TTCI TRANSPORTATION TECHNOLOGY CENTER, INC. TECHNOLOGY DIGEST

MAY 2021 TD21-011

The research described was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Key Findings:

- A frog at the end of its service life was removed and repaired using a semi-automatic robotic welding process, and then returned to service on the same rail line.
- The repaired frog was compared to the original frog casting to determine performance.
- The repaired frog has performed well in its first 65 MGT of revenue service traffic.
- Maintenance required has included grinding of the running surface plastic flow, typically seen on most frogs.
- The initial height loss (wear and deformation) for the repaired frog was significantly higher than for the original frog casting.
- The increase in initial height loss varied with the width of the frog point, decreasing toward the heel of the frog.
- The repaired frog developed a vertical warp, but this concave profile has not significantly affected the wing-to-point transfer for wheels.

Revenue Service Test of a Robotically Welded Frog

Stephen Wilk, Duane Otter, Benjamin Bakkum, and David Davis (retired)

Norfolk Southern Railway (NS) and TTCI conducted a revenue service test of a mainline Number 20 frog repaired using a semi-automatic robotic welding process. The frog has performed well in its first 65 million gross tons (MGT) of revenue service traffic since being reinstalled in-track in 2018.

Prior to repair, the frog was at the end of its service life. It previously served in the same heavily used route with several running surface weld repairs for approximately 382 MGT of service. Under a Federal Railroad Administration (FRA) program, the frog was rebuilt using a robotic welder. The scope of repair was significant, with approximately 4 feet of frog point and each wing rebuilt from the bottom of the flangeways to the finished running surface. Since re-installation, the repaired frog has been ground to remove metal (typical for frog weld repairs made by current railroad practice) and has not required a weld repair.

To determine performance, the repaired frog was compared to the original frog casting. It was installed in the same line as the original test location, making the traffic virtually the same between the two testing locations. Both turnout locations control passing sidings on a busy single-track route. However, train speed at each location may be different due to grade and the proportion of traffic using the diverging route at each location may be different.

BACKGROUND

The repaired frog was built in 2013 as part of an AAR-sponsored industry evaluation of frog designs.[1] It was built initially as a heavy point frog with conformal (lateral profile) running surfaces. The heavy point design means the frog point is wider than the theoretical design over its first 4 feet. At the 5/8-inch point (the physical start of the frog point) it is 31/32 inch wide. Figure 1 is a cross section drawing of standard and heavy point frogs at the 5/8-inch point.

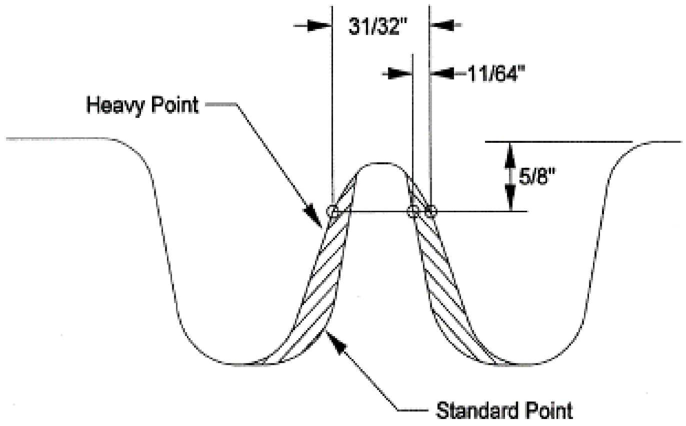

Figure 1. Heavy point frog cross-section

Figure 2 shows the original frog installed at Kings Mountain, Kentucky in 2013. Figure 3 shows the repaired frog at Corman, Kentucky, installed in late 2018.

Figure 2. Kings Mountain, KY test location

Figure 3. Corman, KY test location

TEST PROCEDURES

Testing involved a time series of measurements taken on the same frog before and after weld repairs were made. The inspections included visual examination of the frog for both track (geometry) defects and frog defects. Measurements included running surface transverse profiles throughout the wheel transfer zone for about 7 feet, centered on the 5/8-inch point of the frog. Running surface hardness measurements were also taken using a rebound-type hardness tester. The profiles were then overlaid to determine running surface wear. Due to differences in the running surface profiles between the original frog and the repaired frog, the performance of the wings could not be directly compared.[2] The portion of the frog point beyond the point slope provided the best comparison of the frog materials and was used in this analysis.

RESULTS

The weld repair has thus far proven to be durable. Figure 4 shows the running surface during the 65 MGT measurement. The running surface is almost free of cracking and spalling, with only a few spots on the frog point. Plastic flow has been managed through grinding, as can be seen in the grind marks on the gage corners of the wings. There is evidence of a smooth transition for wheels from wing to point (facing moves) and point to wing (trailing moves), as shown in Figures 4 and 5.

Figure 4. Running surface condition of weld repaired frog near 5/8-inch point

Figure 5. Running surface condition of weld repaired frog towards heel end of wheel transition zone

Note that there is minimal deformation on the wing gage corners and on the frog point, back toward the heel. The lack of gouges or worn grooves indicates that most wheels are transitioning with low dynamic loading.

While the wear is generally even (i.e., proportional to point thickness) throughout the weld repair, the rate of wear and deformation is significantly higher than that measured on the original casting material. Figure 6 shows height loss versus location for the first 60 MGT on each frog.

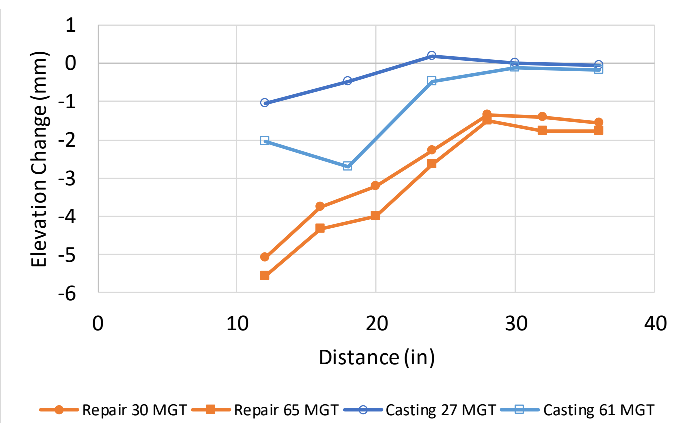

Figure 6. Frog point height loss versus distance from the 5/8-inch point

The height loss is measured from the centerline of the frog point. The ratio of weld repair to casting height loss ranges from about 4 mm at location +12 (from the 5/8-inch point) to 2 mm at location +36 after 30 MGT. The difference in height loss rate decreases as tonnage accumulates. A major disadvantage of a weld repair is difficulty hardening the running surface. The original casting was explosively hardened to ~360 Brinell hardness (BHN); whereas, the weld repair had a surface hardness of ~220 BHN.

This initial height loss difference can be seen in the cross section profiles taken on each frog. Figures 7 and 8 show each frog at location +28 (from the 5/8-inch point).

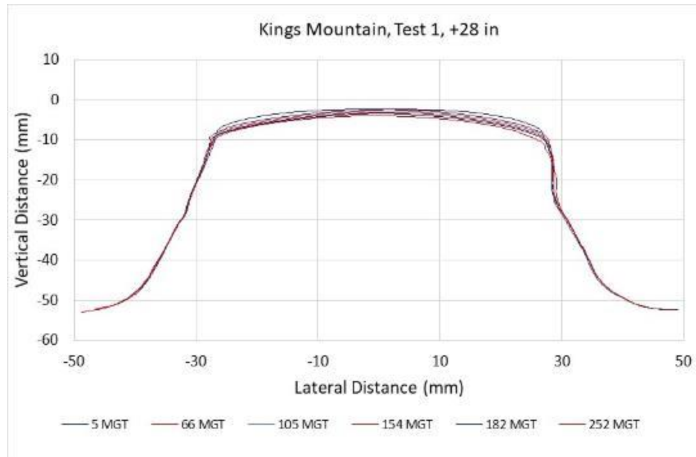

Figure 7. Original casting frog point profiles at +28 inches from the 5/8-inch point

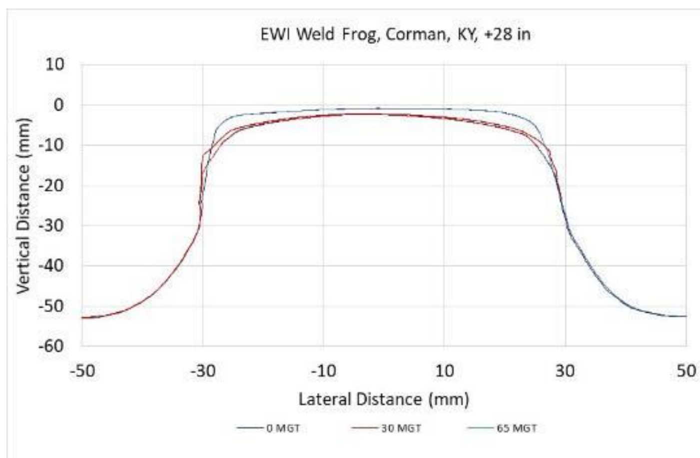

Figure 8. Repaired frog point profiles at +28 inches from the 5/8-inch point

The most obvious difference between the two frogs is the initial height loss after installation. The height loss in the first 30 MGT for the repaired frog is about an order of magnitude higher than it is for the original casting.

FROG WARPING

The repaired frog does exhibit a pronounced bowing of the casting, with the toe and heel ends being higher than the middle. This concavity was not noted at the 0 MGT measurement because the frog was placed on uneven ground near the tracks when measured prior to installation; however, it was noted at the first profile measurement made in-track at 30 MGT. It looked the same after 65 MGT of service. Figure 9 shows a side view of the frog in-track during the 30 MGT measurements. The photograph shows that the frog toe and heel ends are higher than the middle portion. It is not known whether the heat input from the rather large weld repair caused the frog to warp, but this possibility should be investigated.

Figure 9. Repaired frog in-track showing bowed shape

In addition to the bowing, casting cracks were noted just beyond the weld repair by inspection personnel.

CONCLUSIONS

Overall, the repaired frog has performed well in the first 65 MGT of service. Trains have operated smoothly over the frog with minimal dynamic action. Still, the wear rate of the weld repair is significantly higher than that of the original explosively hardened casting. The repaired frog exhibited a vertical bend with a low middle.

FUTURE WORK

Continued monitoring of the frog to determine the failure mode(s) and service life of the weld repair is necessary. Also, the vertical bending of the frog should be investigated to determine if the weld repair was the cause.

References

1. Jimenez, R., D. Davis, X. Shu, and I. Aragona. June 2016. “Performance of No. 20 Frogs of Various Designs in Revenue Service.” *Technology Digest* TD16-028. AAR/TTCI, Pueblo, CO.
2. Sasaoka, C., D. Davis, and D. Guillen. 2003. “Service Evaluation of Improved Running Surface Profile Frogs.” *Research Summary*, RS-03-004. AAR/TTCI, Pueblo, CO.

For comments or questions about this publication, contact Stephen_Wilk@aar.com