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Performance of Thermite Head Defect Repair Welds at the Eastern Mega Site

Megan Archuleta and Kyle Ninness

Summary

In October 2013, thermite head defect repair welds from two different suppliers were installed at the eastern mega site near Princeton, West Virginia on the Norfolk Southern (NS) Railroad. Eight head defect repair welds in total were installed on two 6.8-degree curves. Two welds from each supplier were installed on the high rail and two welds from each supplier were installed on the low rail of each curve. These welds had accumulated 120 million gross tons (MGT) as of August 2016.

The head repair welds at the eastern mega site have demonstrated the following performance:

- All eight head defect repair welds had surface rolling contact fatigue (RCF) and minimal metal flow at the heat affected zones (HAZ).
- Supplier B low rail welds contained small amounts of shelling or pitting near the HAZ. Supplier A low rail welds contained a greater amount of shelling or pitting throughout the weld material as well as the HAZ.
- Periodic preventive grinding has been conducted on these test welds, which has kept the RCF and the metal flow from the soft HAZ under control.
- There have been no weld failures to date.

Thermite head defect repair welds were developed as an alternative repair process to the conventional thermite weld procedure that consists of removing a section of rail with the defect and replacing it with a plug with two welds at each end. By only removing the section of the railhead where the defect is located, fewer welds are needed, the web and base of the rail remain intact, and the neutral rail temperature and longitudinal rail stress are preserved. The process for both suppliers can repair the head of a rail or weld by the use of a single head defect repair weld if the defects are less than 2 inches long.

The work presented in this digest was conducted by the Transportation Technology Center, Inc., in conjunction with NS, and is funded by the Association of American Railroads and the Federal Railroad Administration.

Please contact **Megan Archuleta (719) 584-0636** with questions or concerns regarding this *Technology Digest.* E-mail: **megan_archuleta@aar.com**.
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INTRODUCTION

Head defect repair welds were developed as a way to eliminate the need for a rail plug and additional field welds by only cutting out the section of the railhead that contains the defect. The time it takes to go through the head defect repair weld procedure for both suppliers is less than the time it would take for one welding crew to align and pour two welds that would be necessary when installing a plug. The major benefit of a head defect repair weld is that it does not change the longitudinal rail stress since the rail is not cut. Two suppliers have developed their own versions of the head defect repair weld.

Supplier A's practice involves milling a slot into the rail or weld head with a depth of 1 inch from using a modified Matweld frog grinder. This process can remove defects that are within 1 inch in depth from the running surface and 2 inches in length longitudinally. Air/propane is used in this process to preheat the rail for 6 minutes prior to pouring the weld.

Supplier B's practice is to mill out the full depth of the rail head using a dedicated Portico grinder with spark shield. This process can remove defects that are within the depth of the railhead including 0.25 inch below the head fillet and less than 2 inches in length longitudinally. Oxy/propane is used in this process to preheat the rail for 3 minutes prior to pouring the weld. This process is similar to the standard thermite installation process typically used at the eastern mega site. Figure 1 shows each process.

For both methods, the weld portion is poured into a slot using materials and processes that are similar to those used for conventional thermite welds, according to each supplier's guidelines.

Figure 1. Slots cut out for railhead repair welds. The process for Supplier A requires a 1 inch slot (left) and Supplier B's process requires the slot to be the depth of the full railhead (right).[1]

FAST TESTING AND RESULTS SUMMARY

In 2010, Transportation Technology Center, Inc. (TTCI) completed the testing of head defect repair welds from two suppliers at the Facility for Accelerated Service Testing (FAST) High Tonnage Loop (HTL) in Pueblo, CO.

With the last round of testing at FAST, multiple improvements were made.

Both manufacturers modified and improved their welding procedures and processes before the welds were installed on the HTL. The overall weld performance of the railhead repair welds improved greatly when TTCI and the suppliers implemented periodic rail grinding every 25 MGT.[2] Based on the results from the tests at FAST when the welds were exposed to increased accumulated tonnage in a controlled environment, railroad advisory committees recommended that the welds be installed in revenue service at the eastern mega site in West Virginia, to determine their performance in a revenue service environment.

EASTERN MEGA SITE INSTALLATION

In 2013, eight head defect repair welds total were installed at the eastern mega site in two 6.8-degree curves that are 1 mile apart. Figure 2 shows their layout.

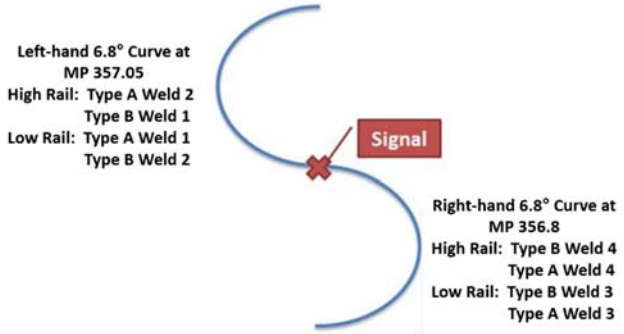

Figure 2. Head repair welds test layout at the eastern mega site.

Two welds from each supplier were installed 20 feet apart on the high rail and on the low rail in each curve to minimize preferential effects due to the location in the curves on any one weld supplier's product. All welds were made over new premium RMSM DHH 136 lb. rail.

At the beginning of this study, the head defect repair welds at the eastern mega site were not to be ground in order to limit metal loss to wear, and to gain more accurate wear information from the longitudinal profiles. However, after significant RCF was found on the rail in that section of track after 23 MGT, a grinding schedule was implemented.

RESULTS

As of August 2016, all eight of the head repair welds were still in track and had accumulated 120 MGT. The trains run at a train speed between 15-25 mph and a balanced speed of 23 mph through this section of track, causing welds on the low rail of curves to be exposed to the highest load and higher rates of running surface deformation. Therefore, the performance of the low rail welds from each supplier is the major focus of this study.

Overall, the welds on the high rail of each curve are visually in good condition with the exception of some RCF and minimal metal flow in the HAZ.

Figure 3 shows two welds, one from each supplier installed on the low rail of each curve at the eastern mega site.

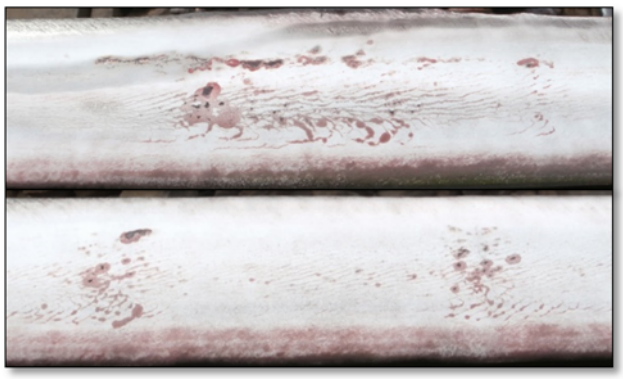

Figure 3. (Top) Supplier A head defect repair weld installed on the low rail. (Bottom) Supplier B head defect repair weld installed on the low rail.

These welds are representative of the other low rail welds in the 6.8-degree curves and dye penetrant was used to contrast the surface for these images. Supplier B head defect repair weld installed on the low rail is showing minor RCF throughout the whole weld and HAZ and minor pitting only in the HAZ. Supplier A head defect repair weld installed on the low rail is showing an increased amount of RCF throughout the weld material and HAZ however the pitting is seen not only in the HAZ but in the weld material location.

Visual inspections and subsequent measurements have been conducted on a semi-annual basis to monitor and document the performance of the test welds. NS has provided periodic manual ultrasonic scanning to monitor the welds for the development of internal defects; however, no internal defects have been found thus far.

Figure 4 shows longitudinal profiles taken using a portable profilometer before and after the curves were ground since installation. The resulting longitudinal profile includes the parent rail, HAZ, and weld material on each side of the weld centerline.

Figure 4. Portable profilometer apparatus sitting on the magnetic stand connected to the rail.

TTCI collected longitudinal profiles for the welds and plotted the profiles. Figure 5 shows the profiles of two low rail head defect repair welds, one from Supplier A (top) and one from Supplier B (bottom).

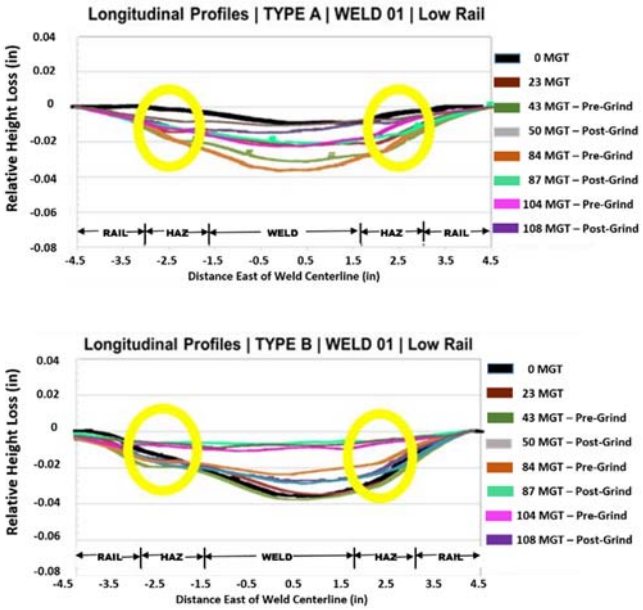

Figure 5. Longitudinal profiles of two welds, one from each supplier, on the low rail of the 6.8-degree curves. Type A refers to welds from supplier A and Type B refers to supplier B.

Both of these welds are located on the low rail of the curves at mile post 357.05. Figure 5 shows a type of overlay that places the profiles based on constant or unchanging reference on the head of the parent rail. As a result, the overlays highlight wear rates of the weld relative to the parent rail by the distance between the successive profiles. One measurement for the Supplier A weld was corrupted and removed from this graph. Pre grind and post grind measurements are noted in Figure 5. Post grind measurements were taken at 50 MGT, 84 MGT, and 108 MGT.

The same trend seen with the normal running surface wear for a standard thermite weld is also seen in the profiles for the head defect repair welds. The HAZ location on either side of the weld center batters faster than the rest of the running surface. The yellow circles on both welds in Figure 5 show HAZ dipping of 0.02-0.03 inch. The difference between the initial measurements (black lines) for both suppliers is not due to Supplier B's weld wearing more than the other, but because Supplier B's weld was offset when poured. However, subsequent grinding has corrected the initial offset of this weld after 87 MGT.

Figure 6 shows the surface hardness values that were also measured at five locations for each weld. These included parent rail at approximately 12 inches from the HAZ, at the HAZ, at weld material adjacent to the weld on the negative and positive side of the weld centerline, and at the centerline.

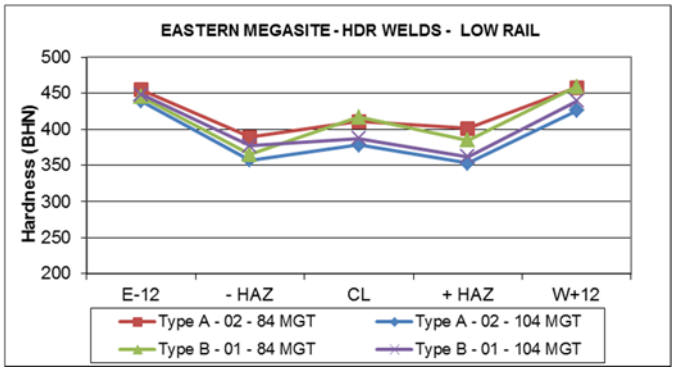

Figure 6. Most recent weld hardness for low rail head defect repair welds. Post grind measurements are shown with the data taken at 84 MGT. Type A refers to welds from supplier A and Type B refers to supplier B.

The hardness values measured at the centerline were slightly lower than those of the parent rails, which are head-hardened premium rails. As expected, the hardness results measured in the HAZ were lower than those measured for both the parent rails and the welds.

CONCLUSIONS

As of August 2016, the head defect repair welds installed at the eastern mega site are performing as expected in the HAL operating environment.

At 104 MGT, all eight of the welds had surface RCF. The low rail welds also contained small amounts of shelling or pitting near the HAZ. Supplier A low rail welds contained small shelling or pitting throughout the weld material as well. Periodic preventive grinding has been conducted on these test welds, which has kept the RCF and the metal flow from the soft HAZ under control.

In general, the performance of the head defect repair welds from both suppliers at the eastern mega site is similar to the performance of those at FAST with regard to small amount of RCF, HAZ metal flow, and pitting that were observed on the low rail head defect repair welds.

TTCI will continue to monitor the performance of all eight welds at the eastern mega site and report on their progress.

The eastern mega site is part of a joint research program funded by the Association of American Railroads and the Federal Railroad Administration and hosted by NS. This site provides a HAL revenue service environment needed to investigate the effects of HAL operations on track components.

REFERENCES

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2. Gutscher, Daniel. "Thermite Railhead Repair Weld Test at Facility for Accelerated Service Testing." *Technology Digest* TD-11-050. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado. December 2011.

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