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TIMELY TECHNOLOGY TRANSFER

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Testing of Thermite Welds with Treated Heat Affected Zones

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Summary

Transportation Technology Center, Inc. (TTCI) conducted testing of thermite welds with overlay treated heat affected zones (HAZ) at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado, in cooperation with two weld suppliers, as part of the Association of American Railroads Strategic Research Initiatives Program. This study is being conducted to reduce batter on the running surface to possibly extend the life of welds. Observations of the overlay treatment of the HAZ test welds at FAST came to an end as of December 2014 after 239.6 million gross tons (MGT) of heavy axle load traffic. The following is a summary of the test results. TTCI installed 21welds from two different suppliers.

- Nine conventional welds from Supplier A were installed. TTCI treated six of the welds with the overlay treatment of the HAZ and three were left untreated and defined as control welds for the test.
  - At the conclusion of the experiment, there were three overlay treated HAZ welds that were still in track on the high rail. Two of the treated welds were removed because of shelling on the gage corners of the welds, and one treated weld was removed with the shelled welds but contained no defects at 239 MGT.
  - One of the three untreated welds from Supplier A was in track after the end of this experiment. The remaining two untreated welds failed because of shells at approximately 230 MGT.
  - One weld was removed because of a rail break that occurred adjacent to the weld after 86 MGT and was replaced with a new treated weld.
- Nine conventional welds from Supplier B were installed. TTCI treated six of the welds with the overlay treatment of the HAZ process and three were left untreated.
  - All nine conventional welds were removed because of gage corner shells. The first treated weld was removed after 166 MGT. The last treated weld was removed at 239 MGT. The remainder of the welds, treated and untreated, were removed between 191 and 230 MGT.
- Supplier B provided a total of three head alloyed welds (HAW) that were installed. TTCI treated two of them with the overlay treatment of the HAZ process, and one was left untreated.
  - Two of the three HAWs, one treated and one untreated, are still in track at 240 MGT. The remaining weld was removed at 225 MGT because of scheduled track maintenance. It contained no defects.

Additional tests of HAZ treatment for thermite welds are underway in revenue service to evaluate the procedure under a wider range of conditions.

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INTRODUCTION

TTCI tested thermite welds with treated HAZs to mitigate the problem of the soft weld HAZ on both sides of the weld battering faster than the adjacent rail.

The increased batter in the HAZ is more pronounced in high-hardness, head-hardened rail and increases the potential for fatigue damage at welds. One method being examined as a possible solution to surface degradation and batter is a weld overlay treatment of the HAZ for thermite welds to heat-treat the running surface of the original HAZ.

OVERLAY TREATMENT METHOD

As reported in TD-14-003, "Initial Service Testing Results of Thermite Welds with Treated Heat Affected Zones," the overlay treatment method reduced batter in the HAZ and in the weld.[1] Following publication of TD-14-003, at the request of a Class I railroad, TTCI developed and distributed a document to the railroads and suppliers that listed steps for the process of the overlay treatment of the HAZ from the point of removing the weld mold after the weld has been made. Below is a summary of the process.

1. Shear thermite head riser, per standard procedure.
2. Clean surface to be welded with a wire brush.
3. Weld boundaries should be between 0.25 and 1.0 inch beyond the edge of sheared thermite weld.
4. Apply stick weld in a weave pattern between the two boundaries progressing from gage corner to field side (Figure 1).
5. Rough and finish grind the overlay treatment of the HAZ and the rest of the thermite weld, per standard procedure.

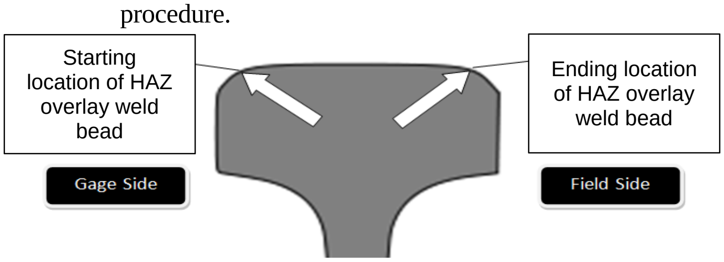

Figure 1. Weld Start and End Locations on the Railhead for the Overlay Treatment of the HAZ

For this process to be most effective, the overlay treatment of the HAZ (Step 4) should be completed within 3 minutes after the weld is sheared. When the treatment is completed within this timeframe, it allows the overlay to successfully change the shape of the weld's original HAZ, as Figure 2 shows.

The heat from the overlay narrows and pushes the soft HAZ outward from the weld centerline, which increases the width of the higher hardness reaustenitized HAZ of the weld along and immediately below the running surface.

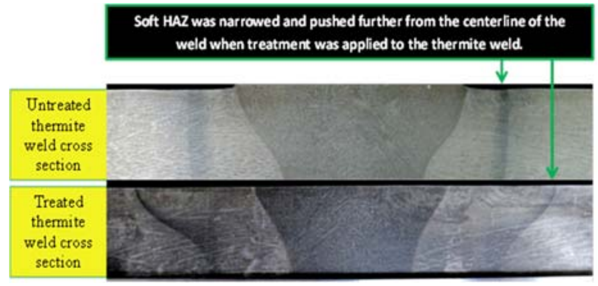

Figure 2. Image showing Narrowed Soft HAZ of a Treated Thermite Weld

TESTING RESULTS AT FAST

In July 2012, 21 welds were installed in track at FAST in Section 31 of the High Tonnage Loop (Figure 3). Nine were conventional welds from each supplier (three untreated and six treated) and three were HAWs (two treated and one untreated) from Supplier B.

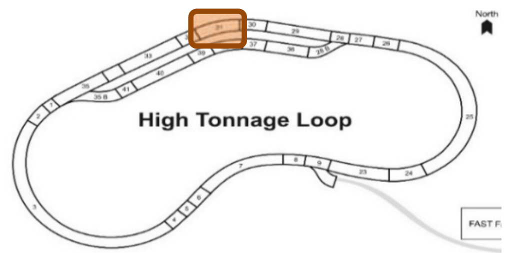

Figure 3. Installment Location of the Thermite Overlay Treatment of the HAZ Welds on the High Tonnage Loop

In April 2013, after only 30 MGT, the differences between the treated and untreated welds were already present. Figure 4 shows running surface comparisons at 86 MGT. For the untreated welds, in the location of the soft HAZs on both side of the centerline of the weld, tear-drop shaped material deformation is seen; although, this metal flow is reduced when the welds are treated with the overlay method.

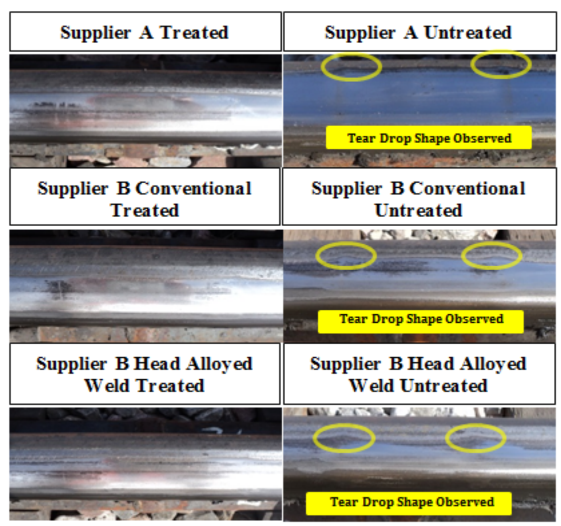

Figure 4. Overlay Treatment of the HAZ Treated vs. Untreated Thermite Welds for Both Suppliers and All Types of Welds Tested at 86 MGT
(Gage side is located at the bottom of every figure.)

Figure 5, (a) (b) (c), shows the longitudinal profiles taken down the center line of the rail for all types of welds and HAZ overlay combinations at 166 MGT. As Figure 5 (a) and (b) show, the conventional thermite welds without the overlay treatment of the HAZ indicate greater metal deformation (dips) at the soft HAZ locations. These dips represent the metal flow that occurs from dynamic wheel loading. The batter of the treated welds was about 30 percent less than the control and untreated thermite welds. In Figure 5 (c), the HAWs without the overlay treatment of the HAZ also show HAZ dipping similar to the conventional untreated thermite welds; however, the harder weld material resulted in less weld batter than in the conventional untreated and treated welds. The combination of a HAW and overlay treatment of the HAZ resulted in the least batter and provided the best running surface.

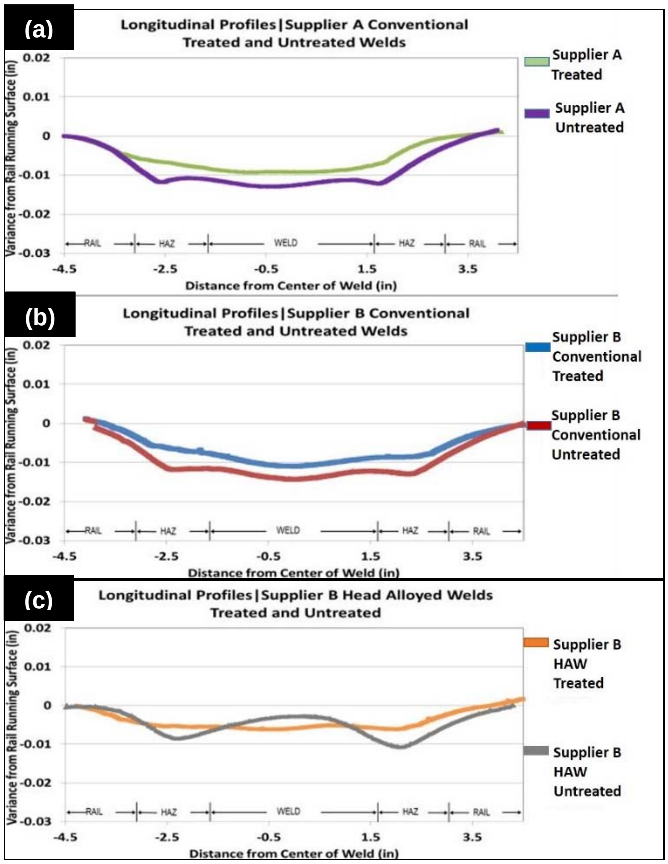

Figure 5. Longitudinal Profiles showing HAZ Overlay Treated vs. Untreated Weld for (a) Supplier A Conventional Welds, (b) Supplier B Conventional Welds, and (c) Supplier B Head Alloyed Welds at 166 MGT

Hardness values for all six types of welds tested were collected at 2 MGT and are presented in Table 1.

Table 1. Average Hardness Values for all three types of test welds as well as a comparison between the untreated and treated welds

Weld Type	Average centerline weld hardness (BHN)	Average hardness 1 inch away from the end of the thermite weld metal (BHN)
A	337	
B	349	
HAW	385	
All untreated		286
All HAZ treated		353

The monitoring of the HAZ treated thermite welds at FAST ended December 2014. At the conclusion of the test, there were still four treated welds and two untreated welds in service. Included in this count were two of the original three Supplier B HAW welds, one treated and one untreated. Table 2 lists the remaining welds and their causes for removal.

Table 2. End of Test Status and Removal Information for all 21 Welds

THERMITE HAZ OVERLAY WELDS - SECTION 31 - INSTALLED JULY 2012			
SUPPLIER	CONDITION	MGT	SHELL SEVERITY
A	TREATED	86.84	RAIL BREAK 3 INCHES FROM WELD
B	TREATED	166.1	SEVERE
B	TREATED	166.1	SEVERE
B	TREATED	190.55	MODERATE
B	UNTREATED	192.44	SEVERE
B	TREATED	192.6	MODERATE
B-HAW	TREATED	225.33	REMOVED FOR MAINTENANCE
B	UNTREATED	225.33	SEVERE
A	TREATED	225.33	LIGHT
A	UNTREATED	225.33	MODERATE
B	TREATED	239.63	MODERATE
B	TREATED	239.63	REMOVED FOR MAINTENANCE
B	UNTREATED	239.63	SEVERE
A	TREATED	239.63	REMOVED FOR MAINTENANCE
A	TREATED	239.63	LIGHT
A	UNTREATED	239.63	SEVERE
B	TREATED	STILL IN TRACK	
B-HAW	TREATED	STILL IN TRACK	
B-HAW	UNTREATED	STILL IN TRACK	
A	TREATED	STILL IN TRACK	
A	TREATED	STILL IN TRACK	
A	UNTREATED	STILL IN TRACK	

Supplier A had two treated welds that failed because of shells; both shells were labeled as light in severity, as Figure 6 (c) shows. For the conventional welds from Supplier B, five treated welds were removed at 166 MGT and 239 MGT. These welds, however, were extracted from the rail with more moderate to severe shell severity, as Figure 6 (a) and (b) show. All untreated welds, except for the two still in track, were of moderate to severe shell severity and failed within 192 MGT to 240 MGT.

A severe shell was labeled as a shell that was formed with chip out greater than an inch long; whereas, a moderate shell was described as a shell with less than an inch of chip out. A defect that was considered light in nature was a shell that was located visually or by using ultrasonic detection but has not yet chipped out.

For the HAWs provided by Supplier B, no removals due to defects or indications took place. The only HAW that was removed was due to maintenance occurring near that weld's location.

A majority of treated conventional welds from Supplier A contained either small or no defects by the end of the test. These welds survived longer than 220 MGT. The majority of treated conventional welds from Supplier B failed at tonnage lower than 200 MGT and contained larger-sized defects and more defects. The HAWs provided by Supplier B had little wear when untreated and even less when treated and therefore show that this combination has the least amount of batter wear thus potentially having a longer life.

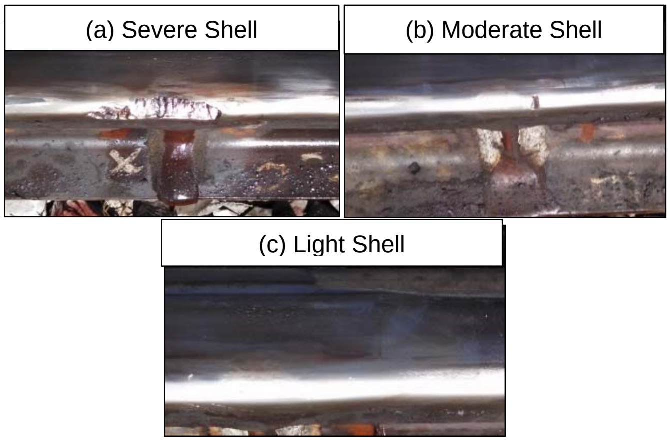

Figure 6. Photos of (a) Severe Shell, (b) Moderate Shell, and (c) Light Shell after the Welds were removed from Track

Shelling is a common failure mode for thermite welds at FAST, which is more likely to occur when welds and adjacent rail are not periodically ground. There is no clear evidence that HAZ overlay treatment reduces the tendency for shelling under these conditions.

INITIAL TESTING IN REVENUE SERVICE

Canadian National Railroad

At the CN sites (Superior, Wisconsin, Winnipeg, Manitoba, and Toronto, Ontario), TTCI is monitoring nine overlay treatments of the HAZ welds. Three more welds were kept untreated as control welds. CN track crews installed all 12 test welds between September and November 2012. All of welds are still in track and have accumulated between 164 and 175 MGT. Figure 7 displays the longitudinal profiles for two of the CN test welds with the treated weld wear profiles presented in the top graph. The shape of the untreated weld at 21 MGT is caused by the weld material being higher than the rail after shearing and grinding.

At the CN test locations, the test welds receive approximately 60 MGT of traffic yearly. The rails are ground semi-annually. The rail grinds reduce the differences in longitudinal profiles, as Figure 7 shows. Frequent grinding removes the metal flow in untreated thermite welds and can provide a possible alternative to the overlay of the HAZ process.

Union Pacific Railroad

At the UP test weld sites in the South Morrill Sub in Nebraska, 11 welds including two HAWs were installed between July and August of 2014, with 7 of the welds treated with the overlay treatment of the HAZ process. Since these welds were installed so recently, the comparison of longitudinal profiles cannot be made. However, given that the welds are exposed to a yearly tonnage of about 190 MGT, the test welds will be closely monitored. All 11 welds are still in track and have accumulated between 147 and 163 MGT.

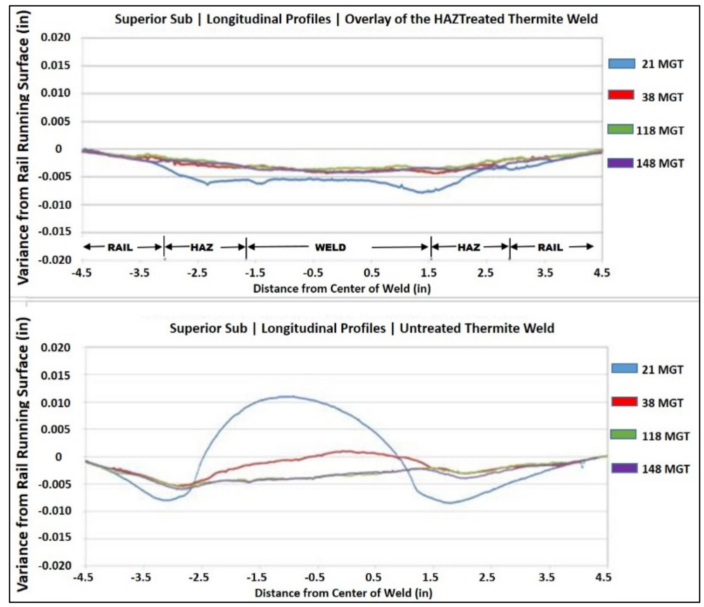

Figure 7. Longitudinal Profiles from an Untreated Weld and Overlay Treatment of the HAZ Weld at One of the CN Test Sites

FUTURE TESTS

Thermite weld overlay treatment of the HAZ research examines how the alteration of the HAZ can effectively reduce the flow of metal in the zone and potentially extend the life of a thermite weld. Because weld batter and less than desired weld lives are issues in revenue service, there will be future tests related to the overlay treatment of the HAZ tests to assist in extending the life of thermite welds. Monitoring of the welds will continue in revenue service. Additional and similar tests are planned for electric flash butt rail welds in order to obtain the same result of increasing the life of revenue service welds.

REFERENCE

1. Gutscher, Daniel, Joseph LoPresti, and Martita Mullen. April 2014. "Initial Service Testing Results of Thermite Welds with Treated Heat Affected Zones." *Technology Digest* TD-14-003. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.