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# Performance of a Moveable Point Frog under Heavy Axle Load Traffic

David D. Davis, Daniel Szablewski, Rafael Jimenez, and Joseph LoPresti

## Summary

Transportation Technology Center, Inc. (TTCI) evaluated the performance of premium frogs under heavy axle load (HAL) traffic in the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado. One of the frogs tested is a moveable point frog (MPF).

MPFs have been evolving for HAL service as the railways and suppliers continue to upgrade and improve the designs. Recently, TTCI installed a current generation No. 20 MPF with 136RE rail into the HTL. The frog was evaluated under 315,000-pound cars at 40 mph operating speeds. Traffic through the frog was accumulated at a ratio of 3:1 mainline versus diverging route.

The tested MPF performed well dynamically, reducing loads and improving ride quality as compared to fixed-point frogs. Maximum vertical forces for a 39,000-pound wheel load car at 40 mph were 54,000 pounds on the MPF. In comparison, maximum vertical forces for fixed-point frogs typically range from 60,000 pounds to 80,000 pounds. In addition, fixed-point frogs routinely trigger ride quality exceptions. These are measured vertical and lateral truck side frame accelerations above 4 g and 3 g, respectively. In comparison, the MPF rarely triggered ride quality exceptions. Many of these triggered exceptions were lateral accelerations.

However, the service lives of the wing rails were much shorter than expected. The wings failed from bending fatigue at machining marks on the base of each rail at 100 million gross ton (MGT) of mainline and 65 MGT of diverging traffic. This type of failure is known to occur in revenue service; although, the relatively low tonnage at which it occurred at FAST was unexpected. In revenue service, under 286,000-pound car traffic, these frogs are expected to provide a service life in excess of 1,000 MGT.

MPFs offer the improved performance of a continuous running surface for both routes through the turnout. The elimination of flangeway gaps, by the use of a moveable point, reduces dynamic loads. This results in significant reductions in maintenance and condition based speed restrictions for HAL operations. This further leads to longer service lives and increased capacity.



**INTRODUCTION**

MPFs offer the improved performance of a continuous running surface for both routes through the turnout. The elimination of flangeway gaps, by use of a moveable point, reduces dynamic loads. This decrease results in significant reductions in maintenance and condition-based speed restrictions for HAL operations, which further leads to longer service lives and increased capacity.

The improved performance comes with a first cost increase. A switch machine to throw the frog point and the associated signalling equipment is required for this frog. Thus, MPFs are used in locations where there is sufficient savings to justify the first cost premium. Many HAL and dual use corridors are potential candidates for MPFs.

MPFs have been evolving for HAL service as the railways and suppliers continue to upgrade and improve the designs. Recently, TTCI installed a current generation No. 20 MPF with 136RE rail in the HTL at FAST. Figure 1 shows the frog with the point centered for taking running surface profiles.



Figure 1. Moveable Point Frog in Test at FAST

Train operations consisted of 315,000-pound cars operating at 40 mph. The 4-axle cars have static wheel loads varying from 39,000 pounds to 40,000 pounds. Facing and trailing point moves are equal. The ratio of mainline to diverging moves varies with other track testing and track maintenance requirements, but is intended to be in the range of 3:1.

**Performance Measurements**

The performance of the frog was measured using several methods, which included the following:

- Component breakage from track inspections
- Dynamic loading from load measuring wheelsets
- Ride quality from an instrumented freight car
- Running surface wear from transverse profiles

**Service Life**

The frog had two broken wing rails in 165 MGT of operations. Both wing rail fractures required removal of the frog from service for repairs. The main wing fractured after 100 MGT of mainline traffic; however, the FAST train continued to operate over the frog for an additional 20 MGT on the diverging route while awaiting a replacement frog. The diverging wing rail failed after 65 MGT of diverging traffic. The two wing rails had similar failures, originating at the base of the rail near the location where a curved vertical cut started. Operating with the mainline wing broken lowered the bending stiffness of the frog, likely contributing to the failure of the branchline wing.

**Component Failure: Defect Root Cause Analysis**

Investigation of the defect root cause found that both main and diverging wing rails had similar failure mechanisms on the fracture surfaces. Both fractures originated at the curved wing base, which was ground when creating the radius. The grind marks made those locations notch sensitive during loading, which ultimately lead to the formation of fatigue cracks (Figure 2). Once those cracks propagated to a certain length, critical brittle failure follows.

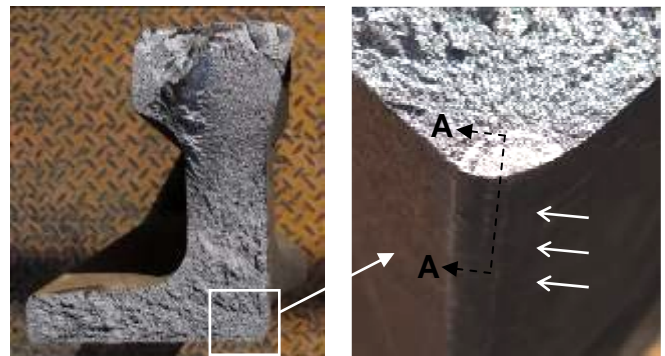


Figure 2. (L) Wing Rail Fractured Surface indicating Fracture Origin and Fracture Initiation Grind Marks (Multiple Arrows); (R) Cross-Section taken for Microstructural Analysis, A-A

Initial observation suggested that excessive grinding in the curved region may have led to the microstructural modification of the wing rail, consequently contributing to the fracture mode in both defects. However, microstructural analysis of the fatigue locations in both wing rail failures (A-A, see Figure 3) indicated that microstructures in the immediate subsurface of the fatigue defect were fully pearlitic and similar to the bulk wing rail microstructure.

This observation helped identify that the two contributing factors to the fracture failures were the presence of notch sensitive scratch marks and their location in a highly stressed tensile field found at the wing base. Elimination of the grind marks, while keeping the current smooth radius profile on the wing base, will most likely alleviate or in the least delay this fracture mechanism.

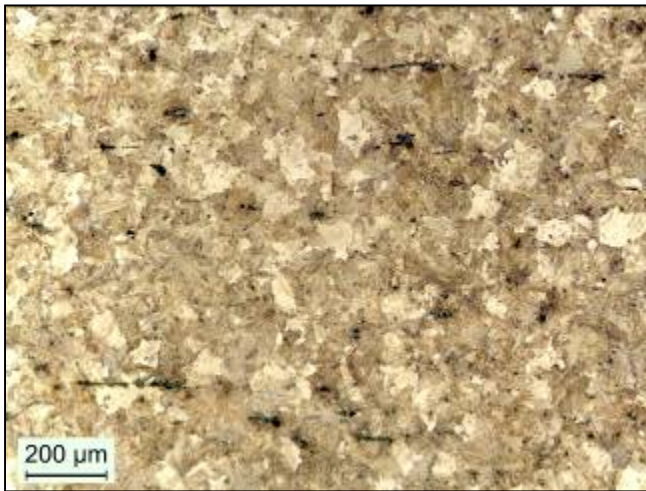


Figure 3. Micrograph of Cross-Section A-A indicating the Microstructure to be fully Pearlitic

**Wheel/Rail Forces**

Wheel and rail forces were measured on the frog using a 315,000-pound car equipped with instrumented wheelsets. Operations at 20, 30, and 40 mph were measured for all four routes through the turnout. Figure 4 shows a time history of the measured lateral wheel load and wheel contact positions at 40 mph in a facing point move.

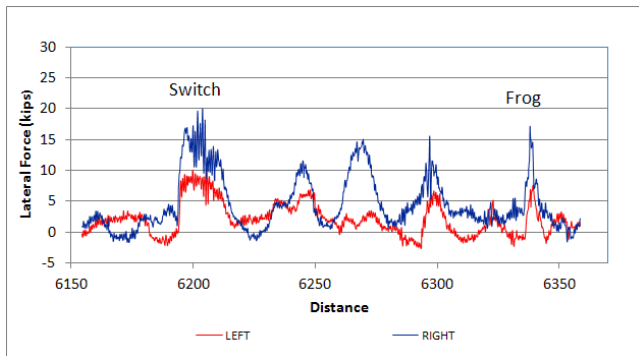


Figure 4. Measured Lateral Loads on the MPF at FAST (Lead Axle, 40 mph, Facing Point, Diverging)

The train was moving from left to right in the figure; passing through the point of switch at around 6,190 feet and the frog at around 6,345 feet. Note that the maximum lateral wheel load at the switch in this diverging move is 20,000 pounds. Also note that the maximum lateral load at the frog is about 17,000 pounds. The lateral load spike at the switch was expected, but the one measured at the frog was not.

As expected, the vertical wheel loads are relatively low, as compared to fixed-point frogs. The MPF does a good job of reducing dynamic loads from flangeway gaps. As Figure 5 shows, the maximum load at 40 mph is 54 kips. This compares well with the typical 60 to 80 kips measured on fixed-point frogs at 40 mph.

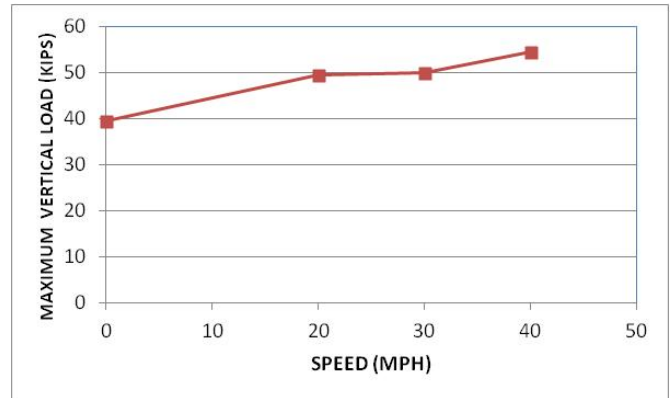


Figure 5. Measured Vertical Wheel Load on Moveable Point Frog at FAST

**Ride Quality**

As measurements taken at FAST show, the ride quality is good for a No. 20 frog. However, the frog had mediocre ride quality compared to what would be expected for open track. There were occasional truck side frame vertical acceleration exceedences of the 4 g threshold. There were also a few exceedences of the side frame lateral threshold of 3 gs. In comparison, the rail-bound manganese (RBM) frog in the turnout at the opposite end of the same siding has regular exceedences of the vertical threshold. This is shown qualitatively in Figure 6, which is a map of locations with side frame vertical exceptions for October 2011. There were none on the MPF (upper left in the plot) and many for the RBM (upper right in the plot). The exceptions are shown as flags all pointing to the frog location.



Figure 6. Vertical Side Frame Acceleration Exceptions FAST HTL October 2011

**Running Surface Wear**

Wear and metal flow of the MPF running surfaces was determined from a time series of transverse profiles. Data from the first 50 MGT of operations was used to determine wear performance. In general, the frog is wearing well, with low wear rates and fairly uniform wear throughout. Figure 7 shows height loss versus distance from the point of frog for the moveable point. The wear rate is relatively uniform from about 6 inches to about 18 inches from the point of frog. Beyond 18 inches, the wear rates are comparable to open track rails.<sup>1,2</sup> For fixed-point frogs, more proportionately wear is seen closer to the point of frog.

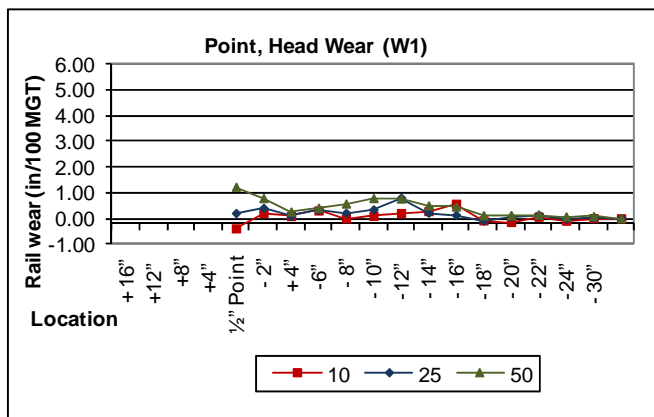


Figure 7. Point Height Loss vs. Tonnage

There is more lateral metal flow on the wing rails near the point of frog. This can be seen in the gage wear measurement as shown for the diverging wing in Figure 8. Note that the gage wear is negative, indicating that the rail is growing (i.e., plastic flow laterally).

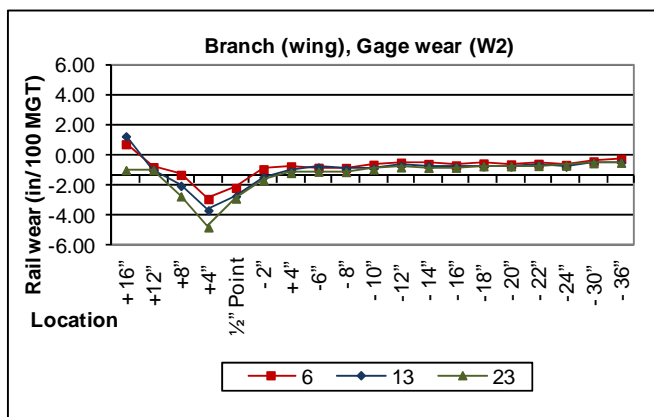


Figure 8. Frog Wing Lateral Wear vs. Tonnage

For comparison purposes, the cross-section area loss from a recently tested fixed-point RBM heavy point frog was compared to the MPF. Using the average cross-section area loss of the point from locations at 2, 4, and 6 inches from the point of frog, the plot in Figure 9 was produced. In the first 25 MGT, the MPF has about 40 percent less wear. Note that the RBM frog, due to the work hardening capability of AMS (austenitic manganese steel), has decreasing wear rates with tonnage. The MPF is likely to have a more consistent wear rate over time.

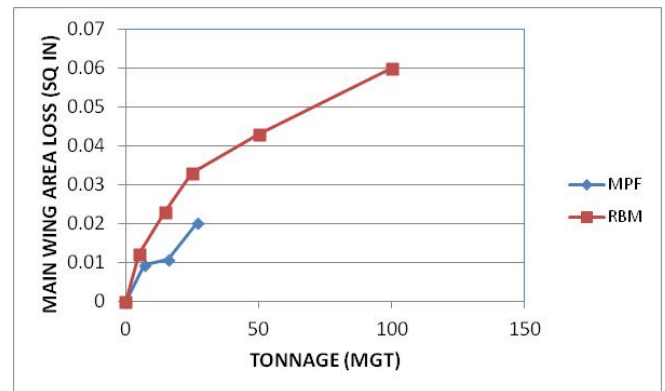


Figure 9. Frog Point Wear Under HAL Traffic

**CONCLUSIONS**

The MPF performed well dynamically, reducing loads and improving ride quality as compared to fixed-point frogs. However, the service lives of the wing rails were much shorter than expected. The wings failed from bending fatigue at machining marks on the base of each rail. This type of failure is also known to occur in revenue service. What was unexpected was the relatively low tonnage at which they occurred. In revenue service, under 286,000-pound car traffic, these frogs are expected to provide a service life in excess of 1,000 MGT.

**FUTURE WORK**

MPF designs provide significant dynamic performance benefits over fixed-point frogs. To be economic, these frogs must continue to provide a reliably long, low maintenance service life. Thus, industry efforts should be focused on developing a more robust frog wing rail design.

**REFERENCES**

1. Szablewski, Daniel, Semih Kalay, and Joseph LoPresti. 2011. "Preliminary Evaluation of Premium Rail Steels for Heavy Haul Operations," *Technology Digest* TD-11-031, Transportation Technology Center, Inc., Pueblo, CO.
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