TECHNOLOGY DIGEST
TD-13-029
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TIMELY TECHNOLOGY TRANSFER

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Testing of Head Alloyed Thermite Welds at Facility for Accelerated Service Testing

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Summary

Transportation Technology Center, Inc. (TTCI) regularly tests new or improved rail welding products submitted by industry vendors at the Facility for Accelerated Service Testing (FAST), Pueblo, Colo. One such weld product recently tested by TTCI is the head alloyed thermite weld from Orgo-Thermit, Inc. Head alloyed thermite welds are designed to have increased running surface hardness compared to standard thermite welds. The increased head hardness better matches the surface hardness of high strength rail, while maintaining the toughness of a standard thermite weld in the base. Results of laboratory and in-track testing at FAST include the following:

- Hardness at the center running surface of the weld is approximately 390 HB, closely matching the hardness of premium rail.
- The welds meet AREMA guidelines for slow bend testing, indicating that the head alloying process does not compromise the toughness of the web and base.
- Head alloyed thermite welds installed at FAST in February 2011 have accumulated 324 million gross tons (MGT) of heavy axle load traffic with no service failures.
- Head alloyed thermite welds in high strength rails have shown a ~50-percent reduction in the rate of wear and deformation at the weld centerline compared to standard thermite welds.

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INTRODUCTION

TTCI tested the Orgo-Thermit head alloyed thermite welds as part of the Improved Rail Welding and FAST Heavy Axle Load Strategic Research Initiatives (SRI). One of the project objectives is to test new and or improved rail welding products in the laboratory and in track at FAST.

Orgo-Thermit developed the head alloyed thermite weld to provide increased weld running surface hardness that better matches the running surface hardness in high strength rails.

Figure 1 illustrates the hardness mismatch that can occur when standard thermite welds are used in premium rails, and the closer hardness match that alloyed welds can provide.

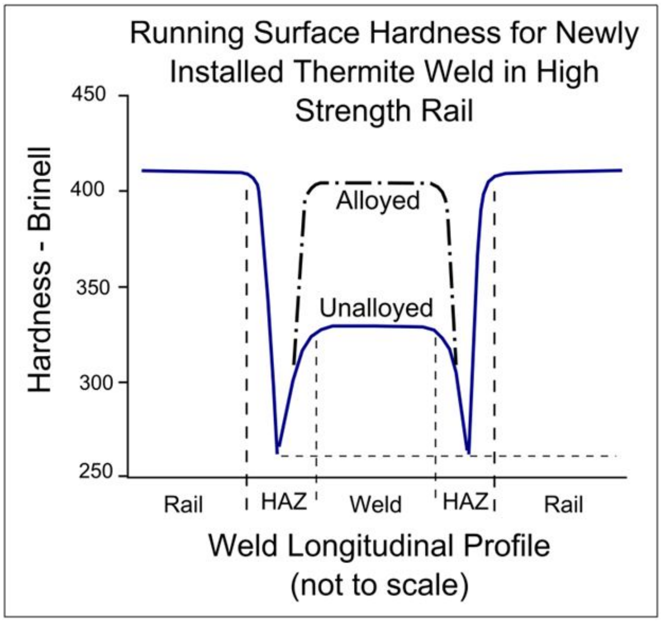

Figure 1. Conceptual Diagram Showing Hardness Differences Between Premium Rails, Alloyed Welds, Standard Welds, and Heat Affected Zones

The Orgo-Thermit head alloyed thermite welds are identical to Orgo-Thermit standard thermite welds except that alloying elements, which increase hardness and strengthen the weld metal, are added to the head of the weld when the head riser fills during the weld pour. The alloying elements are contained in a small metal container that is incorporated into the bottom of the thermite weld diverter plug. When the head riser fills, the hot molten steel melts the alloy container, dispersing the alloy elements into the head of the weld. The metallurgy of the web and base of the weld are not altered by the plug.

Figure 2 shows a diverter plug used to alloy the welds. The process, portion, and weld kit are the same as for a standard thermite weld with the exception of the alloy plug.

Figure 2. Alloy Container Incorporated into Bottom of Diverter Plug (The container melts when head riser fills, dispersing the alloying elements into the head of the weld)

Current AREMA guidelines indirectly limit thermite weld hardness/strength. The limitation is a result of the recommendation for slow bend testing for thermite welds. The recommended minimum deflection for welds in high strength rail is 0.6 inch.[1] Thermite welds made with full-section high hardness weld portions generally cannot meet this deflection. The 4-point slow bend test places the base of the weld in tension. Because the capability of materials to deflect under bending loads generally decreases as hardness increases, welds with harder bases tend to fail at lower deflections. Field testing has demonstrated that full-section higher hardness welds fail differently than standard welds. Testing at FAST during the first phases of 39-ton axle showed that thermite welds with full section hardness of 370 HB were more susceptible to web cracking than standard hardness thermite welds.[2]

LABORATORY TESTING

Prior to beginning in-track testing, TTCI conducted laboratory evaluations of the welds. Figure 3 shows a detailed hardness map of the weld, including the heat affected zones. Figure 4 shows hardened regions of the weld overlaid on a longitudinal cross section of the weld. The majority of the hardening occurred within the top 2.25 inches of the weld. The weld metal adjacent to the heat affected zones developed hardness in excess of 410 BHN. AREMA recommends checking the welds microscopically for martensite when the weld hardness exceeds 410 BHN. No martensite was found in these regions in the welds tested by TTCI. The hardness of the heat affected zone decreases to approximately 260 BHN similar to unalloyed welds.

Head alloyed thermite welds were tested in 4-point bending as recommend by AREMA. The welds consistently met the minimum deflection of 0.6 inch required for welds made in high strength rails.

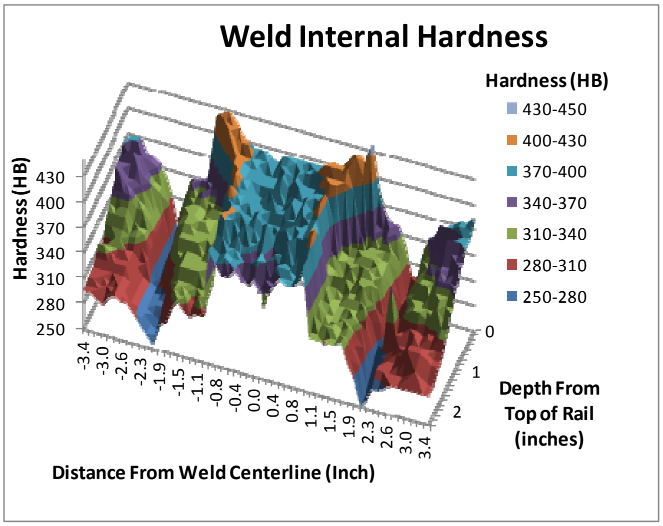

Figure 3. Hardness Map of Head Alloyed Thermite Weld, and Heat Affected Zones

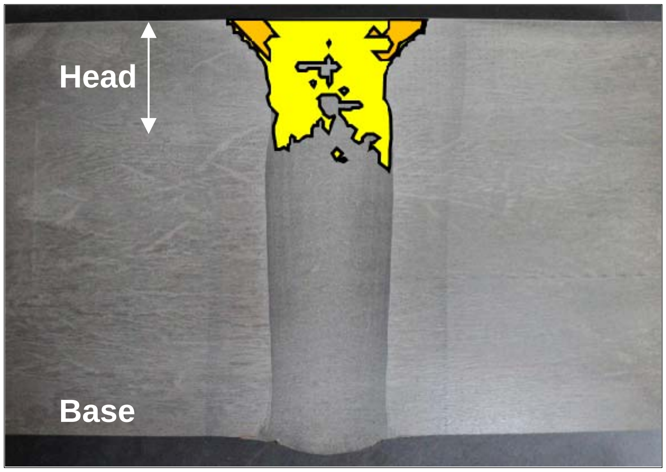

Figure 4. Longitudinal Cross Section of an Orgo-Thermit Head Alloyed Thermite Weld showing Weld Regions Harder than 380 BHN (yellow) and 400 BHN (orange)

INTRACK TESTING AT FAST

In February 2011, TTCI installed 10 welds in the high rail of HTL section 3, a 5-degree curve. Seven of the welds were made in high strength rail with an initial hardness of approximately 390 BHN. Two of the welds were made in intermediate strength rail with a hardness of 340 BHN. One weld was made at the junction of the two rail grades; this was to investigate how misapplication of the alloy plugs could affect weld service performance. The manufacturer does not recommend using the alloy plugs in mixed strength or standard strength rail welding applications. None of the 10 welds failed in 324 MGT of testing under 39-ton axle loads.

TTCI conducted visual inspection, hardness measurements, and longitudinal profiles of all the weld running surfaces. Initial measurements were taken within 4 MGT of installation, and subsequent measurements were taken at varied intervals throughout the test. Longitudinal plots of the weld running surface from the different MGT levels were overlaid such that the rail running surfaces were aligned. This approach allowed observation of weld and HAZ running surface changes relative to the adjacent rail surfaces.

Figure 5 shows the layout of the 10 welds tested in the HTL at FAST.

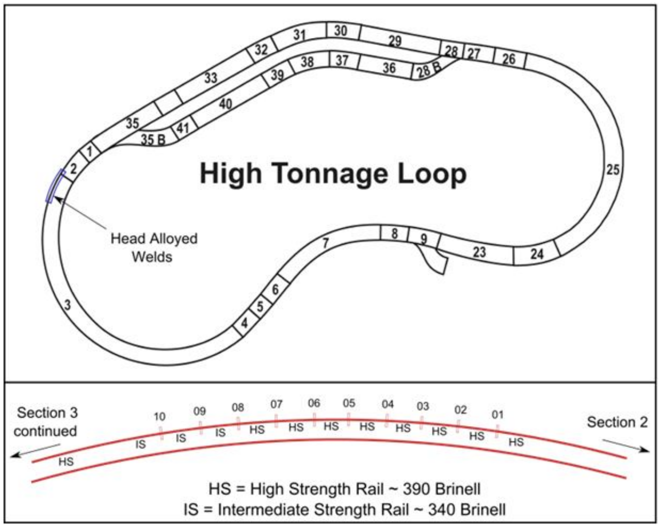

Figure 5. (top) Map of HTL Showing Location of Test Welds (bottom) Layout of Welds in Test Zone (~20-feet distance between welds)

Figure 6 shows a head alloyed thermite weld in premium rail, with the profile of a nearby standard unalloyed thermite weld in the same premium rail. The wear (i.e., deformation) rate at the weld centerline was approximately 50 percent lower for the alloyed weld.

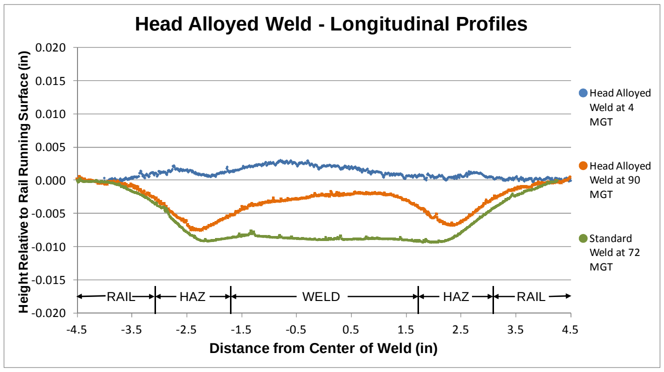

Figure 6. Longitudinal Profile of Head Alloyed Thermite Weld and Standard Thermite Weld in Premium Rail

Figure 7 shows profiles at various MGT levels for a weld which was made in high strength rail. A steady wear was observed at the centerline of the weld running surface. Figure 8 shows the profiles for a weld that was made in intermediate strength rail. In the intermediate strength rail, the alloyed weld centerline experienced a slower wear rate than the surrounding rail, making it appear to grow over time. This was a direct result of the weld being significantly harder than the adjacent rail. Having a weld that is harder than the adjacent rail is expected to provide no benefits, and the bump between the battered HAZ may be more likely to shell over the long term.

Orgo-Thermit's recommended practice for thermite welding of different rail grades (different hardness rails) is to employ the thermite-portion welding kit specified for the lower strength (lower hardness) of rail that is joined; i.e., if the rails to be joined are both high strength, then use the head alloyed thermite welding kit, consisting of the alloyed plug with an intermediate hardness portion. If the weld is joining a high strength rail to an intermediate or standard strength rail, Orgo-Thermit recommends using the intermediate hardness welding kit consisting of an intermediate hardness portion only. The same intermediate hardness welding kit is also used if both rails to be joined are intermediate or standard strength rails.

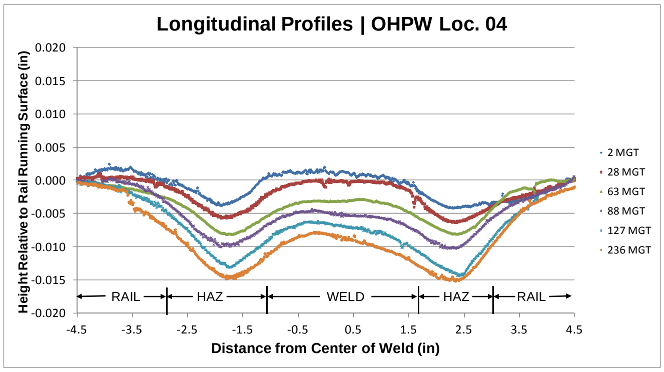

Figure 7. Longitudinal Running Surface Profiles for a Weld Made in High Strength Rail Steel

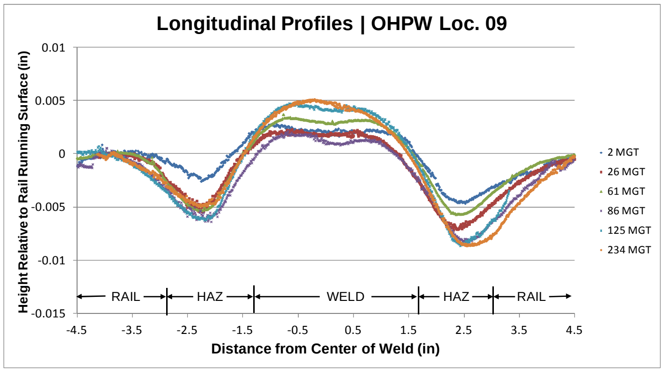

Figure 8. Longitudinal Running Surface Profiles for a Weld Made in Intermediate Strength Rail Steel

CONCLUSION

Compared to standard thermite welds, head alloyed thermite welds tested by TTCI have shown:

- Increased head hardness
- Reduced wear/deformation
- Similar deflection in 4-point slow bend tests compared to unalloyed welds

These characteristics should results in improved weld performance in premium rails. None of the 10 head alloyed thermite welds installed at FAST in 2011 failed in 324 MGT of testing. Standard unalloyed thermite welds installed in Section 3 at FAST during the same time frame exhibited an average weld life of 165 MGT.

FUTURE TESTING

Additional head alloyed thermite welds were installed at FAST in 2013. The heat affected zones adjacent to some of these welds were treated with a process developed under the AAR SRI Program.[3] The heat affected zone treatment should reduce batter and improve weld performance. Head alloyed thermite welds will also be included in future revenue service testing.

REFERENCES

1. Association of Railway Engineering Maintenance of Way. 2010. *Manual for Railway Engineering*, Chapter 4, 3.13.4.7 "Slow Bend Testing," Lanham, Maryland.
2. Garcia, Greg and Jon Hannafious. September 1995. "Thermite Weld Performance Under Heavy Axle Load Operations at FAST." *Technology Digest* TD-95-020. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
3. Gutscher, Daniel. July 2013. "Improving Thermite Weld Heat Affected Zones." *Technology Digest* TD-13-013. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.