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Testing of Electric Flash Railhead Repair Welds at FAST

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Summary

In December 2013, Transportation Technology Center, Inc. (TTCI) concluded the first and second rounds of in-track testing of electric flash railhead repair welds. In January 2011, eight laboratory produced welds were installed in a 5-degree curve (section 3) of the Facility for Accelerated Service Testing (FAST) High Tonnage Loop. Eight additional welds were installed using a mobile welding unit in September 2011.

Following is a summary of the observations and results from these tests:

- No laboratory produced welds failed during the test period. As of December 2013, the welds have accumulated 449 MGT of 39-ton axle load traffic.
- All welds experienced metal flow across the entire length of the weld insert (material between flash welds at the surface of the rail).
- Mobile unit produced welds experienced accelerated surface metal flow compared to the laboratory produced welds.
- Three of eight mobile unit produced welds failed in service because of fatigue that initiated at a stress concentrator under the railhead.
- One mobile unit produced weld was found by rail flaw detection to contain a fatigue crack near the bottom of the railhead.

The fatigue cracking observed with the welds in this test initiated at geometric discontinuities. These discontinuities can be addressed through proper application of under head post weld grinding.

Holland LP and EWI (formerly Edison Welding Institute) jointly developed the repair welds in response to industry demand to develop a method to repair railhead defects that does not alter the stress-free rail temperature.

Holland LP has made modifications to the weld unit and inserts based on the performance observed at FAST. A new round of testing for the improved weld process is scheduled to begin at FAST in early 2014. A revenue service test at the eastern mega site is also expected to begin in 2014.



INTRODUCTION

Current remediation practices for transverse railhead defects in North America generally involve cutting out a section of rail containing the defect and replacing the removed section with either a rail plug and two welds or a single weld if the defect is narrow enough. This practice typically alters the rail stress-free temperature, which could necessitate future work to restore the proper stress-free temperature. Railhead repair welds, however, enable the repair of narrow head defects in rail without cutting through the full rail cross section. This preserves the rail stress-free temperature by maintaining the base and web integrity (i.e. only the head portion containing the defect is removed).¹ Railhead repair welds also have the potential to produce a stronger repair than a full section weld, because railhead repair welds leave the web and base of the rail intact; as-rolled rail is typically stronger than either thermite or electric flash welded rail.

Holland and EWI developed a railhead repair method using electric flash welding. TTCI tested these welds in track in the FAST High Tonnage Loop (HTL). TTCI previously tested other methods for repairing railhead defects, including slot welds, and thermite railhead repair welds.^{1,2}

IN-TRACK TESTING AT FAST

In December 2010 and January 2011, Holland and EWI produced a series of head defect repair (HDR) welds in the laboratory. The welds were made in short rail plugs that were then sent to the Transportation Technology Center (TTC) for installation in the FAST track. In January 2011, Holland sent a weld truck to TTC and welded the rail plugs together as they were placed in track. Six HDR welds were installed in the high rail and two HDR welds were installed in the low rail.

After the January 2011 install, Holland transitioned the weld technology from the laboratory into a mobile weld unit. In September 2011, Holland sent a mobile weld truck with the prototype HDR welder head to install a series of test welds in the HTL. A total of eight welds were installed in section 3, five in the high rail, and three in the low rail. For this test, TTCI did not seek to determine the effectiveness of the welds in repairing a specific defect (there were no known defects in the rail), but focused on evaluating the installation process and in service performance of the weld.

Each installation consisted of several steps. First, a V-shaped cut was made in the railhead using a rail saw and specially designed jig. A weld insert was set in place and the welder head lowered over the rail. The weld was initiated and proceeded automatically through the flash and forge process. The expelled metal was sheared and the welder head was removed. The weld was then manually ground to finish. Each installation at FAST took approximately 45 minutes to complete (from arrival at location to completing final grind of weld). Figure 1 shows the Holland weld truck on track with the welder head extended and being prepared for welding. Figure 2 shows a rail that is cut and ready for installation of the new insert. The longitudinal length of the cut is 4.5 inches at the top of the rail. Figure 3 shows a completed weld. The

weld has been etched to reveal the macrostructure at the running surface. An HDR weld consists of a single flash weld that intersects the running surface at two locations, approximately 6 inches apart (this is larger than the initial cut due to flashing of the insert into the rail). Figure 4 shows a vertical longitudinal cross section of a completed weld.



Figure 1. Holland Mobile HDR Weld Truck on Track and being prepared for Welding



Figure 2. V-cut made in Railhead using Rail Saw and Angle Jig

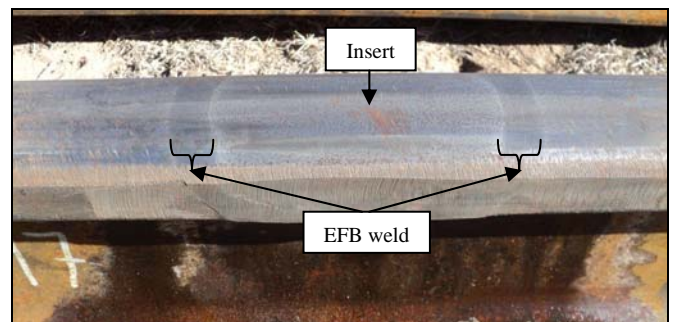


Figure 3. Completed Weld with etched Railhead revealing Running Surface Macrostructure

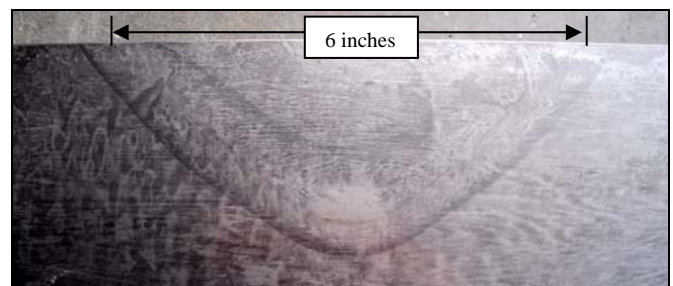


Figure 4. Vertical Longitudinal Cross Section of HDR

RESULTS

TTCI conducted periodic measurements of longitudinal running surface profile and hardness of the test welds. Profiles were overlaid to reveal trends in running surface metal flow and wear. Figure 5 shows the longitudinal profiles for one of the laboratory produced welds, and Figure 6 shows the profiles for one of the mobile unit in-track welds. For both groups of welds, metal flow occurred across the entire length of the insert (i.e., between both ends of the flash weld at the running surface). After installation, the laboratory weld inserts had running surface hardness values near 410 Brinell, and the mobile unit weld inserts had hardness values near 360 Brinell. A comparison of running surface metal flow showed the mobile unit welds at 100 MGT had more than twice the height loss of laboratory produced welds at 107 MGT.

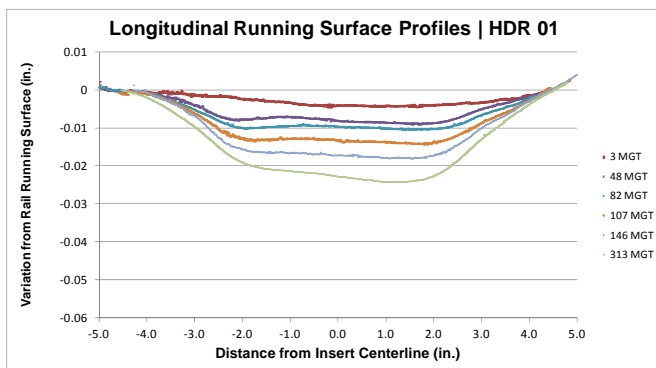


Figure 5. Longitudinal Profiles for a Laboratory Produced HDR Weld

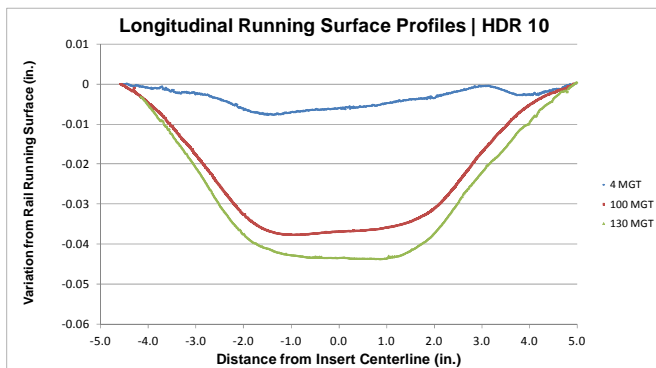


Figure 6. Longitudinal Profiles for a Mobile Unit In-track Weld

None of the original laboratory generated welds have failed in service and have accumulated 449 MGT of traffic. Of the eight mobile unit produced welds, two were removed for non test related maintenance on the track. Three of the mobile HDR welds experienced fatigue fractures in service. Figure 7 shows one of the fatigue fractures. One weld was identified by rail flaw detection to have a fatigue crack and was removed from service. Of the four welds that had fatigue cracking, three of these initiated at geometry transitions under the railhead and the fourth initiated under the railhead at a defect near the center of the insert. Figure 8 shows the sharp geometry transition under the railhead where three of the

fatigue cracks occurred. The bottom of the railhead has been identified as a high stress region in standard rail weld types, thermite railhead repair welds, and rails.³⁻⁵ (The geometry discontinuity under the railhead can be addressed with under head post weld grinding.)



Figure 7. Fatigue Fracture Initiated at Stress Concentrator at bottom of Railhead



Figure 8. HDR Weld after Production (Arrow indicates geometry transition at the bottom of the railhead that acted as a stress concentrator)

Table 1 summarizes the performance of the laboratory produced welds, and Table 2 summarizes the performance of the mobile unit produced welds as of December 2013.

Table 1. Status of Laboratory Produced HDR Welds at FAST Laboratory Produced HDR Welds Installed January 2011

Weld ID	Total MGT	Rail	Status
1	449	High	In service
2	449	High	In service
3	449	Low	In service
4	449	High	In service
5	449	High	In service
6	449	High	In service
7	449	High	In service
8	449	Low	In service

Table 2. Status of Mobile Unit In-track HDR Welds at FAST

Mobile Unit HDR Welds Installed September 2011			
Weld ID	Total MGT	Rail	Status
10	132	High	Removed, detected transverse defect under railhead at stress concentrator
11	-	High	Removed from test by TTCI for non test related reasons
12	188	Low	Removed with weld No. 13, had sharp dip at running surface
13	188	Low	Vertical fatigue fracture initiated under railhead at stress concentrator
14	335	High	In service
15	315	Low	Vertical fatigue fracture initiated under railhead at stress concentrator
16	-	High	Removed from test by TTCI for non test related reasons
17	94	High	Vertical fatigue fracture initiated under railhead at defect in insert

CONCLUSION

- No laboratory produced welds failed during the test period. As of December 2013, the welds have accumulated 449 MGT of HAL traffic.
- All welds experienced metal flow across the entire length of the weld insert (material between flash welds at the surface of the rail).
- Mobile unit produced welds experienced accelerated surface batter compared to the laboratory produced welds.
- Three of eight mobile unit produced welds failed in service, because of fatigue that initiated at a stress concentrator under the railhead. A fourth weld was found by rail flaw detection to contain a fatigue crack and was removed from service.

FUTURE DEVELOPMENT AND TESTING

Holland and EWI are making several changes to the welding process to address the issues observed in the testing at FAST. These improvements incorporate the following:

1. The inserts are being machined to better match the rails, and the weld shear is being redesigned to better conform to the rail. The result of these changes will be a final weld that is more conformal to the rail and eliminates the sharp under head transition from rail to insert that acted as stress concentrators and contributed to fractures observed in this test. This change will also reduce the post weld grind time.

2. Inserts are being manufactured with improved chemistry and heat treatment to better produce the desired hardness for strong running surface performance and resistance to batter.
3. The mobile welder head transformer is being reworked to better distribute the power between the rail and insert. This will result in reduced heating of the insert, which will improve the metallurgical integrity and target hardness.
4. Modifications were made to the welder hydraulic system to change how the wedge inserts are forged into place. This results in reduced stresses and improved running surface.

TTCI is currently in discussion with Holland and EWI about establishing a new HDR test at FAST that will evaluate these changes.

A new revenue service test was initiated in November 2013 at the eastern mega site. This test currently includes two types of thermite railhead repair welds. A set of Holland HDR welds will be included in the test pending host railroad laboratory testing and approval. Installation of the HDR welds is expected to happen in early 2014.

REFERENCES

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