Conformal Frog Evolution at CSX

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Number of Words
2158

Abstract

Prior to 2007, CSX had been using the “flat top” rail bound manganese (RBM) frog as its standard. This style of rail bound manganese frog had limitations to adapting to the typical wheel profile. The inability to conform to the typical wheel profile, for both new and worn, leads to several undesired outcomes. The first is increased maintenance costs due to maintenance teams performing profile repairs. Another undesired outcome is high contact stresses caused by the difference in the frog profile to that of a typical wheel profile.

CSX began exploring an alternative design to address the performance of the flat top RBM frog. It was thought that the flat top RBM frog did not provide enough contact area between the wheel and the running surface of the frog. A running surface that conformed or matched a new wheel’s 1:20 slope was believed to be the ideal design. Working with track work suppliers, CSX settled on a conformal design that was thought to be sufficiently adapted to the typical wheel profile.

After several years of using the conformal design, issues began to surface for the number 20 frog. The issue was a premature crushing effect on the point of the frog. The location averaged to be approximately 16 inches to 18 inches behind the point of frog. The preponderance of these issues was found on CSX’s high speed, intermodal routes in our northern region. Several different designs were developed and tested over the years in hopes to alleviate the crushed point issue. These designs ultimately lead CSX to its current design for No. 20 frogs, both RBM manganese and boltless frogs.

Background

One advantage of the conformal shape is to distribute the loads over a larger area. The left photo below shows the smaller contact area using a 5/8 inch point versus the larger contact area for a 27/32 inch point as shown on the right photo 1. Another advantage to using a conformal design is that it protects the frog point and permits longer life before striking the first weld repair. CSX switched to heavy point same time as going conformal verse many other roads that already used heavy points prior to moving to conformal.
Fully Conformal Design

The initial design of CSX’s conformal frog came about in 2007 that used a 27/32 inch point, tapered heel, and a 1:20 slope for both the wing and points. The purpose of using the 1:20 slope is to match the 1:20 slope of a new wheelset. The notion behind matching both the wheel and frog slopes is to increase the surface contact patch. By increasing the surface contact patch, in theory, the contact stresses would be reduced. A 3/16 inch point slope over 10 inches was used instead of a 5/16 inch point slope over 15 inches as found for the standard number 20 AREMA frog. The wing had a 3/16 inch riser sloped over 24 inches. Before this design could be fully assessed, CSX abandoned this frog design as the industry went with a fully conformal design.

In 2008, CSX adopted the fully conformal design, along with its industry peers, for its standard frog for number 10s, 15s, and 20s. What was the standard in 2008 came with a 27/32 inch heavy point and a tapered heel. Both the point and wing had a 1:20 taper to match new wheels. It was not until 2010 when engineering field managers began contacting the CSX Engineering Standards department regarding issues with the No. 20 fully conformal frog.

Engineering field managers reported the point crushing typically 16 inches to 18 inches behind the point of frog as depicted in the photo 2. The immediate cause for the short lifespan before the fully conformal frog needed repair was not known. The most common and widely accepted cause was the population of hollow tread wheels was greater than what was estimated. Figure 1 below depicts a new wheel versus a hollow tread wheel.

The fully conformal design did not take into account the disproportionate excess number of hollow tread wheels. These hollow tread wheels ride on the wings longer than expected and at some point, transition onto the point. This transition from the wing to the point is believed to have larger impact loads than what the manganese steel is capable of withstanding. Figure 2 shows the 6 inch intervals that were used to help analyze worn wheel behavior. Figure 3 depicts a worn wheel at 18 inches behind the point of frog.
Figure 1 – new and worn wheel profiles

Photo 2 – Crushed point about 16 to 18 inches behind point of frog

Figure 2 – 6 inch sections used to help analyze worn wheel behavior
Many theories arose as to why the fully conformal frog was experiencing premature failures. To settle these theories, CSX conducted a study of all main line frogs on its intermodal route between New York and Chicago. Nicknamed the water level route, this route consists of over a 1,800 mile long stretch with mostly flat to some gentle grades with high speed intermodal traffic. 1,039 frogs were analyzed, including boltless frogs with a fully conformal running surface. To help with the analysis, teams were given specific items to record on a prescribed form, such as size of the turnout, right or left hand, types of frog plates, accumulated tonnage, installation date, tie and ballast conditions, guardrail type, facing direction (i.e. east or west), rail weight, manufacturer, casting manufacturing location, and timetable speed.

Engineering Standards analyzed the data to find a common trait for those frogs that were deemed in less than desirable condition. After careful analysis, no trait was found to be tied with any failed frogs. Nonetheless, something had to change in order to provide a better service life to CSX.

Some engineering managers believed the use of hook twin plates caused premature failure. The reason for this was that the use of hook twin plates was thought to not adequately prevent movement of the frog. Maintenance teams favor the use of hook twin plates over milled seat plates. Milled seat plates come with panelized turnouts. The hook twin plates’ popularity over milled seat plates comes from the ease of installing them. Cost is another factor. In the end, the use of hook twin plates was ruled out as a contributing factor for the short life span of the fully conformal frog.

One takeaway from the water level route study is the boltless conformal frogs had a lesser propensity to develop the crushed point. During the study, several spot checks were made on the austenitic manganese steel’s hardness. On average, the boltless conformal frogs were found to be 10-15 Brinell hardness number (BHN) points lower than their rail bound manganese counterparts.

The belief as to why the boltless conformal frogs performed better, albeit slightly better, is that the manganese steel was better able to conform to the territory’s average wheel set. The somewhat “softer” metal was able to transform at a rate that reduced the propensity of cracking. The standard AREMA BHN value of 352 is believed to be just hard enough to not allow the austenitic manganese steel to reshape to the average wheelset for that route. Slightly softer casting results in accelerated false flange wing grooving.

Initial Modified Design Test from Full Conformal

After evaluating the first design, CSX Engineering Standards, along with Progress Rail Services developed a new conformal frog called the design modified or DM for abbreviation. The designed modified conformal frog kept the 1:20 conformal point along with the 3/16 inch point slope over 10 inches and but added a longitudinal slope on the wing. The wing longitudinal slope sloped approximately 3/16 inch in height over 18 inches in length to be level with the top of wing rail, as depicted by figure 4.
Section D-D, as depicted by figure 5, shows two contact patches. At 18 inches behind point of frog using the design modified frog, the wheel contact patch area increased.

Figure 4 – 3/16 inch point slope over 18 inches with corresponding cut sections

Figure 5 – Wheel contact at 18 inches behind point of frog

Despite the best efforts of trying to improve the longevity of the frog, the design modified frog did not last as long as expected. The design modified frog performed somewhat worse than its predecessor. At the second sixth month interval inspection or one year after the installation, the frog’s point began to show signs of crushing. Another design modified frog was tested at a different location and that frog, too, suffered the same fate.
Multi-Design Test

Three types of conformal frogs were tested on one of CSX’s high speed, high tonnage routes. A total of five frogs, of three varying designs were tested. Two frogs tested the traditional AREMA “flat top” design. Two other frogs tested a flat wing with a conformal point while another tested the fully conformal design with a lower BHN value.

Each of the three types of test frogs was tested for various reasons. The AREMA “flat top” was tested simply for the ease of repairing the frog. CSX’s frogs used a flat running surface prior to switching to the fully conformal design. To utilize the perceived benefits of a conformal point, CSX opted to test a flat wing using a conformal point. Last, the fully conformal design with a lower BHN value was tested due to the conditions found on the Water Level route study.

A good test needs to have a control along with a variable. These three types of conformal test frogs were installed in locations that previously had failed standard fully conformal frogs. Follow-up inspections were performed with a representative from Progress Rail Services and the regional welding manager to track the performance. These follow-up inspections were conducted at three month intervals.

Items, such as accumulated tonnage, surface wear, and weld repair, if conducted, were recorded at each inspection. Inspections included photographs to record wear using prescribed gauges that were agreed upon by all personnel involved. Inspection team members observed each other as someone took measurements, thereby preventing any doubts as to the accuracy of a measurement.
The flat wing with a conformal point was selected as the new design after having accumulated over 61 million gross tons (MGT) on the Great Lakes division. CSX’s other two frogs with flat wings and conformal point had accumulated just over 100 MGT in two years on the Albany division. The two frogs with the flat wing and flat point failed along with the fully conformal design with a lower BHN at 67 MGT and 84 MGT, respectively.
Current Design

The current number 20 frog at CSX uses a flat wing with a 1:20 conformal slope along with the 5/16 inch slope over 15 inches. CSX calls this frog the hybrid frog due to the mix of using a flat wing with a conformal sloped point. CSX switched from the fully conformal frog to the hybrid design in late 2015. Because the premature crushing of the point was only an issue for number 20 frogs, CSX kept the fully conformal design for its number 10s, 15s, and even for its maintenance number 16 frogs.
Photo 6 – Flat wing with conformal point – no cracking nor crusing

Lessons Learned

Many of the assumptions on wheel to rail relationships were thrown out the window after the conclusion of the water level route study along with the multi-design test frogs on the Great Lakes division. To design a frog to solely accommodate a new wheel profile is inadequate simply due to the large population of hollow tread wheel profiles. Milled seat plates are preferred but are not a necessity for optimum performance of a fully conformal frog.

Conclusion

Results of the hybrid conformal frogs are promising. Engineering Standards, along with the regional welding manager, continue to monitor the original test frogs to determine the life expectancy of this design. The most demanding test environments proved the concept worthy enough to change the standard. After nearly nine years of evaluating various designs, CSX has selected its number 20 frog for the long term.

Although the majority of the issues were found on CSX’s high speed intermodal routes, the hybrid design will benefit other areas of the network, including those with slower speeds. Many years went by before finding the optimum design that is a “one size fits all”. CSX wishes this design may benefit other railroad owners and operators, so that they too, can benefit.
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**Background**

- Prior to 2007, CSX used flat top frogs
  - Limitations to adapting to typical wheel profile - both new and worn
  - Maintenance costs from high contact stresses

**Background**

- Fully conformal frog introduced to CSX in 2008
  - 1:20 slope to match slope of new wheel
  - 27/32” heavy point
  - Tapered Heel

**Perceived Advantages:**
- 1:20 slope to match slope of new wheel
- Increased surface contact area
  - Reduced stresses
  - Longer service life

**Conformal Design**

**Initial Design:**
- Released in 2007
- 27/32” heavy point and tapered heel
- 3/16” point slope over 10” (No. 20)
- Wing had a 3/16” riser sloped over 24”
- Long term success unknown as industry preferred fully conformal design

**Conformal Design**

**Fully Conformal:**
- Adopted in 2008 as CSX standard
- 27/32” heavy point and tapered heel
- 3/16” point slope over 10” (No. 20)
- No wing slope
Conformal Design

Fully Conformal:

- Issues began to surface in early 2010 for No. 20s on intermodal routes
- Field managers reported crushing of point 16 to 18 inches behind the point
- Many theories arose to cause – use of hook twin plates suspect

Conformal Design

Fully Conformal:

- Detailed study needed to find common denominator
- 1,039 frogs analyzed on “Water Level Route” between New York City and Chicago
- All aspects considered – plates, surface, etc
- No stone left unturned!

Conformal Design

Fully Conformal:

- Test started early June 2012
- 27/32” heavy point and tapered heel
- Kept 1:20 conformal point along with 3/16” point slope over 10” (No. 20)
- Difference: Wing sloped approximately 3/16 inch over 18 inches
Conformal Design
Design Modified:

Cut sections used for analyzing wheel contact

Section “D-D”

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Conformal Design
Design Modified:

Crack outlined with chalk – June 25, 2013

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Conformal Design
Design Modified:

Depression above crack

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Conformal Design

Three New Designs Tested:

- Flat Top / Flat Point
- Fully Conformal with lower BHN – similar to Boltless Fully Conformal Frogs
- Flat Top with Conformal Point (Hybrid)
- Tested in locations with history of failures

Conformal Design

Flat Wing / Flat Point:

Depression above crack

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Conformal Design

Two-Shot Explosive Depth Hardening:

Point is crushed out

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Conformal Design

Two-Shot Explosive Depth Hardening:

Point is crushed out

Conformal Design

Flat Wing / Conformal Point (Hybrid):

Conformal Design

Flat Wing / Conformal Point (Hybrid):

Conformal Design

Lessons Learned:

- Many assumptions on wheel to rail relationships were thrown out after multi-design test frogs
- Do not design to solely accommodate new wheel
- Population of hollow tread wheels are larger than anticipated
- Milled seat plates are not a necessity

Conformal Design

Conclusion:

- Results of hybrid conformal frogs are promising
- Original test sites still monitored to determine life expectancy
- Most demanding locations proved concept worthy to change standard
- Benefit other areas of CSX network (southern region) and other railroads
Conformal Frog Evolution at CSX

Thank you!