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Thermite Railhead Repair Weld Test 2 at Facility for Accelerated Service Testing

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Summary

In 2009 and 2010, Transportation Technology Center, Inc., (TTCI) installed thermite railhead repair welds for the second in-track test at the Facility for Accelerated Service Testing (FAST) High Tonnage Loop (HTL). The welds were provided by Railtech Boutet, Inc. and Orgo-Thermit, Inc. and installed for three different applications: (1) in June 2009, over the cribs between ties, (2) in March 2010, on electric flash-butt (EFB) welds, and (3) in July 2010, directly over ties.

Overall weld performance for the second test of railhead repair welds has significantly improved over that of the first test conducted in 2008 and 2009. This can be attributed to TTCI's implementation of periodic rail grinding and to manufacturer improvements in weld design and procedures. Grinding was conducted at approximately 25 to 35 MGT intervals with the goal of remediating heat affected zone batter and preventing associated shelling damage. Railtech Boutet increased the size of its mold to reduce dipping at the running surface adjacent to the welds and improved their installation procedures. Orgo-Thermit increased the depth of its slot and improved the venting to improve weld performance.

As of June 2011, the thermite railhead repair welds at FAST HTL have demonstrated the following heavy axle load service performance:

- Ten welds, five from each manufacturer, were installed over cribs between ties. The welds have accumulated 168 million gross tons (MGT) with no failures. One weld has developed shelling of the gage corner.
- Ten welds, five from each manufacturer, were installed over EFB welds. The welds have accumulated between 102 and 116 MGT depending on the date of installation. One fatigue crack was found in a weld by routine rail flaw inspection at 102 MGT. The crack was located at flashing under the railhead about 1 inch away from the EFB weld. Another weld was removed due to an unrelated adjacent rail break. Initial results indicate that thermite railhead repair welds may be useful for repair of head defects in EFB welds.
- Eight welds, four from each manufacturer, were installed above ties. Two welds located over concrete ties fractured at 52.1 and 64.7 MGT. The remaining welds have accumulated 67.0 MGT.

Railhead repair welds enable the repair of narrow head defects in rail without cutting the rail. This preserves the rail stress-free temperature by maintaining the base and web integrity. An estimated 36,000 railhead repair welds can be performed annually in North America using thermite railhead repair welds. The estimated number of repair welds may be increased if railhead repair welds can be successfully implemented on defective plant welds. Conversely, the estimated number of repair welds may be reduced if the process is found unsuitable for use over ties.

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INTRODUCTION

In 2008, TTCI in cooperation with two North American thermite weld vendors began testing thermite railhead repair welds in track at FAST. The test ran for approximately one year, and the welds accumulated 116 MGT of traffic. Similar to standard thermite welds at FAST, the dominant degradation mode was shelling.[1] Of the welds that remained at the end of the test, 100 percent were experiencing shelling at the gage corner regardless of the manufacturer.

During that first year of testing, both manufacturers continued to modify and improve their welding procedures and processes. At the request of the Association of American Railroads' Heavy Axle Load Engineering Research Committee (HALERC), TTCI conducted another round of in-track testing for the improved thermite railhead repair welds. In June 2009, Test 2 thermite railhead repair welds were installed at FAST HTL. Welds were installed over cribs between ties in Section 31. In March 2010, Test 2 was expanded to include testing of railhead repairs made on EFB welds. In July 2010, the test further expanded to include testing welds installed directly over ties. Figure 1 shows the location of the welds in Test 2 at FAST HTL.

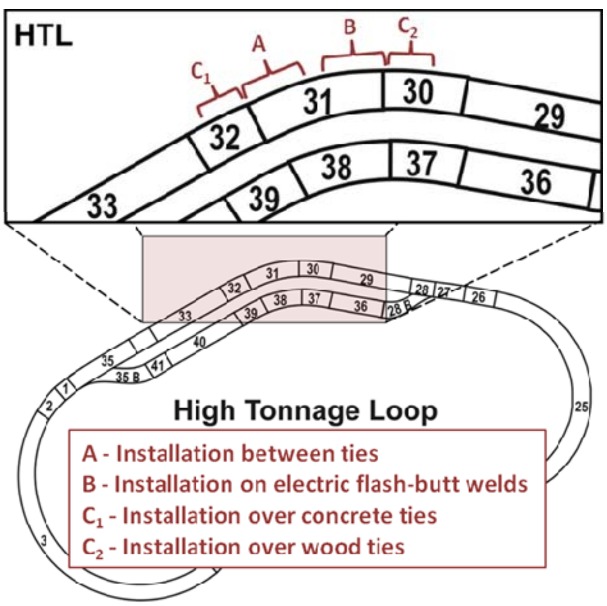

Figure 1. Locations of Railhead Repair Weld Tests at FAST HTL

Track components rapidly accumulate tonnage in a controlled environment at FAST. Sections 30, 31, and 32 accumulate about 120 MGT per year. The FAST consist utilizes 115 cars with a gross weight of 315,000 pounds each. The train typically operates at about 40 miles per hour through section 31, which has a balance speed of 33 miles per hour. This places increased vertical and lateral loads on the high rail. This environment enables TTCI to test welds at loading conditions that typically exceed those in revenue service in North America. Welds that perform well under the FAST environment can be expected to perform at least as well in revenue service in North America.

WELD INSTALLATION OVER CRIBS

For Test 2, TTCI installed 10 thermite railhead repair welds, five from each manufacturer, in Section 31 of FAST HTL. The welds were made in rail between ties at approximately 20-foot intervals in a concrete tie zone with 24-inch tie spacing. The primary difference between Test 2 and Test 1 is that Test 2 implemented periodic maintenance rail grinding to better replicate how welds perform in revenue service conditions. Rail grinding is not typically performed at FAST due to the use of rail lubrication and the conformal nature of the wheels and rails, which minimizes contact stresses and produces little rail damage in the form of rolling contact fatigue or spalling. Maintenance rail grinding was performed in the test zone at 12, 36, 64, 102, and 125 MGT.

Weld hardness followed a typical work hardening pattern where hardness rapidly increased early in weld life followed by a general decrease in work hardening rate. Pre grind and Post grind heat affected zone (HAZ) hardness differences became more evident at the 61 MGT measurement cycle, with the post grind hardness measuring 15 to 30 Brinell lower than the pre grind measurements.

The running surface for each weld type quickly developed the typical batter in the HAZ. The initial grinding at 12 MGT effectively removed the accumulated batter without eliminating early gains in running surface hardness at the HAZ. Figures 2 and 3 show the running surface profiles for Orgo-Thermit and Railtech Boutet welds, respectively. As with all thermite welds, batter of the HAZ occurs very quickly. The dipping of the HAZ causes high impact loading at the weld that promoted shelling as observed in the first round of testing in 2008. Rail grinding removes high spots to produce a smooth running surface. As a result, a gentle dip develops across the weld over time that results in lower impacts at the weld than those created by the HAZ batter. Rail grinding appears to have become less effective in subsequent grindings as a result of cumulative gains in HAZ hardness and corresponding reduced formation of batter.

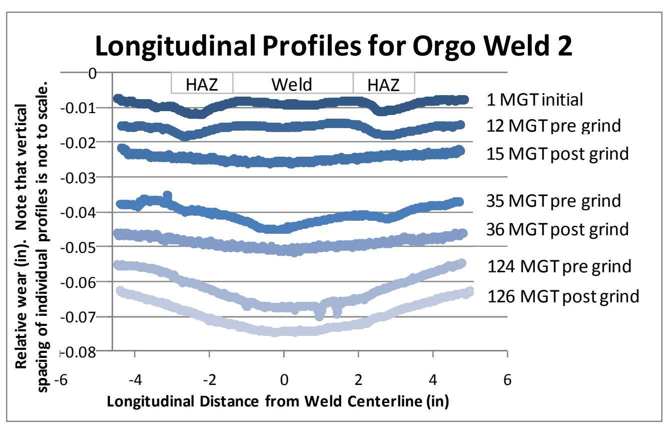

Figure 2. Longitudinal Profiles for Orgo Weld No. 2

Note that vertical spacing of the welds does not represent the amount of wear between measurements or total wear. Spacing was chosen to aid comparison of before and after grinding profiles.

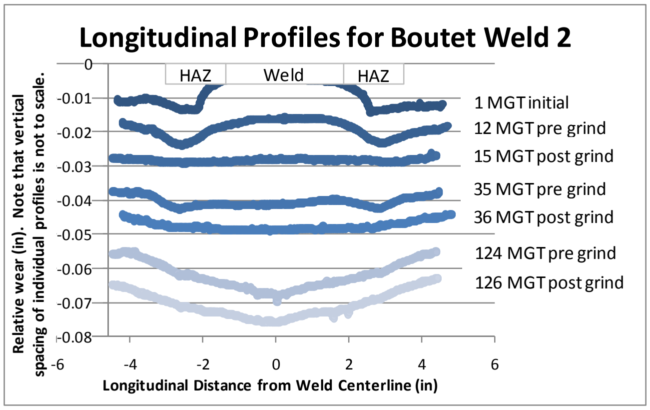

Figure 3. Longitudinal Profiles for Boutet Weld No. 2

Note that vertical spacing of the welds does not represent the amount of wear between measurements or total wear. Spacing was chosen to aid comparison of before and after grinding profiles.

WELD INSTALLATION OVER EFB WELDS

TTCI was tasked by the Rail Weld Technical Advisory Group, comprised of several Class I railroad members, to investigate the potential for using thermite railhead repair welds to make repairs over defective plant welds. Laboratory testing conducted by TTCI revealed a complex longitudinal residual stress pattern in the weld combination that oscillated between compression and tension through the weld from top to bottom.[2] Based on the laboratory test results, TTCI decided to proceed with in-track testing.

In preparation for the test, TTCI installed 10 EFB welds on the high rail of a 5-degree curve using a mobile flash welding unit. Welds were spaced at 20-foot intervals throughout the first 200 feet of FAST HTL Section 31, which consists of wood ties spaced at 19.5 inches and elastic fasteners.

The railhead repair welds were installed on the EFB welds using the same procedure used for installation on rail. Slots were ground in the head of the EFB welds and were crowned according to each manufacturer's welding procedure (approximately 0.050 inch for Orgo-Thermit and 0.030 inch for Railtech Boutet). In addition to the standard weld procedure, TTCI ground the EFB weld collars to enable a better fit between mold and rail thereby reducing the potential for flashing under the railhead.

The welds have received rail maintenance grinding at 1.5, 35, 51, and 71 MGT. As of June 2011, the welds have accumulated between 102 and 116 MGT, depending on the actual installation date. Periodic rail flaw detection found one Railtech Boutet weld that had a fatigue crack growing into the web. The crack initiated at flashing under the railhead about 1 inch from the EFB HAZ. Figure 4 shows the weld and crack. Figure 5 shows an internal macro etch view of the crack that reveals the crack propagation up into the railhead toward the thermite weld and downward into the rail web away from the EFB weld. Flashing under the railhead has been previously identified as a potential crack initiation site.[1,2,3] Another weld was removed due to an unrelated adjacent rail break.

Figure 4. Magnetic Particle Inspection of Crack under Railhead (Arrow indicates location of crack initiation behind flashing under the railhead.)

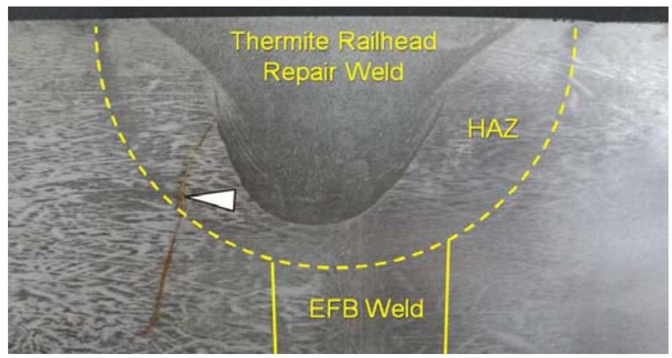

Figure 5. Macro Etch of Longitudinal Centerline Cut (Arrow shows part of visible crack nearest to origin.)

WELD INSTALLATION OVER TIES

Standard thermite welds are not typically installed over ties due to space constraints and the need to access the base of the rail. Additionally, weld geometry on the base of the rail is not compatible with the tie plates and creates extreme stress conditions that are detrimental to weld life. Unlike standard full section thermite welds, thermite railhead repair welds do not require access to the bottom of the rail or alter the geometry at the base of the rail. This creates the potential for installing railhead repairs over ties.

In the first round of testing (2008-2009), TTCI installed four Orgo-Thermit welds over ties to explore how the welds would perform. Of these four welds, two fractured due to fatigue that initiated under the railhead, and one was removed due to shelling. The two welds that fractured failed at 20.3 MGT and 85.5 MGT.[1]

In 2010, at the request of HALERC, TTCI installed eight welds over ties, four from each manufacturer. Two welds from each manufacturer were installed over wood ties (Section 30) and two welds were installed over concrete ties (Section 32). When welding over concrete ties, the weld molds from both manufacturers had to be filed on the bottom outer edge to clear the shoulder inserts in the ties.

As of June 2011, the welds installed over ties had accumulated 67.0 MGT. Both Orgo-Thermit welds located over concrete ties experienced fatigue fractures, which occurred at 54.0 MGT and 64.7 MGT. The first fatigue fracture initiated at the weld-to-rail geometry transition under the railhead and the second initiated at surface pitting under railhead near the longitudinal centerline of the weld. Both breaks demonstrated a gentle 'S' shape similar to those observed in the first round of testing.[1] Neither of the Railtech welds located over concrete ties has failed. None of the welds located over wood ties have failed.

WELD SERVICE PERFORMANCE SUMMARY

Table 1 summarizes the tonnage accumulated and service performance of the welds in the FAST HTL.

Table 1. Interim Weld Performance Results as of March 10, 2011

Weld ID	Locale	MGT	Status
Orgo-Thermit Head Repair Weld Full head slot depth			
1	Over crib	168	In service
2	Over crib	168	In service
3	Over crib	168	In service
4	Over crib	168	Shelling, In service
5	Over crib	168	In service
6	Over EFB weld	122	In service
7	Over EFB weld	64.2	Removed; unrelated adjacent rail break
8	Over EFB weld	102	In service
9	Over EFB weld	102	In service
10	Over EFB weld	102	In service
11	Over wood tie	67.0	In service
12	Over wood tie	67.0	In service
13	Over concrete tie	64.7	Centerline weld vertical fatigue fracture initiated under railhead
14	Over concrete tie	54.0	Vertical fatigue fracture at flashing under railhead
Railtech Boutet Head Wash Repair 1-inch slot depth			
1	Over crib	168	In service
2	Over crib	168	In service
3	Over crib	168	In service
4	Over crib	168	In service
5	Over crib	168	In service
6	Over EFB weld	102	Removed; detected fatigue crack under railhead
7	Over EFB weld	116	In service
8	Over EFB weld	116	In service
9	Over EFB weld	116	In service
10	Over EFB weld	116	In service
11	Over wood tie	67.0	In service
12	Over wood tie	67.0	In service
13	Over concrete tie	67.0	In service
14	Over concrete tie	67.0	In service

CONCLUSIONS

A total of 28 welds were installed during the second round of testing at FAST HTL. Two Orgo-Thermit welds installed over concrete ties fractured at 54 and 64 MGT. One Railtech Boutet weld installed over an EFB weld was removed after the rail flaw detector car identified a crack. The crack initiated at flashing under the railhead and did not appear to be directly related to the presence of the EFB weld. One weld was removed due to an unrelated adjacent rail break.

In general, the surface degradation of the Test 2 welds was significantly reduced from the welds in Test 1. This can be attributed to several factors. First, each manufacturer made improvements to their weld design since the first test. Second, improved weld crowning procedures resulted in less dipping in the rail running surface adjacent to the weld upon cooling. Last, the implementation of periodic rail grinding remediated the progressive formation of HAZ batter that develops with tonnage. The effectiveness of grinding decreased for later grindings as gains in HAZ hardness helped reduce subsequent formation of batter.

Interim results indicate that thermite railhead repair welds can be successfully utilized for repair of EFB welds. The EFB welds must be ground flush to the rail prior to welding to ensure good mold fit against the rail web and bottom of the railhead. Additional tonnage accumulation is required to adequately address performance of welds located over ties. Currently, two welds located over concrete ties have failed. Both failures are related to geometry and surface conditions, which can be addressed through process and design improvements.

FUTURE WORK

TTCI will continue to closely monitor weld performance at FAST. TTCI is working with mega site host railroads to establish a revenue service test of thermite railhead repair welds.

REFERENCES

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