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Laboratory Testing of Thermite Railhead Repair Welds

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Summary

Thermite railhead repair welds were independently developed by Railtech Boutet, Inc. and Orgo-Thermit, Inc. in response to industry demand for a portable and economic way to repair railhead defects. Railhead repair welds allow the repair of railhead defects without the need to cut the rail, thereby eliminating the standard plug and weld procedure. Additionally this procedure maintains the integrity of the rail base and does not alter the rail neutral stress temperature.

Transportation Technology Center, Inc. (TTCI) conducted laboratory testing on three sets of thermite railhead repair welds. Two sets of welds were from Orgo-Thermit, Inc. and one set was from Railtech Boutet, Inc. Welds were examined in a manner similar to the testing recommended by the American Railway Engineering and Maintenance-of-Way Association in the *Manual for Railway Engineering*, Chapter 4, Section 3.14 "Specification for the Quality Assurance of Thermite Welding of Rail."

Following is a summary of the laboratory observations and results.

- Railhead repair welds from both manufacturers performed well in slow bend for base-in-tension (upright) testing. The welds reached the maximum deflection of 1.8 inches, the machine limit, without fracture. However, when the welds were tested head-in-tension (inverted), the welds for both manufacturers averaged 0.47-inch deflection. Standard full-section thermite welds previously tested in head-in-tension averaged 0.68-inch deflection.[1] Inverted tests are not specified by the *Manual for Railway Engineering*.
- The Orgo-Thermit Head Repair Welds with 1 1/8-inch depth slots had cold lapping under the railhead; whereas, both the Orgo-Thermit Head Repair Weld with full-head depth slots and the Railtech Boutet Head Wash Repair weld with 1-inch depth slots had no observed cold lapping under the railhead.
- Railhead repair welds from both manufacturers had a minor increase in porosity along the weld fusion lines near the railhead in comparison to standard thermite welds. Porosity under the railhead associated with cold lapping was difficult to identify using ultrasonic inspection techniques.
- Thermite railhead repair welds were similar to standard thermite welds in regard to microstructure and hardness

TTCI is conducting tests to explore the residual stress condition of the welds and how those stresses affect the stress state of the rail. Additional testing will be conducted to explore the possibility of using thermite railhead repair welds to repair head defects in electric flash-butt welds.

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INTRODUCTION

Railhead repair welds are welds used to repair defects located in the head of a rail without the need to cut the rail. A traditional repair of a railhead defect requires the use of a plug rail and two thermite welds, or the use of a single wide-gap thermite weld. In both cases, the rail must be cut, which alters the rail neutral stress temperature. Using railhead repair welds eliminate the need to cut the rail, thereby maintaining both the integrity of the rail base and the neutral stress temperature of the rail.

In making a railhead repair, the defect is first precisely located and then removed by either grinding or milling a slot across the railhead. The slot is then restored using a suitable welding process to provide the filler metal. In response to industry demand, both Orgo-Thermit, Inc. and Railtech Boutet, Inc. have independently developed and produced thermite railhead repair welds.

In 2008, TTCI conducted laboratory testing of thermite railhead repair welds from both thermite weld manufacturers. Orgo-Thermit, Inc. submitted two welds for testing and Railtech Boutet, Inc. submitted one. The Orgo-Thermit Head Repair Welds referred to hereinafter as OW-1 and OW-2, had initial slot depths of 1 1/8 inches and 2 inches (full-head depth in 136RE rail), respectively. Orgo-Thermit submitted the OW-1 welds first, then, after the initial results, which are discussed here, introduced the OW-2 welds. The Railtech Boutet Head Wash Repair weld referred to hereinafter as BW-1, had a slot depth of 1 inch. Slot depths for the OW-1 and BW-1 are measured from the top of a new rail profile. Slot depths for field welding will vary based on the amount of railhead wear present. For both manufacturers, the slot width was 2 inches.

LABORATORY TESTING

TTCI performed laboratory testing on each of the thermite railhead repair welds. The welds were inspected both visually and ultrasonically. The welds were then subjected to Charpy impact testing, macro- and micro-examinations, and slow bend testing.

Visual inspection of the as-received OW-1 samples revealed severe cold lapping on the bottom of the railhead. Orgo-Thermit eliminated the cold lapping by increasing the slot depth to remove the full railhead. The OW-2 weld and the BW-1 welds did not have any cold lapping under the railhead. Dye penetrant and magnetic particle testing were conducted on the OW-1 samples to determine the extent of the cold lapping. Figure 1 shows dye-penetrant testing of an OW-1 weld.

Ultrasonic inspection of all three weld types revealed a small increase in fusion line porosity compared to standard thermite welds. The porosity was found using a 70-degree probe on the side of the railhead aimed in the direction of the weld fusion line boundary near the top of the rail. In the OW-1 welds, severe porosity was associated with the cold lapping that occurred under the railhead. Porosity under the railhead is very difficult to detect ultrasonically as it is located immediately under the nonwelded portion of the railhead. The ultrasonic inspection technician sees what appears to be the normal back-wall reflection from the bottom of the railhead and cannot see the underlying material. This can give the false impression of good porosity free material. Figure 2 shows porosity in the cold-lapped region under the railhead.

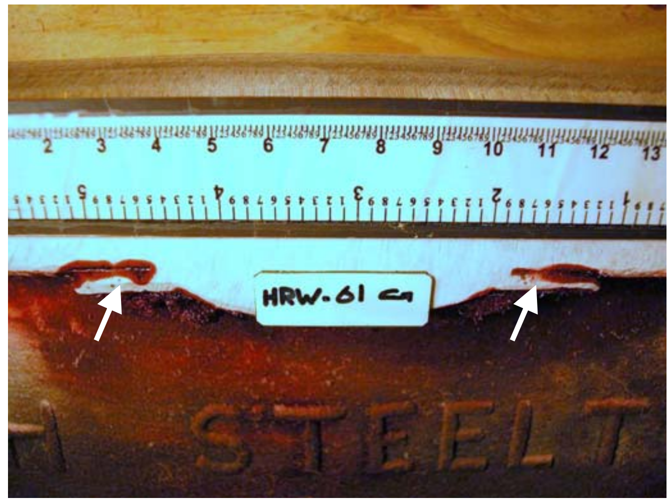


Figure 1. Dye Penetrant Examination of Cold Lapping under the Railhead of the 1 1/8- inch Depth Orgo-Thermit Weld Arrows indicate the locations of cold lapping.

Figure 2. Transverse Cut of an OW-1 Weld showing Porosity in a Cold Lap under Railhead Dashed line indicates location of bottom of railhead.

Macro etches were made of the welds. Samples were prepared by making vertical cuts in the longitudinal direction along the weld centerline. The resulting surfaces were ground and etched to reveal the weld macrostructure. No weld defects, such as porosity or lack of fusion, were observed in the sections for either manufacturer. Figure 3 shows the weld macros for OW-2 and BW-1. The approximate original slot size is included for reference purposes. In general, both welds had similar heat affected zone widths at the top of the rail although the overall width of the welds varied by 0.6 inch.

Each had similar depths of penetration having a difference of 0.17 inch. Table 1 shows the weld dimensional characteristics measured from the macrosections for both manufacturers.

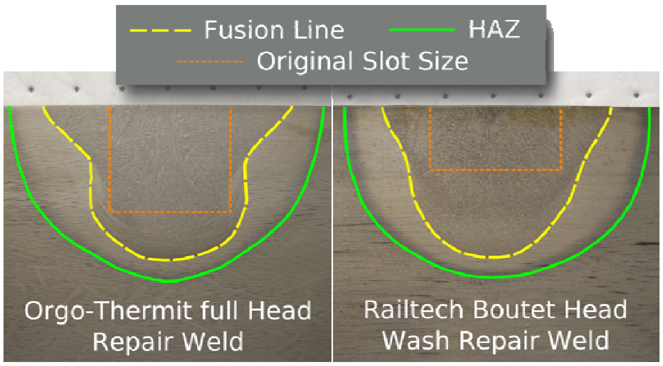
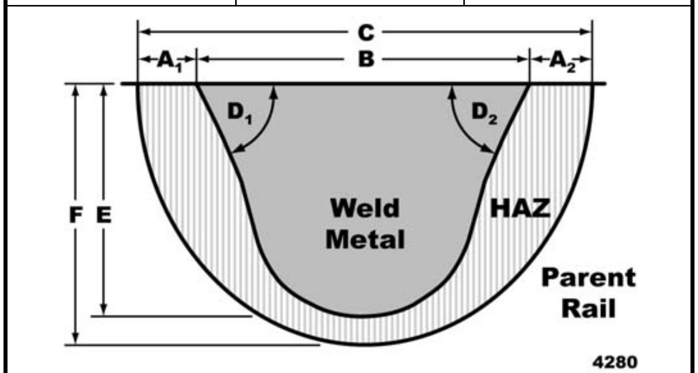


Figure 3. Longitudinal Cross-section Macro-etches of Thermite Railhead Repair Welds. OW-2 (left) and BW-1 (right)

Table 1. Weld Measurements taken from Weld Cross Sections

Measurement ID	Orgo (OW-2)	Railtech (BW-1)
A_1 , A_2	0.60 , 0.55 inch	0.66 , 0.66 inch
B	4.38 inches	3.78 inches
C	5.53 inches	4.38 inches
D_1 , D_2	44 , 46 degrees	60 , 57 degrees
E	2.75 inches	2.56 inches
F	3.06 inches	2.89 inches



Slow bend testing was performed on a total of four welds from each manufacturer. One of the four slow bends was performed with the rail in the standard upright position, base-in-tension, and three were performed with the rail inverted, head-in-tension. The welds tested in the upright position reached the maximum deflection of 1.8 inches, the machine limit, without fracture. However, the welds for both manufacturers tested in the inverted position averaged only 0.47-inch deflection. Standard full-section thermite welds previously tested in the inverted position averaged 0.68-inch deflection.[1]

A minimum of four Charpy impact toughness tests were conducted on each of the weld types. Samples for the Charpy tests were oriented so that the notches were located on the weld fusion line. Figure 4 shows the results for the OW-2 and BW-1 welds. The fusion line impact toughness values for both manufacturers were similar. Results for the railhead repair welds were consistent with results for standard thermite weld fusion lines.

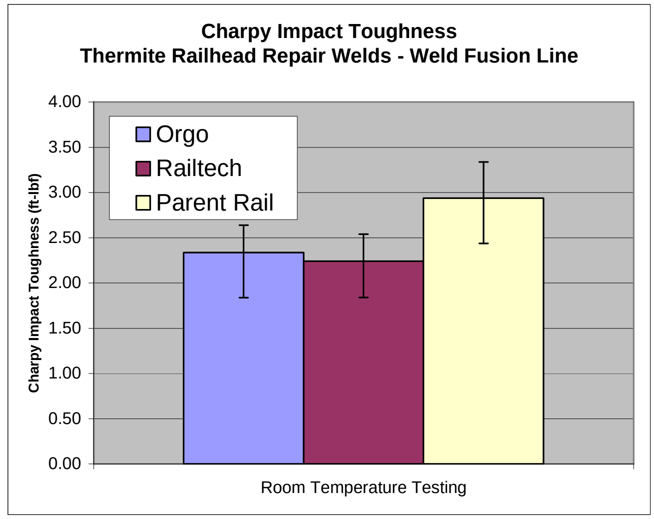


Figure 4. Charpy Impact Toughness Testing Results

Internal hardness traverse measurements were performed on the welds similar to the American Railway Engineering and Maintenance-of-Way Association's procedure for testing electric flash-butt welds. Both welds exhibited the typical thermite weld hardness profiles with the adjacent heat affected zones exhibiting the lowest hardness values. Figure 5 shows the hardness traverse results for the BW-1 and OW-2 welds. The BW-1 weld in this measurement was made on standard rail and the OW-2 weld was made on premium rail.

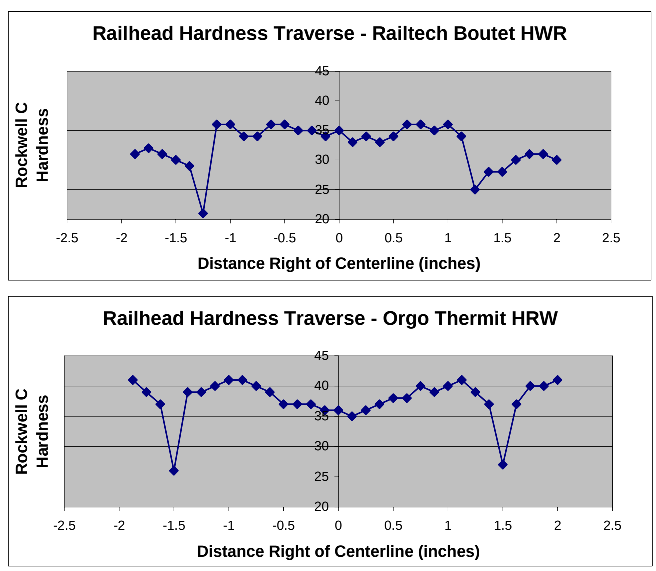


Figure 5. Hardness Traverses of BW-1 (top) and OW-2 Welds (bottom)

TESTING AT THE FACILITY FOR ACCELERATED SERVICE TESTING

Ten welds of each type were installed at the Facility for Accelerated Service Testing, High Tonnage Loop (HTL) in 2008. In general, the test welds experienced shelling degradation common for other field welds in the HTL. Several weld fractures occurred during the test, two of which occurred in welds that were intentionally placed over ties to explore how the welds would perform in a reverse bending scenario. The in-track installation and performance of these railhead repair welds will be covered in a separate *Technology Digest*.

A second round of testing was started in July 2009. Both Railtech Boutet and Orgo-Thermit have welds installed in Section 31 of the HTL. This test will incorporate periodic maintenance rail grinding to better simulate revenue service conditions.

CONCLUSIONS

Thermite railhead repair welds from both manufacturers performed well in slow bend for base-in-tension (upright) testing. The welds reached the maximum deflection of 1.8 inches, the machine limit, without fracture. However, when the welds were tested head-in-tension (inverted), the welds from both manufacturers averaged 0.47-inch deflection. Standard full-section thermite welds previously tested head-in-tension average 0.68-inch deflection.[1] Inverted slow bends are not specified by the *Manual for Railway Engineering* but were performed as a means for understanding how the welds may perform if installed in a reverse bending scenario (e.g., directly over a tie)

Both the Orgo-Thermit full-head depth Head Repair Weld (OW-2) and the Railtech Boutet Head Wash Repair weld with 1-inch depth slot (BW-1) did not have any observed cold lapping under the railhead. The Orgo-Thermit Head Repair Weld with 1 1/8-inch depth slot (OW-1) had cold lapping under the railhead. Orgo-Thermit currently does not offer the OW-1 weld commercially.

Railhead repair welds from both manufacturers had a minor increase in porosity along the weld fusion lines near the railhead. Porosity under the railhead associated with cold lapping was difficult to identify using ultrasonic inspection techniques.

Thermite railhead repair welds were similar to standard thermite welds in regard to microstructure and hardness.

FUTURE WORK

Thermite railhead repair welds differ significantly from traditional thermite welds in regard to overall shape, because they only involve the head of the rail. The effects of this difference on residual stresses in the weldment and in the rail are not known. TTCI will conduct testing to explore the residual stress condition of the welds and how those stresses affect the stress state of the rail. In combination with this, TTCI will also conduct testing to investigate and explore the possibility of using thermite railhead repair welds to repair head defects in electric flash-butt welds.

REFERENCES

1. Kristan, Joseph. July 2004. "Laboratory Evaluation of Robotic Slot Weld for Railhead Repair." *Technology Digest* TD-04-011. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

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