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Evaluation of Flange Bearing Frogs for Turnouts

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Summary

Partial flange bearing frogs provide a good solution for extending the life of turnout frogs in mainline low-volume siding tracks. These one-way flange bearing frogs (also known as lift frogs) are successful for “set out” tracks in high-volume main lines and are successful because they improve the capabilities of the frog to carry a large volume of higher speed, heavy axle load traffic on the mainline side.

In a recent study by the Transportation Technology Center, Inc. on the field performance of the newly designed lift frogs, the following findings were noted:

- Flange bearing turnout frogs are being successfully operated in revenue service mainlines today.
  - Mainline ride quality has been very good.
  - Turnout lift frogs comply with all Federal Railroad Administration track safety standards for Class I track and do not require any waivers or exemptions.
- As currently configured, the flange bearing turnout frog can be operated safely at 5 mph or less. Speed is limited by the lack of flange bearing ramp on the guardrail and the steep slopes of the frog ramps.
- Operations on the diverging route side of the frogs have been successful, with no adverse consequences.
- Higher speed operations may be possible with modifications to the existing frog designs.
- The raised guard on the toe-end casting of some frogs has been struck by track inspection vehicles. Apparently, one type of hi-rail gear for track inspector trucks does not meet the American Railway Engineering and Maintenance of Way Association and Association of American Railroads’ clearance recommendations.
- It is too early to quantify the life extension possible from these frogs. However, a likely failure mode is the wear in the mainline running rail from flange bearing.
  - Maintenance for this frog is less than for a spring frog in the same service.

Current fixed point turnout frogs are designed to be used universally (i.e., for either right- or left-hand turnouts). This minimizes inventory for the railroad, but also means the frog has the same capabilities for the mainline and diverging routes. There are many locations where the traffic is 99 percent main line. Such locations include industrial sidings on main lines and bad-ordered car “set-out” tracks.

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INTRODUCTION

There are many turnouts in mainline track that are essential for network reliability and line capacity, but carry very little diverging route traffic. These turnouts are typically at industrial sidings or bad order "set-out" tracks accessed directly from the main line. For these turnouts, the overwhelming majority of traffic (i.e., more than 99 percent) is on the mainline route. Yet, the conventional No. 10 or 11 frog is built with the same capabilities for the mainline route and the diverging route.

This new design increases the capabilities of the mainline side of the frog while diminishing the capabilities of the diverging side. As the mainline side determines the service life of the frog, this new design is expected to increase service life significantly.

Figure 1 shows a flange bearing turnout frog installed in mainline track. The mainline rail is continuous through the frog, which consists of two austenitic manganese steel castings bolted to the running rail. There is no guardrail on the mainline route because there is no flangeway to cross.

Figure 1. Flange Bearing Turnout Frog (Toe-End View)

In conventional fixed point frogs, a flangeway is formed to allow the flanges of crossing wheels to pass through the running "rail" or surface. The frog is tread bearing with a gap in the tread running surface for the flangeway. In a flange bearing turnout frog, the flangeway for diverging traffic is removed. In its place, ramps are provided on either side of the mainline running rail. The ramps lift the diverging route wheels to an elevation that allows them to roll across the top of the mainline rail and the mainline flangeway.

While using the same design philosophy as the One Way Low Speed (OWLS) flange bearing diamond[1] (i.e., restricted operating speed on the branchline with ramps that allow wheels to climb over the mainline running rails), the flange bearing turnout frog is somewhat more complex. The smaller frog angle causes an overlap of flangeways for the two routes that does not exist for crossing diamond frogs. This flangeway overlap prevents the use of the combined flangeway bottom for flange bearing. In the toe end of the frog, the diverging route elevation change is provided by a tread bearing ramp. The tread bearing ramp raises the wheel to the point where the flange tip is even with the top of the mainline running rail. Figure 2 shows this ramp and adjacent raised guarding surface on the toe-end casting.

Figure 2. Tread Bearing Ramp on Toe-End Casting

The tread bearing ramp places the wheel flange in contact with the running rail top surface. The wheel begins flange bearing at this point, crossing the mainline running rail, flangeway gap, and heel-end casting ramp before returning to tread bearing. Flange bearing is possible past the point of frog due to separation of the two flangeways. Figure 3 shows the heel-end casting with flange bearing ramp.

Figure 3. Heel-End Casting of Flange Bearing Turnout Frog

The running rail opposite the frog is plain rail on both routes. The diverging route has a guardrail, but the main route does not. The diverging route rail opposite the frog is tread bearing throughout. Thus, diverging traffic is flange bearing on the frog side only.

Design Analysis

An analysis of the design was conducted by TTCI. The effects of flange bearing on one rail only were determined using NUCARS® vehicle-track dynamics simulations. The study evaluated staggered ramp OWLS crossing diamonds and lift frogs.

The current design lift frog is economical to build and will relatively easily replace a railbound frog. However, the "flange bearing on the frog side while tread bearing on the guardrail side" design will generate some short duration, high magnitude lateral forces. This is acceptable for low speed diverging traffic applications like set-out tracks and industrial sidings on mainline tracks. It is not preferable for higher speed operations due to potential vehicle acceleration (ride quality) and track degradation (dynamic force) issues.

Figure 4 shows the predicted maximum axle L/V forces an empty hopper car will see as it traverses a staggered ramp diamond. This situation is the same as a lift frog, with one side flange bearing. The criterion for derailment in this situation is an axle L/V ratio above 1.36.[2] The current design frog meets AAR wheel climb limits under the current distance based criterion of 3 feet. The frogs did not meet AAR wheel climb limits under the previous time based criterion of 0.05 seconds.

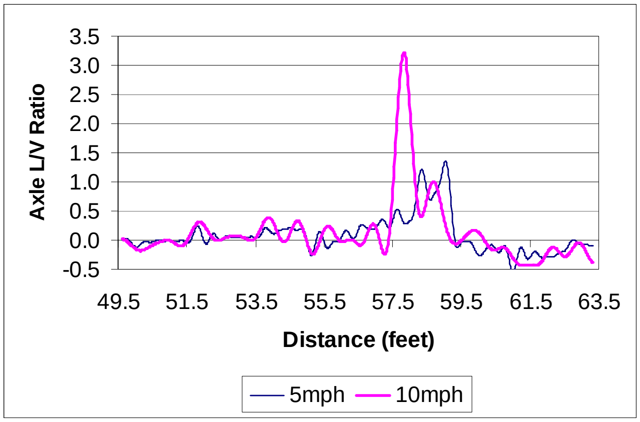

Figure 4. Predicted Lateral/Vertical Forces for Staggered Ramp Flange Bearing Simulations

Figure 4 shows that the adverse steering created by the staggered ramps is the source of concern on this design. When the same length ramps, configured to be parallel, are simulated, the high lateral forces are not present. The rolling radius difference created by having one wheel tread bearing and the other flange bearing can be as much as 3 inches. This causes a solid axle wheelset to steer in the direction of the tread bearing wheel. Also note that the problem is most severe for empty cars. The higher vertical load for loaded cars makes them less likely to derail.

Use of raised inside guards on the flange bearing portion of the frog and a sturdy guardrail on the diverging route rail opposite the frog will mitigate the potential for flange climb at these locations. In addition, the current applications (for industrial sidings and set-out tracks) are generally limited to walking speed operations (e.g., 2 to 5 mph). Under these conditions, the short duration lateral forces generated are acceptable.

Field Performance

TTCI is monitoring flange bearing turnout frogs at two locations: one on BNSF Railway and one on Canadian National. These locations include a set-out track in a two-track main line and a grain elevator siding in a single-track main line. Both locations have seen a relatively small proportion of diverging cars during their time in service.

Observation of these locations has shown that mainline operations are very smooth. The frogs show some dynamic action, presumably due to changes in vertical and lateral track stiffness through the turnouts, and they are quieter than railbound manganese frogs. Mainline route degradation has been mostly on the easers that allow transition of hollow tread wheel profiles across the frogs. Figure 5 shows the metal flow on the easer at the frog location in Leverett, Illinois.

Figure 5. Metal Flow on Frog Heel Mainline Easer Ramp

A set of cross section running surface profiles was measured at the frog location in Mayfield, Kansas. The amount of cross groove wear, from flanges crossing the mainline rail was estimated from these profiles. The amount of cross grooving varies with lateral position across the mainline rail. Where mainline wheel tread contact occurs, the grooving from diverging wheel flange bearing is being worn away. Near the field side of the mainline rail, where there is less mainline wheel tread contact, the cross groove is deeper. The cross groove is about 0.04 inch at its deepest location after about 1 year of service. Figure 6 shows a worn facet from the crossing wheels near the field side of the mainline rail.

To date, the frog has received a relatively small amount of diverging traffic (i.e., less than 1 percent of the mainline traffic). Cross grooving will be monitored over time to establish its effect on mainline ride quality and to determine maintenance limits.

An additional concern for the flange bearing turnout frog is the flange bearing running surface at the point of frog. The mainline running rail to frog casting joint seam will be a low spot in the crossing route running surface (see Figure 6). This running surface will be smooth for mainline wheels, but the rail-casting seam has the potential to generate lateral forces. Use of a raised guardrail on the diverging route will assure that the wheelsets successfully cross the mainline rail.

Figure 6. Mainline Rail Wear due to Crossing Wheels

Planned Research and Development

The flange bearing frog concept for industrial track turnouts is very promising in terms of the economics of very low diverging traffic sites. TTCI is investigating ways to extend the range of potential applications to include more diverging traffic. The dynamic simulations suggest that having a parallel ramp on the guardrail side will reduce wheel climb derailment risk at low speeds (i.e., 5 to 10 mph). Extending the ramps or lowering the ramp rate will reduce dynamic vertical loads, allowing speeds above 10 mph.

Figure 7 shows the predicted effects of an improved frog design with the guard side flange bearing ramp and ramp slopes that are half as steep (i.e., ramps that are twice as long) as the existing frog. With the improved ramps, high lateral forces are virtually eliminated in the range of operating speeds permissible for number 10-11 turnouts.

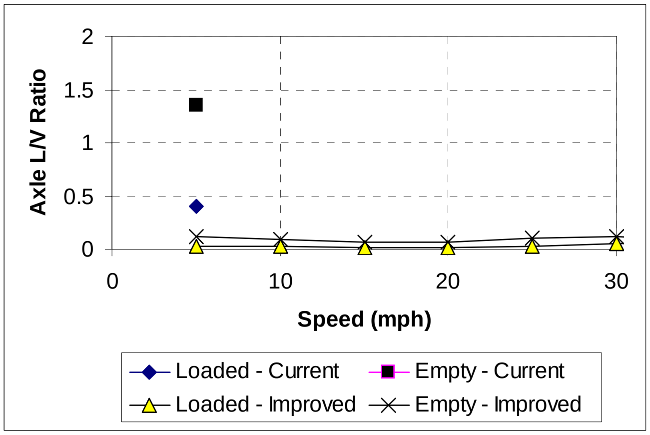

Figure 7. Predicted Lateral Forces for Current and Improved Lift Frog

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