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## **Review of Turnout Frog Running Surface Design**

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### **Key Findings:**

- The current conformal profile design of turnout frogs is to accommodate only new wheels. It will generate impacts for all other wheel profiles.
- This is due to no variation of relative wing and point heights through the frog.
- A conformal transverse profile does reduce wear and metal flow on frog running surfaces.

Turnout frog running surface profile design has been evolving since the introduction of moveable point and moveable wing designs, heavy point frogs, and conformal profile frog designs. These innovations have brought significant benefits to railroads in the form of improved dynamic performance, longer service lives and lower maintenance demands. However, the changes in wheel-rail contact that result from these designs was not fully understood. Problems over the last 10 years in frog performance are largely due to inadequate accommodation of the range of worn wheel profiles in service and the lack of allowance for wear on the frog itself. [Transportation Technology Center, Inc. \(TTCI\)](#) reviewed turnout frog running surface design under the [Association of American Railroads' \(AAR\)](#) Strategic Research Initiatives Project for Special Trackwork.

Designing a running surface profile for North American freight operations is a challenging systems engineering problem. The objectives of providing a smooth ride, a long service life and high reliability all go together. But they are not easily achieved with a single design profile over the life of the frog.

Accommodating a single wheel running surface profile is feasible for a designer. The wide variety of worn wheel profiles in service today makes this design task considerably more difficult. The range of shapes dictates the transverse and longitudinal profiles needed on the frog. They affect the location where wheels will transition from wing to point on the frog.

As with rail, frogs have competing wear and fatigue failure modes. The optimal service life usually occurs in the situations where none of these individual failure modes is optimized, but the resultant service life is longest. This often means more than one failure mode is seen in the field; as small variations in wear or loading shift the predominant failure mode between wear and fatigue.

## FROG RUNNING SURFACE DESIGN

Frog running surface design has evolved over the years, from designs that were easy to make, to designs that mimic worn frogs seen in the field. The easy designs involve planed, usually flat, surfaces. These are amenable to a material like austenitic manganese steel (AMS), which works (hardens) rapidly as it deforms. Thus, a more conformal and durable running surface is developed as the frog is used.

### Cross-section profile

A typical worn cross-section shape is shown in Figure 1. The running surface takes on the shape of the wheels running on it. They develop the average worn shape of the wheel tread; approximating a 1:20 tread taper slope. This general cross-section shape is altered where the wheel tread end, flange and flange root make contact with the frog. This occurs at gage corners of the wings and the point. At the gage corners, one is faced with the conflicting demands of making the running surface conformal to wheels and keeping the flangeway as small as possible. A good compromise between these two demands is to make the gage corner radius closely conformal (but with a radius larger than needed to be conformal) to worn wheel flanges on the frog point, where this portion of the wheel is likely to be in contact. This keeps wheel contact off of the gage corner and allows a place for flowed metal to accumulate before it affects the wheel contact location. On the wings, a sharper radius gage corner can be used. The wheel flanges should never be in contact with the wings, except at the toe end of the frog.

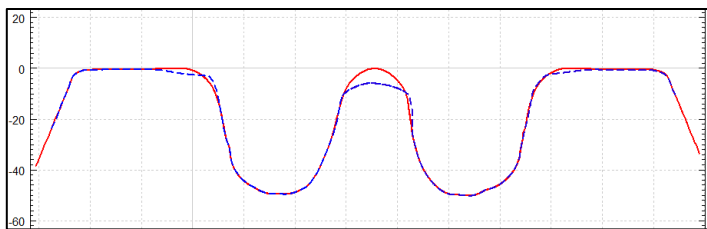


Figure 1. Initial wear on flat profile frog; the basis for the conformal profile design

The use of conformal cross-section profiles for wings and the frog point, with proper longitudinal point and wing slopes, has been shown to reduce initial deformation and wear (and required grinding maintenance) in heavy axle load testing by about 50 percent (as compared to flat running surface profiles).<sup>1,2</sup> Most of the benefit will come from a larger gage corner radius. However, the use of a tapered running surface

also will spread contacts across the wing or point rather than concentrating them all at the gage corner.

### Longitudinal profile

A long frog service life is dependent on many factors: the running surface profile design, timely maintenance of the track and the running surface metal flow, the frog foundation and the dynamic loading applied by vehicles.

For the frog designer, the key determinant of frog service life that can be controlled involves the longitudinal profile design. A good design is needed to accommodate the range of wheel profile shapes that will operate over the frog. As a wheel wears and changes its tread and flange profiles, it will track differently (i.e., take a different path) through a frog. The location where the wheel transitions from wing to point (in a facing point move) changes with wheel and frog wear. New wheels transition from wing to point first, with hollow worn tread profiles transitioning last.

In order to effectively accommodate this range of wheel shapes a frog must have the proper relationship of wing to point elevation. The two critical locations are 1) the 5/8-inch point (i.e. the physical start of the frog point) and 2) the location where wheel treads can no longer reach the wing. Figure 2 shows these locations on a frog.



Figure 2. Plan view of frog with locations noted

To accommodate new wheels, the frog point must be approximately 0.3 inch (5/16 inch) lower than the wing at the 5/8-inch point. This allows the new wheel to clear the frog point in facing point moves. It is important to remember that a tapered profile wheel will drop in elevation as it rolls across a turnout frog. This occurs because the frog wing is deviating

from the gage line of the wheel's path to create the space needed for the diverging route's flangeway. As the wing diverges, the point of contact on the wheel changes from near the flange to near the field side of the tread. As the wheel contact point moves laterally, the wheel elevation drops by an amount that corresponds to the taper in the tread profile. For example, if a wheel with a 1:20 tread taper shifts the point of contact 3 inches laterally, the wheel will drop 0.15 inch.

The point depression also allows the new wheel to transition onto the wing smoothly in trailing point moves. Today, this is typically done with a point depression of 3/16 inch (recognizing another 1/16-inch allowance for initial deformation under lower speed traffic and some risk of a wheel flange strike). In the past this function was sometimes accomplished with a wing riser. The riser raised the wheel to allow the flange and flange root to clear a frog point that did not have a depression. This is an elegant solution in that a wheel with a design tread profile will pass over the frog without changing elevation. Thus, dynamic loading should be reduced. A frog with a wing riser, rather than a point depression, is harder to maintain, however. This is due to fewer level reference points being available when making a weld repair.

The second critical location involves hollow tread profile wheels in both facing and trailing point moves. This location varies with the frog angle but is located where the frog point and flangeway are just wide enough that the wheel can encounter the wing in trailing point moves. Figure 3 shows this location and situation. At this location, the wing must be below the point elevation by about 0.13 inch (or the current wheel tread hollowing limit) to avoid false flange impacts. The goal at this location is to have the wheel come into contact with the top of the wing, rather than the side of the wing. This situation is analogous to that of the switch, where a switch point riser commonly is used to assure that the hollow worn wheel does not cause the stock rail to roll over in trailing point moves.<sup>3</sup>

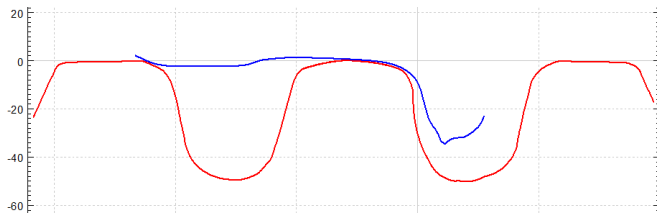


Figure 3. Hollow worn wheel on worn frog: Profile combinations that can cause impacts during wheel transition.

In facing point moves, hollow worn wheels can run on the wing until they fall onto the frog point. This event is detrimental to the frog point and is often seen as a mashed down point in the field. In trailing point moves, the false flange of the hollow worn wheel will strike the side wall of the wing; causing large deformations and high dynamic loads.

Figure 4 shows a longitudinal profile design which performed well in testing under heavy axle load traffic.<sup>1</sup> In this application, a frog point riser could be used. However, this would require that all wheels be raised when only the hollow worn ones should be. Raising the vehicle creates a dynamic loading that is detrimental to the frog. Also, a frog point riser would have maintenance issues as the wing risers of the distant past.

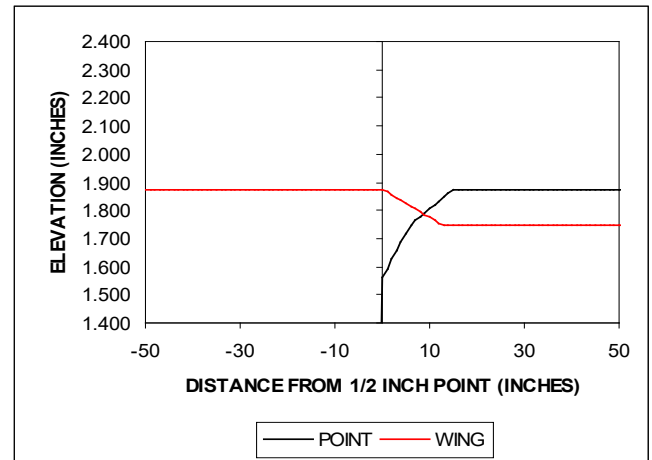


Figure 4. Profile view of longitudinal wing slope (from RS03-004)

A preferred alternative is to use a wing depression/wing slope, like the currently used point depression/point slope. As shown in Figure 5, this will provide the clearance needed for hollow worn wheels in trailing point moves. The ramp will allow wheels to climb up to top of rail height and lift off of the frog point without high dynamic loads.

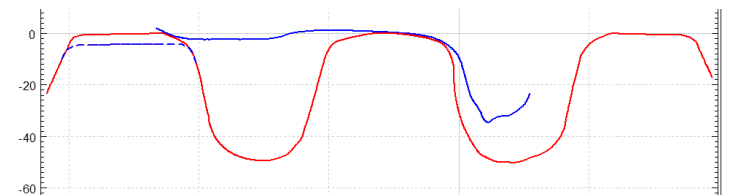


Figure 5. Wing depression with hollow wheel (to avoid impacts on wing and point during transitions). The wing relief (shown in blue on the left) also accommodates frog point wear

### Point slopes

A point slope connects the point depression to the nominal top of rail height of the current frog. For higher speed track, a longer point slope provides a smoother ride for new and moderately worn wheels. Typically, a point slope length in inches equal to the frog number is used. For lower speed traffic, a point slope length equal to one-half of the frog number is often used. This also can extend the service life of the frog or the interval between weld repairs in cases where the wheel shapes are relatively uniform. As the steeper point slope wears, the location of wheel transfer from wing to point in facing point moves migrates toward the frog heel.<sup>4</sup> Thus the dynamic loading cycles are distributed over a longer distance.

### Conformal frog performance issues

In the past five years, there have been issues with some conformal frogs failing due to battered points and wings. These frogs have a conformal cross-section profile with 1:20 slope wings and points. The root cause of the problems with these frogs lies in the longitudinal profiles, not the cross-section profiles. To simplify machining, the frogs are made with a single cutter pass down each wing. The cutter machines a wing and half of the frog point in one pass. This creates an ideal running surface for a new wheel profile. A new wheel can smoothly transition from wing to point at any location in the frog. As a result of this profile, a wheel with any other running surface profile cannot transition from wing to point without a sudden elevation change and a resulting dynamic load.

This is due to the lack of change in the difference in elevation of the wing relative to the point. Thus, most wheels produce an impact on this frog profile. Traditional flat running surface profiles frogs have steeper point slopes than the single cutter pass conformal profile frogs so that a range of wheel profiles have a location to smoothly transition from wing to point.

### ACKNOWLEDGEMENTS

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### References

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