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Testing at FAST of Electric Flash Butt Weld Heat Affected Zone Treatments

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Summary

Transportation Technology Center, Inc. (TTCI) has been investigating two methods to mitigate the running surface degradation of electric flash butt (EFB) welds occurring in heavy tonnage lines under 280,000-pound car operations in revenue service. TTCI had developed and implemented a heat affected zone (HAZ) overlay treatment for thermite welds in 2011 to mitigate soft HAZ defects. Based upon positive results on thermite welds, this method is being tested at the Facility for Accelerated Service Testing (FAST) as a solution to the surface degradation of EFB welds. An additional induction HAZ treatment to mitigate HAZ degradation for EFB welds was developed by EVRAZ North America (EVRAZ) and is also being tested by TTCI at FAST.

Results of laboratory and in-track testing at FAST for both the HAZ overlay treated and induction treated EFB welds show they have the potential to serve as a treatment for running surface degradation and to increase the life of an EFB weld.

TTCI has tested two HAZ overlay treatments for EFB welds at FAST:

- Increased running surface hardness of the welds and the mitigation of metal flow/batter in the soft HAZs have been the major benefits of applying the HAZ overlay treatment. This method is beneficial when the HAZ overlay weld beads are applied in the welding plant immediately after leaving the welder.
- In November 2014, four HAZ overlay treated welds and two untreated control welds were installed at FAST and have accumulated 170 million gross tons (MGT) as of December 2015. No weld failures have occurred; however, one of the four treated tests welds was removed due to an unrelated failed thermite weld nearby.

TTCI has also tested an EVRAZ induction HAZ treatment for EFB welds at FAST:

- In July 2015, four induction treated welds and six untreated control welds were installed at FAST and have accumulated 70 MGT as of December 2015. No weld failures have occurred; however, metal flow in the HAZ of the induction treated welds has been observed. This method of induction treatment is applied before the welds leave the welding plant.



INTRODUCTION

The main focus of the welding program at TTCI is to develop and demonstrate improved rail joining processes for heavy axle load service. Running surface degradation on electric flash butt (EFB) welds was found to be a major factor in the failure of these welds in revenue service. Through previous studies, surface degradation has been found to initiate at the furthest heat affected zone (HAZ) from the weld’s centerline, which is the softest part on both sides of the weld.¹

The HAZ of a weld consists of two primary regions, the near HAZ and the far HAZ. The microstructure in the far HAZ consists of spherical cementite in a soft iron matrix, and as a result is much softer than both the adjacent rail and the recrystallized cementite microstructure of the near HAZ. This soft zone causes weld batter and shortening of the weld life due to metal flow in that location.

Two HAZ treatment methods, one developed by TTCI and one by EVRAZ, presented in this study were developed to increase weld life and quality by improving weld running surface performance. These welds have been installed at the Facility for Accelerated Service Testing (FAST) on a 5-degree curve having 4 inches of superelevation.

HAZ OVERLAY TREATED EFB WELDS

TTCI has developed an overlay of the HAZ treatment consisting of weld beads positioned over each of the original soft HAZ of the EFB weld after shearing but before rough and finish grinding. The weld bead is bound between 0.25 inch and 1.0 inch from the edge of the sheared EFB weld. By applying the weld beads to the softest part of the head of the weld, enough heat is supplied to prevent softening of that section of the weld at the austenitizing temperature, thus increasing the hardness of that section.

LABORATORY EVALUATION

The first batch of test welds was made using an in-track welder to install the EFB weld; however, the extended time between the removal of the welding setup and the application of the overlay allowed for the HAZ to form before the overlay was applied. As a result, two soft HAZ were formed on each side of the EFB weld, which decreased the hardness of the running surface at the HAZ location (Figure 1).

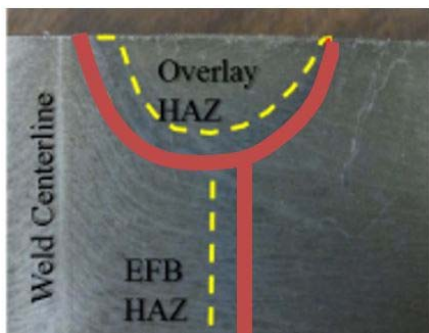


Figure 1. Right Quadrant of a Treated EFB Weld Cross Section after First Installation Attempt

The second batch of test welds was made using an in-plant welder to make the EFB welds. The overlay was applied within the marked boundaries as soon as practicable after the weld exited the welder. Because the heat was still contained in the EFB weld after it exited the welder, the overlay of the HAZ successfully shifted the original soft HAZ away from the centerline of the weld and reduced the width, thereby increasing the overall hardness of the weld’s running surface. Figure 2 is a diagram that shows Vickers hardness measurements of a treated EFB weld cross section from the second batch of test welds. This treatment impacted the shape of the soft HAZ to a depth of 0.25 inch below the running surface.

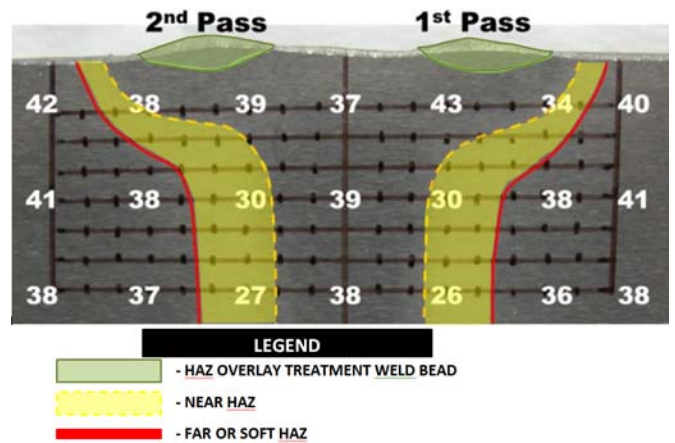


Figure 2. Diagram showing Vickers Hardness Measurements of a Treated EFB Weld Cross Section

IN-TRACK TESTING AT FAST

In November 2014, after the laboratory tests were completed, six test welds were installed on a 5-degree curve at FAST. Figure 3 shows the locations of one untreated control weld (NT#1) and two HAZ overlay treated welds (HAZ#1 and HAZ#2) installed on the high rail and one untreated control weld (NT#2) and two HAZ overlay treated welds (HAZ#3 and HAZ#4) installed on the low rail.

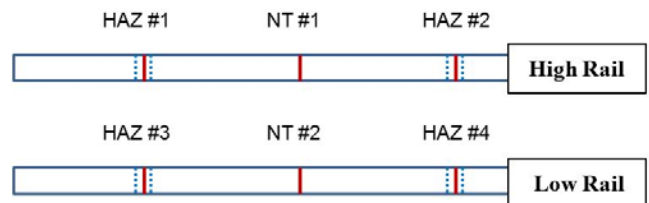


Figure 3. Diagram showing locations of six test welds installed at FAST. NT represents the not treated control welds and HAZ represents the HAZ overlay treated welds

In December 2015, the welds had accumulated 170 million gross tons (MGT) of traffic, and the differences of the untreated and treated welds can be clearly seen in both the surface photographs and longitudinal profiles represented in

Figures 4 and 5. One of the HAZ overlay treated welds has recently been removed due to maintenance from removing a thermite weld nearby.

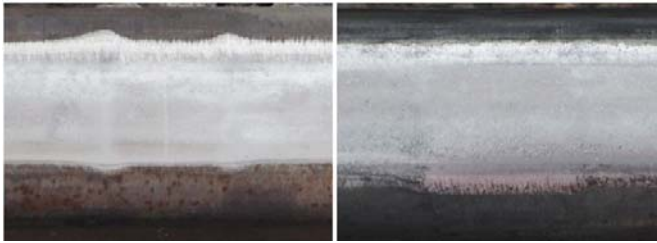


Figure 4. (Left) Surface photo of an untreated test weld (Right) Surface photo of a HAZ treated test weld

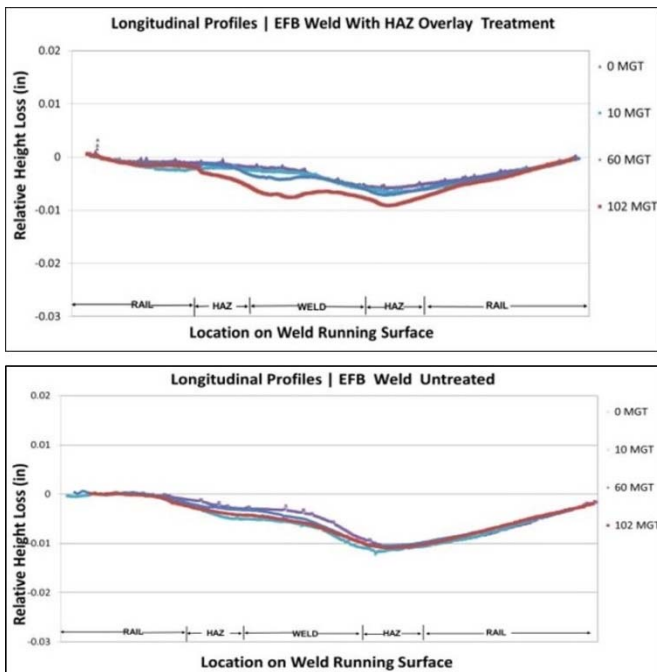


Figure 5. (Top) Longitudinal profile of the running surface of a HAZ treated test weld (Bottom) Longitudinal profile of the running surface of an untreated test weld. All profiles were taken along the center of the weld's running surface.

EVRAZ INDUCTION TREATED EFB WELDS

In 2014, EVRAZ approached TTCI to help with the testing of its EFB weld HAZ induction treatment. This process was completed by placing an induction coil over the head of the weld for a period of time. Currently the treatment is applied in the welding plant but plans to implement the treatment in the field environment are being discussed. The goal of this treatment was to re-austenitize the soft HAZ of the weld, therefore increasing the hardness of the running surface (Figure 6). The induction treatment was found to affect the head of the weld to a depth of 0.203 inch below the running surface.

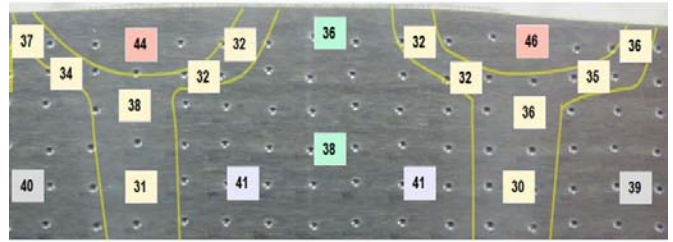


Figure 6. A diagram showing the Vickers hardness measurements of an induction treated EFB weld cross section

LABORATORY EVALUATION

Laboratory tests showed two soft HAZ on each side of the EFB weld when the induction treatment was applied. The treatment was successful in narrowing the soft HAZ from the original width as seen in Figure 7 (left).

Figure 7 (right) displays the effects of the induction coil slightly being shifted from the center of the weld. This shift can influence the alignment of the treatment and cause the original soft HAZ of the EFB weld to align with the soft HAZ of the induction treatment, and thus can create a wider soft HAZ on the running surface.

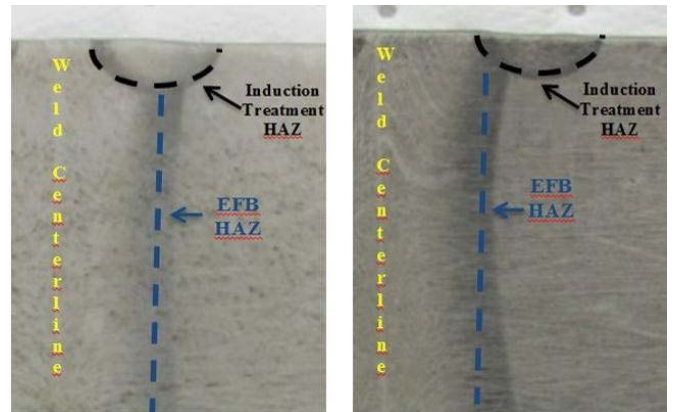


Figure 7. (Left) the right quadrant of an induction treated EFB weld cross section with the correct alignment. (Right) the right quadrant of an induction treated EFB weld cross section with misalignment

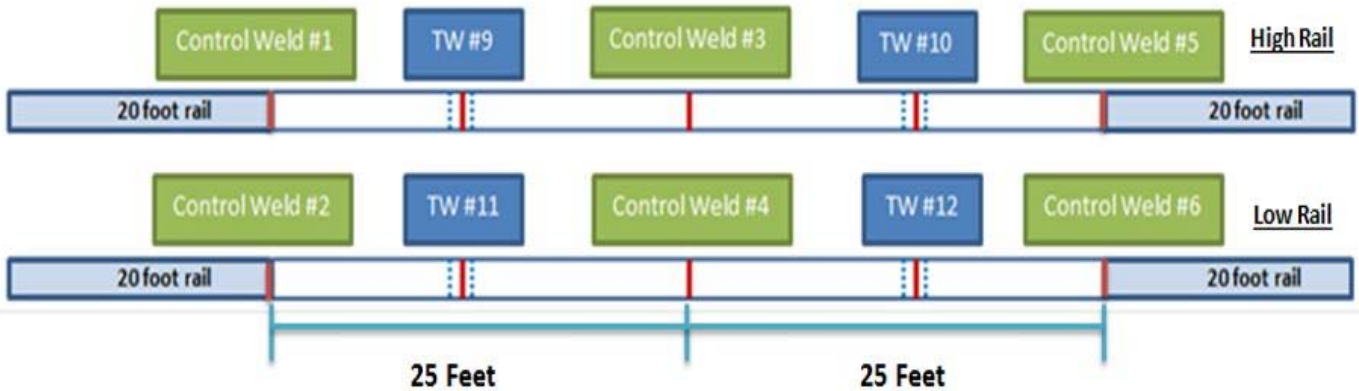


Figure 8. A diagram showing the installation locations of the 4 induction treated and 6 control welds tested at FAST. TW represents the treated welds

IN-TRACK TESTING AT FAST

In July 2015, a 10 weld test zone of TTCI HAZ overlay treated welds was installed on the same 5-degree curve at FAST. Figure 8 shows the locations of two induction treated test welds and three untreated control test welds that were installed on both the high and low rail.

The induction treated welds currently have been exposed to 70 MGT of heavy axle loads, and no weld failures have occurred. The induction treatment creates two narrow soft HAZs on each side of the EFB weld, which explains the similar running surface metal flow between the untreated and treated welds. Figures 9 and 10 display the current photos of the test welds and their corresponding longitudinal profiles.



Figure 9. (Left) Surface photo of an untreated test weld (Right) Surface photo of a HAZ treated test weld

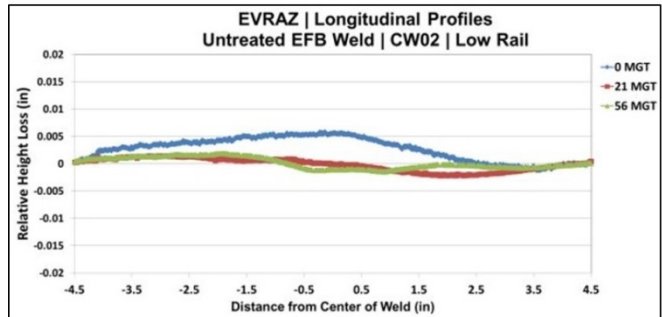
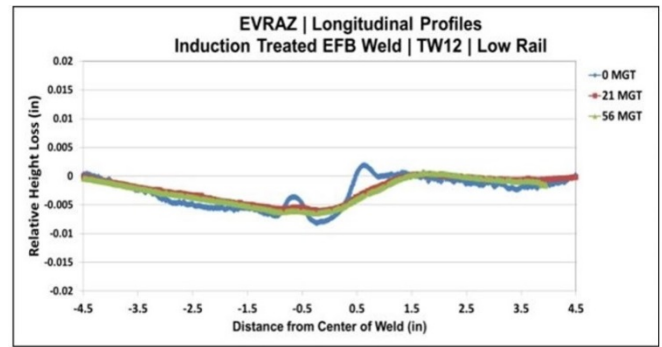


Figure 10. (Top) Longitudinal profile of the running surface of a HAZ treated test weld. (Bottom) Longitudinal profile of the running surface of an untreated test weld. All profiles were taken along the center of the weld’s running surface.

CONCLUSION

Test results of HAZ overlay treated and induction treated EFB welds show both methods narrow and shift the soft HAZ of the EFB weld in the running surface.

Longitudinal profiles at intervals of 50 MGT and photographic documentation will continue to be recorded for both sets of weld testing currently present on the 5-degree curve at FAST, and the effects of each treatment on weld life will be studied.

REFERENCES

1. Gutscher, Daniel. July 2013. “Degradation of Thermite Weld Running Surface in Heavy Axle Load Environment.” *Technology Digest* TD-13-017, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.

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