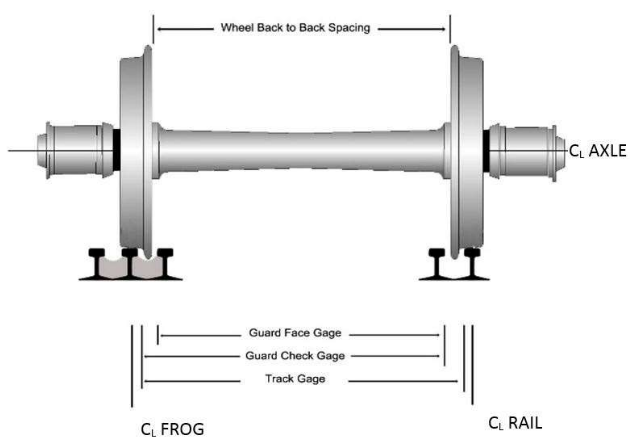

Figure 2. Guard Check Gage and Guard Face Gage

A prototype design was developed by widening the frog flangeways to 1 7/8 inches in the heavy point area as shown in Figure 3 and Figure 4. Such a design would meet all FRA Class 6 safety requirements for track, guard, and face gage.

In previous research under the AAR's SRI Program, researchers at TTCI modeled a new design heavy point frog and simulated both freight and passenger train equipment traveling in the facing point direction. The simulations were performed over a wide range of speeds and track perturbations.

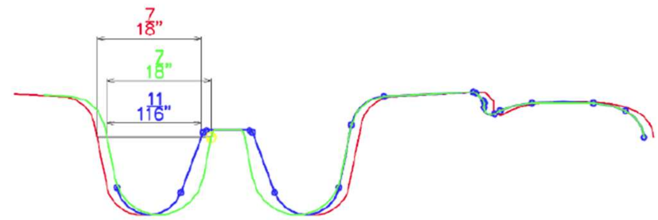

Figure 3. New Design Heavy Point Frog (red), Standard Frog (green), Original Design Heavy Point Frog (blue)

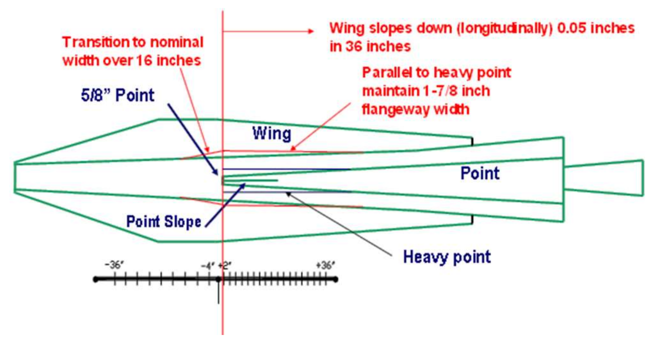

Figure 4. New Design Heavy Point Frog (red), Standard Frog (green)

Results show that this type of frog design has relatively small effects on expected forces and accelerations for the facing point traffic. Overall, the cases analyzed showed similar performances.[1]

Heavy Point Frog Simulation – Trailing Point Direction

In the current study, a loaded hopper car was simulated traveling in the trailing point direction on a number 24 turnout. Two sets of simulations were performed, considering new and worn wheel profiles. The simulated worn profile represents the wear limit of the wheel for 0.16 inch (4 mm) hollow tread. For each profile, simulations at various speeds were analyzed, from 5 mph to 70 mph. However, the results presented hereafter are representative of 50 mph speed, the likely maximum speed for diverging route freight operation on a number 24 turnout.

Figures 5 and 6 illustrate the difference in wheel/rail contact between the new wheel and worn wheel, respectively. Both figures show the contact of the differing wheel profiles at a section situated 13 feet 4 inches before the 1/2-inch POF in the trailing point move.

The frog is on the right side with the running rail and guardrail on the left side in these figures.

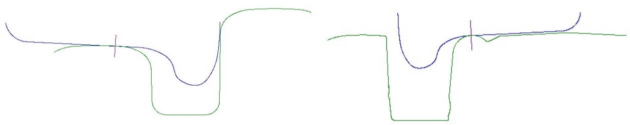

Figure 5. New Wheel Profile, 13′4″ Before 1/2″ POF

Figure 6. Worn Profile, 13′4″ Before 1/2″ POF

Figure 5 illustrates that the new wheel profile would engage the frog rail near the throat of the flange on the right wheel. This instant is just prior to the left wheel being captured at the back of flange by the left side guardrail. The guardrail maintains the wheelset on the right position as it traverses the frog.

The worn wheel profile illustrated in Figure 6 shows the right wheel back of flange in contact with the wing rail. It also shows a second point of contact on the outside of the wheel rim in contact with the frog wrap rail, but with no contact on the frog casting.

Figures 7 and 8 show the most critical contact zone of the frog is represented by the nose-to-wing or point-to-wing transition. Figure 7 shows the interaction between the rail and the new wheel profile in the area of transition between the point and the wing of the frog, approximately 18 inches before the 1/2-inch POF. New wheels continued to be guided by the guardrail on the left rail, with contact between the wheel back of flange and the guardrail. On the right side, the wheel tread traverses smoothly onto the wing of the frog. The point slope facilitates this for new wheels.

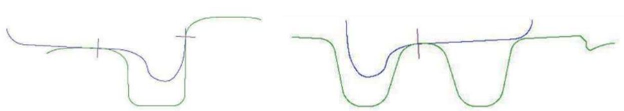

Figure 7. New Wheel Profile, 18″ Before 1/2″ POF

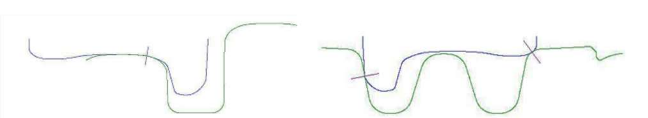

Figure 8. Worn Wheel Profile, 18″ Before 1/2″ POF

In Figure 8, the worn wheel has transitioned onto the frog wing sooner due to the hollow tread. This is shown by the gap between the frog point and the wheel. The wheel back of flange contacts the left wing, guiding the wheelset through the frog. The wheel rim travels on the frog wing. There is no contact between back of flange and guardrail on the left wheel. The contact between the wheel rim and the frog wing is indicative of a high contact stress condition that will lead to more rapid wear of the wing. The wider flangeway of the prototype will make point-to-wing transitions happen closer to the 1/2-inch point of the frog. This suggests the point slope may come into play; potentially worsening dynamic loads from hollow profile wheels.

The point-to-wing transition happens before the 1/2-inch POF is reached in trailing point moves. Figure 9 shows the contact between new wheel and rail in the point-to-wing transition zone, approximately 56 inches after the 1/2-inch POF. The wheelset is restrained laterally by the guardrail on the left side. The right wheel is running on the wing of the frog.

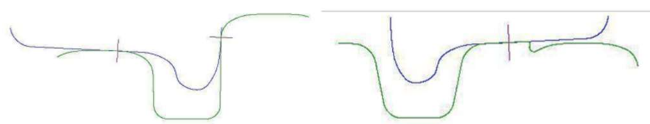

Figure 9. New Wheel Profile, 56″ After 1/2″ POF

The interaction with the worn wheel profile illustrated in Figure 10 shows that the wheelset is laterally constrained by the wing on the frog. The wheel involved in the frog is traveling on the wrap rail.

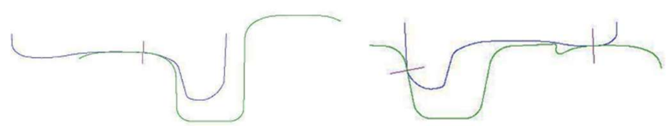

Figure 10. Worn Wheel Profile, 56″ After 1/2″ POF

As can be noticed in the various cross sections in Figures 5-10, the right wheel with worn profile contacts the frog in two points. The right wheel back of flange contacts the frog wing, while the outer rim travels on the wrap rail instead of involving the casting wing. The difference in the contact between the two wheel profiles and the frog causes a difference in the wheel/rail forces. Figure 11 shows a distance history overlay of the predicted lateral and vertical forces for the new wheel (blue) and the worn wheel (red). The worn wheel generates much larger dynamic transient forces. These larger forces may result in unwanted vehicle dynamic response as well as accelerated rail wear.

It should be noted that the new, unworn frog profile is typically the worst case for hollow worn wheels. Some wear on the frog will improve vehicle steering and lower the lateral and vertical dynamic forces for worn wheels.

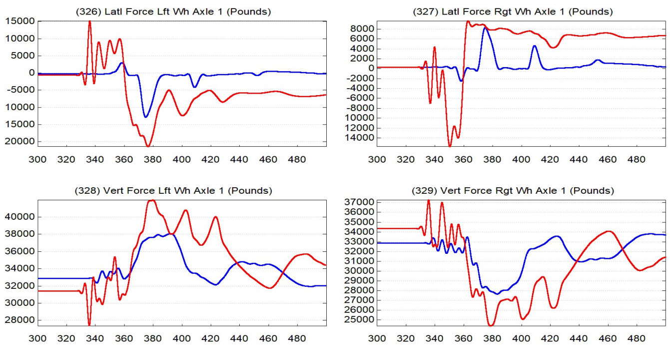

Figure 11. Vertical and Lateral Forces - New (blue) and Worn (red) Wheel Profile

The upper two plots of Figure 11 are the right and left lateral forces, respectively. The lower two plots of the figure are of the right and left vertical forces, respectively. In general, the worn wheel creates undesired contact locations, which result in rolling radius conditions that may cause undesired lateral position of the wheelset or opposite steering. These conditions create transient dynamics that result in larger lateral and vertical forces.

The difference in contact affects the predicted wheel/rail forces. The difference of wear between new and worn profile is consequent to the load difference. The wear indices for both new wheel and worn wheel profiles are reported in Table 1. Worn wheels show a higher wear index on the simulated track.

Table 1. Wear Indices for New and Worn Profiles for Trailing Point Moves at 50 mph

Wear Index [lb.-in./in.]	New Profile	Worn Profile
Right Rail Head	11	345
Left Rail Head	12	341
Right Rail Gage Face	0	91
Left Rail Gage Face	19	574
Total Right	11	436
Total Left	31	915

CONCLUSIONS

The analysis shows that the heavy point frog designed to meet the FRA standards could be considered for use in the future. The new wheel profile travels smoothly through the heavy point frog sections. Traveling along the frog, the right wheel tread is always contacting the frog wing. The new wheel profile wheelset is led through the frog by the guardrail on the left side, as it is supposed to be.

The worn profile wheelset engages the frog guided by the wing: the right wheel back of flange contacts the wing of the frog that maintains the wheelset on track. The 0.16 inch (4 mm) hollow in the worn profile causes the wheel rim to contact the wrap rail.

The heavy point frog design with a wider flangeway causes the wheel to run out of contact sooner than the standard design. As the transition is shorter, impacts increase and generate concentrated wear on the frog point. As stated in previous research, it is recommended that the wing-to-point transition zone have longitudinal slopes to accommodate both frog wear and a wider range of wheel profiles. This can be accomplished with a combination of a wing riser, a groove for false flanges, and/or a wing downward slope from the POF toward the heel end.[1] These designs will help minimize dynamic loading over the life of the frog.

References

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2. Sasaoka, Charity, David Davis, and Don Guillen. "Service Evaluation of Improved Running Surface Profile Frogs." December 2003. Research Summary RS-03-004, AAR/TTCI, Pueblo, CO.