TECHNOLOGY DIGEST

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TIMELY TECHNOLOGY TRANSFER

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Initial Service Testing Results of Thermite Welds with Treated Heat Affected Zones

Daniel Gutscher, Joseph LoPresti, and Martita Mullen*

Summary

Transportation Technology Center, Inc. (TTCI) conducted service trials of a new treatment for thermite weld heat affected zones (HAZ). The treatment consists of an overlay weld that is applied to the rail running surface, over the thermite weld HAZ. In July 2012, 14 treated and 7 untreated thermite welds were installed in track at the Facility for Accelerated Service Testing (FAST) in Pueblo, Colorado. In September and October of 2011, TTCI worked with Canadian National Railway to install treated welds at three locations in revenue service.

The initial observed results from the test are as follows.

FAST:

- Based on limited data, the treatments reduce the overall rate of thermite weld batter. This includes the weld centerline, which is not directly treated. The treatments reduced weld centerline batter at FAST by approximately 30 percent.
- 108 MGT accumulated as of January 2014.
  - One untreated thermite weld fractured because of fatigue that initiated in the base/web radius.
  - No treated welds failed; however, one treated weld was replaced with a new treated weld after an adjacent rail break, unrelated to the test, resulted in premature removal.
- A combination of treating the HAZ and alloying of the thermite weld head produced the best combination to mitigate running surface degradation in high strength rails.

Revenue Service:

- Welds have accumulated from 51 MGT to 56 MGT as of January 2014.
- No weld failures have occurred to date.

*Canadian National Railway

INTRODUCTION

Without intervention, thermite weld running surfaces will tend to degrade under service operating conditions, resulting in weld failures or additional maintenance. This is especially true for thermite welds in high strength rail under heavy axle load service conditions. TTCI conducted laboratory testing and in-track observations at FAST to better understand how and why thermite welds degrade.[1] Based on results from these studies, TTCI investigated several means to mitigate the HAZ softening.[2,3] One of these methods was a treatment that consists of applying a weld bead to the rail over the region where the soft HAZ forms, adjacent to the weld. This is done while the thermite weld is still hot in order to make use of the thermite weld heat as preheat for the overlay welding. Because the overlay is applied during thermite weld production, the process adds little to no extra time to the overall weld installation. The result of the treatment was a modified HAZ shape near the running surface of the rail that reduced the width of the softened HAZ by 44 percent in the initial laboratory testing performed by TTCI.[2,3] Overlays were made using commercially available welding electrodes designed for rail end buildup.

In the fall of 2011, TTCI conducted preliminary testing of treated thermite welds in the High Tonnage Loop (HTL) at FAST. Five pairs of welds, each pair with one treated and one untreated, were installed in a 6-degree curve (Section 25) and monitored for running surface degradation. Based on the results of that test, TTCI began a formal test at FAST in July of 2012. In October 2012, the Canadian National Railway (CN) worked with TTCI to begin a revenue service test of treated thermite welds. Following is a report of the findings from tests at FAST and in revenue service.

SERVICE TESTING AT FAST

TTCI installed 21 test welds in the high rail of Section 31, a 5-degree curve, in the HTL in July 2012. The test welds included treated thermite welds and untreated thermite welds from two different manufacturers. Treated head alloyed thermite welds were also tested. Table 1 summarizes the welds that were installed.

Table 1. Summary of Welds Installed in HTL Section 31

Thermite Weld Type	Treated	Untreated
Manufacturer 1	5	3
Manufacturer 2	5	3
Head alloyed	4	1

As of January 2014, the welds have accumulated 108 MGT. Two welds have been removed. The first weld (treated weld) was removed because of an unrelated adjacent rail break caused by a nick in the base of the rail. TTCI replaced the weld with a new treated weld. The second weld was an untreated weld that broke from a fatigue crack that initiated in the base/web radius near the edge of the weld collar.

TTCI conducted longitudinal profile measurements of the welds along the centerline of the rail. Figure 1 shows representative profiles for a treated and an untreated weld. The first graph, a treated weld, shows minimal HAZ dipping, although still present. The second graph, an untreated weld, shows the HAZ dipping on both sides of the weld.

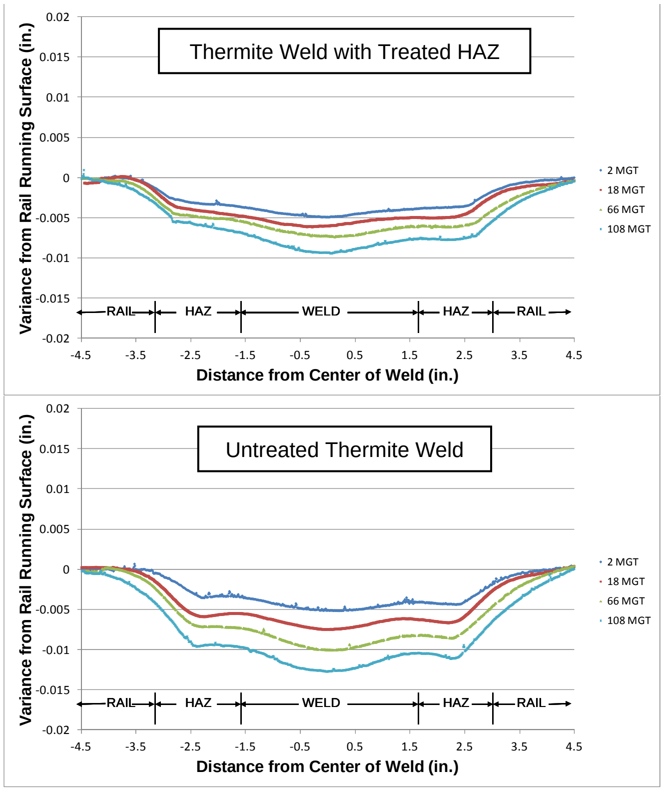

Figure 1. Profiles for Two Welds in Test at FAST (Top) Thermite Weld with Treated HAZ, (Bottom) Untreated Thermite Weld

The dipping in the HAZ of the treated weld is more than expected based on the preliminary testing conducted at FAST. This is likely due to a modification in the weld procedure that was implemented in this test. In the standard procedure, the overlay weld is applied to the top of the rail on the thermite HAZ starting at the gage side and finishing at the field side. The procedure implemented with this round of testing applied the overlay in two steps. The overlay weld started next to the gage side and ended at the center of the rail. Then a second weld was started at the field side and finished at the center of the railhead on top of the first overlay weld. Figure 2 illustrates these procedures. This process likely produced a second HAZ at the center of the railhead where the longitudinal profiles are taken. To evaluate this hypothesis, TTCI engineers will examine the internal microstructures of the welds as they are removed.

The treatment of the HAZ does not directly affect the thermite metal properties; however, from the two sets of profiles, the overlay does affect the rate of batter (represented by the vertical spacing between profiles) at the weld centerline. For the profiles shown, this is approximately a

30 percent reduction. This effect is likely due to a reduction in dynamic forces experienced by the weld because of a smoother transition across the weld running surface (i.e., the wheel does not impact the weld as hard).

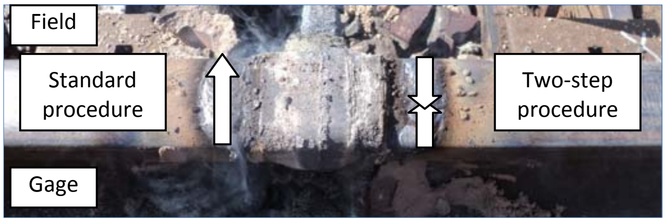

Figure 2. Two Weld Procedures showing Application of HAZ Overlay Next to Sheared Weld

TTCI previously evaluated in-track performance of head alloyed thermite welds in high strength rails at FAST.[4,5] The alloying increases the hardness of the weld metal and reduces the rate of deformation. The alloying directly affects the hardness of the weld metal but does not directly improve the HAZ properties since they occur outside the weld in the adjacent rail. Based on the weld metal performance of the head alloyed thermite welds and the preliminary improvements of the overlay treatment, TTCI decided to combine the two to determine if further improvement in running surface performance could be achieved.

Figure 3 shows a series of longitudinal profiles for a head alloyed thermite weld with overlay treated HAZ. A profile for an untreated head alloyed weld is also included for comparison. There was approximately a 50 percent reduction in HAZ batter for the treated weld compared to the untreated weld. The combination of the two processes produced welds with the least amount of overall batter at the running surface.

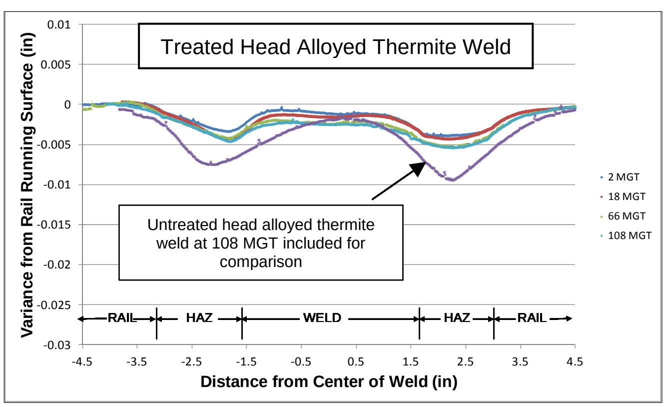

Figure 3. Overlay Treated Head Alloyed Thermite Weld

REVENUE SERVICE TESTING

CN worked with TTCI to install three sets of test welds to evaluate overlay treatments. Six welds were installed in a line near Superior, Wisconsin, in September 2012. Two welds were installed in a line near Toronto, Ontario, and four welds were installed in a line near Winnipeg, Manitoba, in October 2012; all were in tangent track. Overlay treatments made on the revenue service welds used the standard welding procedure described in the previous section. Each location, however, had a different set of installation parameters (preheat type and welding method). Table 2 summarizes the welds installed at these locations. The selected lines accumulate from 40 to 44 MGT annually. TTCI is investigating automation of the overlay welding process, which should significantly reduce quality related issues such as porosity.

Table 2. Summary of Welds Installed at CN Test Locations

Location	Preheat	Overlay	Test welds	Untreated welds
Superior WI	oxy-propane	SMAW	4	2
Toronto ON	air-propane	SMAW	2	-
Winnipeg MB	air-propane	FCAW	3	1
Notes:	SMAW = Shielded Metal Arc Weld (stick Weld)			
	FCAW = Flux Core Arc Welding (wire weld)			

As of January 2014, none of the welds have failed and all remain in service. The welds near Superior, Wisconsin, have accumulated approximately 56 MGT, and the welds near Toronto and Winnipeg have accumulated approximately 51 MGT. Figures 4 and 5 show a treated weld and an untreated weld near Winnipeg. Visually, the treated weld shows almost no metal flow at the running surface while the untreated weld is already developing signs of lateral metal flow at the soft HAZ.

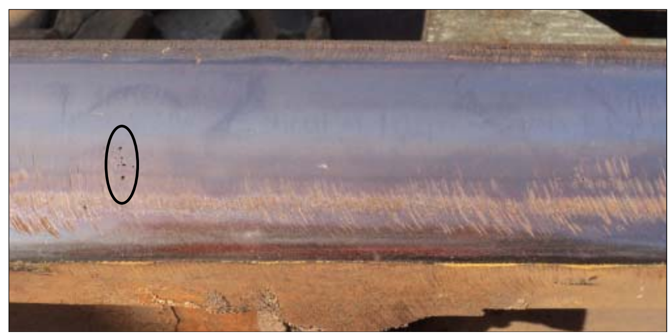

Figure 4. Treated Thermite Weld Running Surface at approximately 36 MGT, 5 MGT after Rail Grind (Oval indicates surface porosity at overlay.)

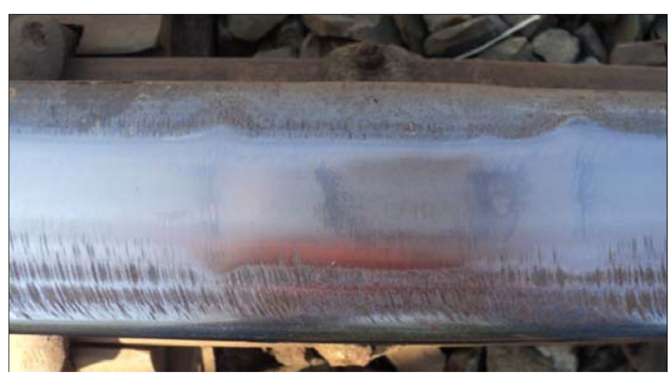

Figure 5. Untreated Thermite Weld Running Surface at approximately 36 MGT, 5 MGT after Rail Grind

Observing applications of the overlay treatment in the revenue service environment allowed TTCI to better understand challenges that may be faced by railroads in implementing the treatment. Individual railroads will have some slight differences in procedures; however, the overall process will generally be the same. All welds produced for the CN tests were conducted using CN cold weather procedures.

The overlay treatments were performed as soon as possible after the thermite weld head riser was sheared (but no later than 5 minutes after shearing). Upon completion of the overlay treatment, the weld was hot ground and then covered. In general, the application of the overlay treatment in service conditions worked well. The biggest challenge encountered was that several welds had porosity at the running surface where the overlay treatment was applied. The oval in Figure 4 shows porosity. TTCI is investigating automation of the overlay treatment, which should significantly reduce quality related issues such as porosity.

TTCI is monitoring weld longitudinal profiles twice yearly. Figure 6 shows the running surface profiles for one of the welds installed near Winnipeg. The treatment eliminated the HAZ dipping on the sides of the weld. More in-depth analysis will be conducted as additional tonnage is accumulated and data is collected.

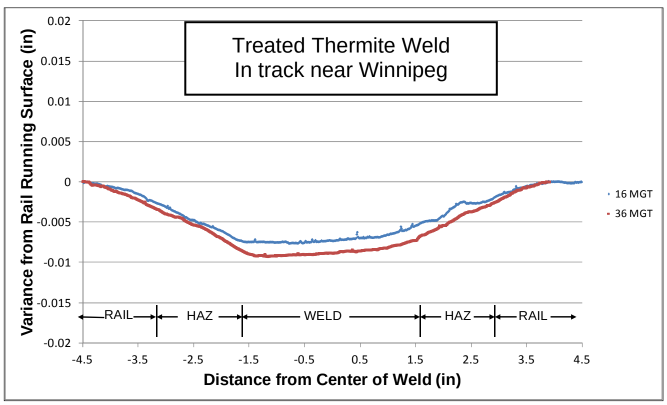

Figure 6. Overlay Treated Thermite Weld in Track near Winnipeg

CONCLUSIONS

TTCI has conducted testing of overlay treated welds at FAST and has worked with CN Railway to test overlay treatments in revenue service.

Welds at FAST have accumulated 108 MGT with one weld failure in a control weld as of January 2014. Figure 7 shows representative profiles for the four general weld/treatment combinations tested at FAST. Based on limited data, overlay treatments reduce the overall rate of thermite weld batter, including at the weld centerline. The combination of overlay treatment and alloying of the weld head produced the greatest reduction in running surface degradation.

Welds in CN revenue service lines have accumulated from 51 MGT to 56 MGT with no failures.

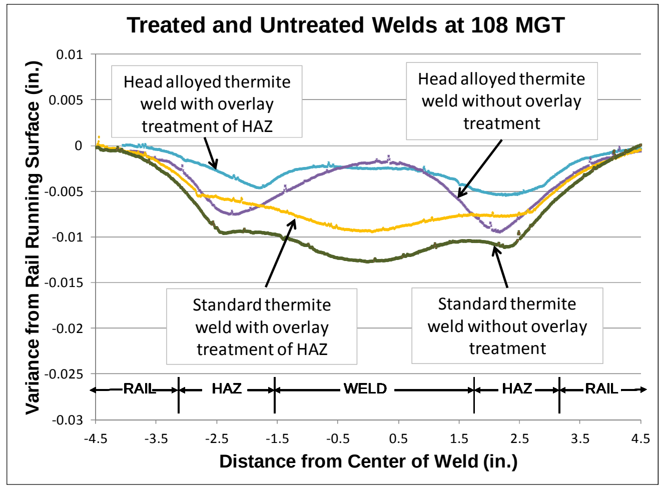

Figure 7. Summary Profiles for FAST Test Welds at 108 MGT

FUTURE WORK

TTCI is starting a project in 2014 to automate the overlay welding process in cooperation with industry vendors. Automation is expected to reduce operator dependence of the process and increase consistency in quality.

TTCI is currently working with a western railroad to begin a second revenue service test. TTCI is also investigating the possibility of using a similar treatment for electric flash welds to improve weld running surface performance.

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