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Modified Frog Wing Slope Profile Test

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Key Findings:

- The current generation of conformal frog profiles does not sufficiently accommodate hollow tread worn wheels, which could contribute to premature failure of frog running surfaces.
- A relatively simple change in the longitudinal profile, analogous to the switch point riser used today, will accommodate wheels with up to a 4-mm hollow profile. Prototypes were developed and tested under AAR funding in 2002.
- Frog wings wear to conformal in transverse profile.
  - Initially flat and initially 1:20 profile wings both wear to a conformal shape.
  - Conformal wings have lower initial wear rates than flat wings.

Transportation Technology Center, Inc. (TTCI) is monitoring revenue service frogs near Lexington, KY (Kings Mountain) as part of an evaluation of modified frogs designed in 2014. Data analyzed by TTCI engineers and supported by observations from the field have shown the need for additional modifications of current conformal frog designs.

The initial round of testing focused on design changes that included a heavy point and a conformal wing slope. The results indicated that the heavy point and conformal shape generally performed better than the current standard designs in terms of both dynamic acceleration and degradation. However, severe wear on the frog wings was observed during subsequent follow-up inspections.

Frogs are one of the most critical components in the railroad operating environment. They work in conjunction with multiple components at a turnout location to provide operational fluidity to the rail network. As a frog wears, dynamic loading can become more severe, and often will lead to material flow on both the point and wing running surfaces. Remediation options include performing a weld repair, a short-term fix that can provide highly variable results; or a renewal, a time-consuming and expensive process.

Based on the available data, the current conformal design of the wing running surface does not accommodate hollow tread wheels as well as thought possible. TTCI, in partnership with multiple North American special trackwork vendors, Norfolk Southern Railway (NS), and the Federal Railroad Administration (FRA), has begun monitoring two frogs installed in revenue service and one frog at the Facility for Accelerated Service Testing (FAST) near Pueblo, CO. Each of these frogs has a modified longitudinal wing slope that should both prevent the occurrence of less-than-ideal contact with hollow tread worn wheels and decrease the degradation of the wing running surface. The results included in this *Technology Digest* are preliminary. Future work will include ongoing monitoring of the frogs with modified wing slope design and reporting results based on this additional data analysis.

BACKGROUND

Since 2014, TTCI has been evaluating design modifications in Number 20 frogs. Part of the Association of American Railroads' (AAR) Strategic Research Initiatives Program, this test was specifically designed to observe changes to the size of the frog point and the surface of the frog wing. Other modifications considered as part of this original evaluation were modifed heel designs.

Frog heels are the transition locations where wheelsets transfer fully off of the frog casting and back onto the running rail. These transitions are normally short and abrupt, and, with older style designs, prone to premature failure. A low-impact heel design, also known as a tapered heel, was tested along with a more conventional 60-degree angle cut design (see Figure 1). Data collected during this initial phase of the test showed that the tapered heel design decreased deformation at the frog/heel interface. Data collected showed that the dynamic loading environment was also typically less severe with the frogs that had better heel interface designs.[1]

Figure 1. 60-degree convention angle cut heel (top) low impact or tapered heel (bottom)

Initial results also indicated that these design changes appear to cause less deformation on both the point and wing running surfaces. TTCI continued observation of the original four test frogs, and during subsequent observation trips began to note severe degradation of the wing running surface (Figure 2).

The heavy point concept, in which the frog has more material when compared with a standard style point, was used in conjunction with a conformal wing running surface. The conformal wing design was selected because TTCI's previous experience indicated that as frog wings wear over time they will inevitably wear to a shape that is conformal with the wheel shape of the fleet that traverses across them.[2,3] By making the frog wing conformal initially, this surface does not undergo rapid initial deformation as it "wears" into a conformal shape. Rather, it starts off as essentially conformal and experiences some minor degradation based on natural variation in wheels of different ages.

Figure 2. Wing running surface damage at South Fork test frog location

An analysis of cross-sectional profiles taken at the frogs reveals a potential issue with contact from hollow tread wheels. Figure 3 shows a plot with an overlay of a new and a hollow worn wheel profile for the Kings Mountain location. Only a proper elevation relationship between wing and point will provide a smooth wheel transition. For hollow tread worn wheels, the potential of lateral interference between the false flange and the wing (or concentrated point loading on the frog wing running surface) exists. This problem is exacerbated in situations where the frog point has worn to be substantially lower than the running surface of the wings, resulting in more wheels contacting the wing running surface or flangeway wall along the backside of the wheel. This condition can lead to accelerated degradation such as that seen in Figure 2. Based on this analysis of profiles, TTCI engineers began considering additional modifications that could be made with the conformal profile that would alleviate the contact issue with hollow tread wheels.[4]

TTCI engineers ultimately settled on a modification to the conformal wing that introduced a longitudinal slope to each wing running surface. Field observations indicated that the previously mentioned lateral interference between the hollow worn false flange and the frog wing does exist. Worn wheels have to climb up the flangeway to get on top of the wing, which, in turn, can result in high force and stress on the frog wings.

In the facing point direction, hollow worn wheels will ride on the wing until the point becomes wide enough that the wheels run out of wing and "fall" onto the point. In this scenario, the point is not tall enough to contact the wheel tread, which results in the mashed down point often being seen in the field.

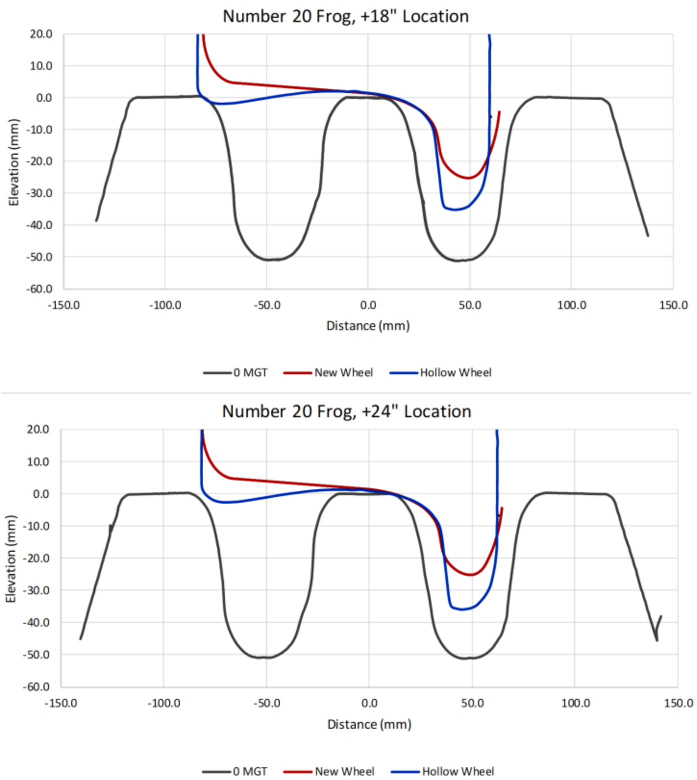

Figure 3. Kings Mountain test frog, +18 in. (top) and at +24 in. (bottom) from the frog 5/8-in. point with new and 4 mm hollow tread wheel overlays

This discussion eventually led to development of an evaluation for the current set of design modifications: a frog with point slope and conformal wings with longitudinal wing slopes. The successful model for this design is the switch point riser that is already used in railroad operations. The difference between the switch point riser and the frog running surface design is that, for the latter, the wing is lowered rather than raised placing the frog point above nominal rail height.

LONGITUDINAL WING SLOPE DESIGN

Based on the conversation and discussion between TTCI, NS, and the vendor's technical staff, two frogs were fabricated by special trackwork vendors. The slope design itself was based on work performed by TTCI at FAST.[2,3] Figure 4 illustrates the profile view of the longitudinal wing slope in relation to the frog point.

The goal of this downward slope was to prevent impacts between frog points and hollow tread wheels in facing point moves as well as collisions between wheels and the wing surface in trailing point moves. There was initial discussion on the length and steepness of the longitudinal slope to be fabricated for testing.

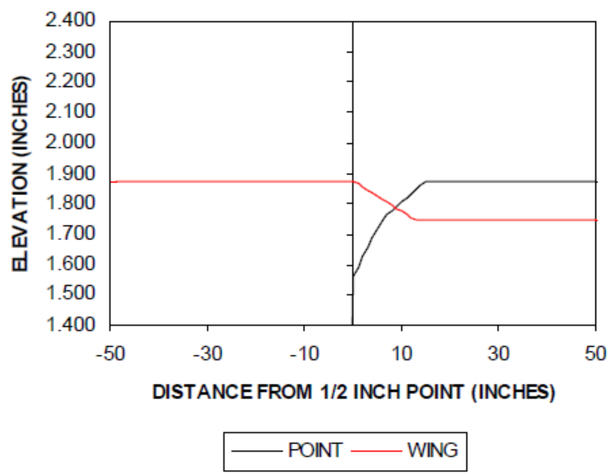

Figure 4. Profile view of longitudinal wing slope versus frog point slope

Through this discussion, it was determined that one of the frogs would have uniform longitudinal slopes on both wings while the second frog would have longitudinal slopes of different lengths and inclines. Therefore, one wing was built with a steeper slope design and the other wing was built with a gentler slope design to investigate which would be more ideal. Figure 5 shows the frog that was fabricated with these two different slopes.

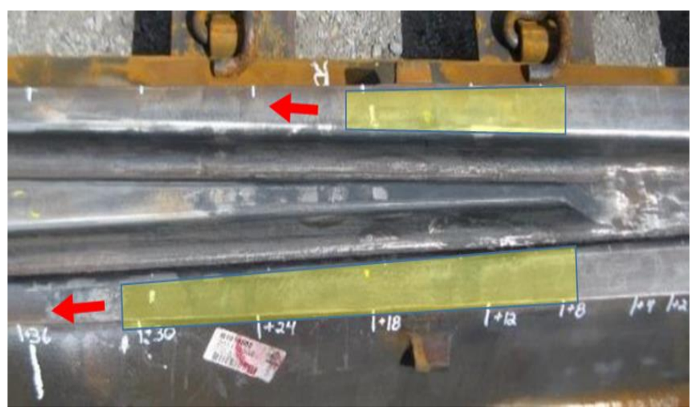

Figure 5. NS test frog with two different longitudinal wing slopes: steep (top) and gentle (bottom)

CONFORMAL WING ANALYSIS

TTCI engineers analyzed wear data from the test frogs installed to determine if additional modifications to the conformal wing shape were necessary. The original conformal wing shape had a 1:20 slope intended to match the AAR-1B profile tread taper for new wheels. The review of the worn frog profiles showed the following:

- The conformal profile is useful for the toe end of the frog where the wheels are running only on the wing.
- Worn frogs had wing slopes that ranged from approximately 1:20 to 1:30.
- The conformal profile is not needed on the part of the wing that reaches beyond where the tapered portion of the wheel tread contacts the wing.
- Frogs built with conformal wings have lower wear rates than frogs built with initially flat wings.
- The reduction in vertical wear ranges from 15 to 30 percent.
- The conformal profile is useful in reducing metal flow over the entire length of the frog point.

Regardless of the initial transverse profile, traffic will wear the wings to a conformal shape shown in Figure 6. This example originally had flat wings. To avoid contact on the field side of the wheel tread, the design profile should be no steeper than 1:20. The wear pattern shown is typical of the frogs measured. As the frogs accumulate MGT, the initial wear is concentrated on the gage corner and then spreads laterally over a wider area.

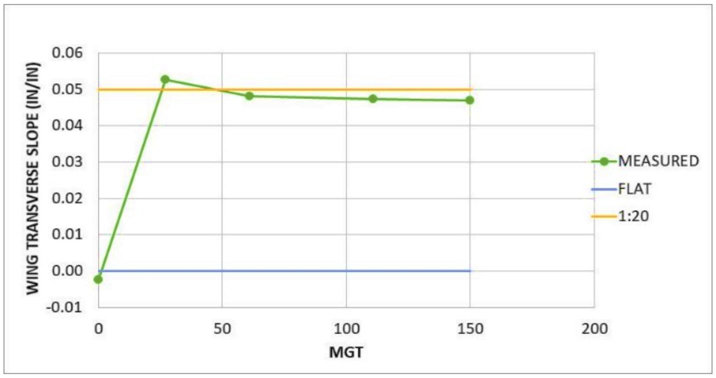

Figure 6. Example progression from flat to conformal wing profile, Number 20 frog

The reduction rate in height loss is illustrated in Figure 7 by comparing the two test frogs that were installed in the same turnout at Kings Mountain. The first was a conformal profile using a welded, boltless frog. The second was a flat profile using a welded, boltless frog. In a comparable 89 MGT period early in the lives of the frogs, the conformal profile frog "wore" from 15 to 30 percent less. The height loss rate depended on the measurement location on the frog.

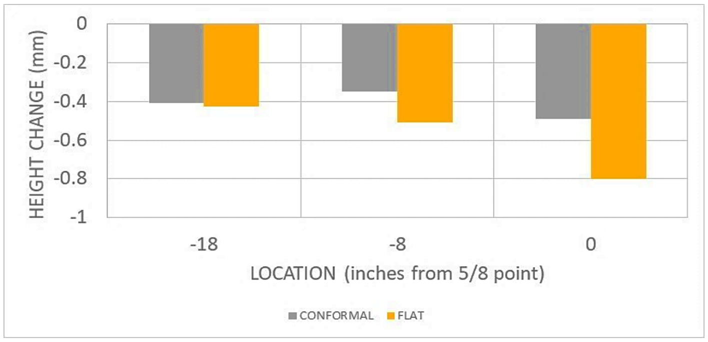

Figure 7. Flat and conformal wing wear versus location in the frog

FUTURE WORK

The two test frogs installed on NS track in late 2019 have accumlated approximately 133 MGT as of March 2021. The test frog installed at FAST has accumulated approximately 217 MGT as of the same date. TTCI engineers plan to continue monitoring the two frogs in revenue service, as well as the frog at FAST, as they continue to accumulate tonnage. Additional data compiled will be analyzed and updated results will be reported in subsequent issues of *Technology Digest*.

References

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4. Davis, D., B. Bakkum, S. Wilk, and D. Otter. May 2019. "Review of Turnout Frog Running Surface Design." *Technology Digest* TD19-002. AAR/TTCI. Pueblo, CO.

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