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Wide-Gap Weld Testing at Eastern Mega Site

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Summary

In 2005, Transportation Technology Center, Inc. (TTCI) and Norfolk Southern Railway (NS) began a test of wide-gap weld (WGW) products at the eastern mega site near Bluefield, West Virginia. WGWs enable the repair of weld or railhead defects with a single weld instead of the typical plug and weld procedure that requires two welds. A defect limited to less than 2.75 inches in the longitudinal direction can be replaced with a single WGW.

Two types of WGWs were installed adjacent to a high strength rail test: 16 Orgo-Thermit welds in 2005 and 16 Railtech Boutet welds in 2006. The WGWs have accumulated 355 and 300 million gross tons (MGT) of traffic, respectively. The following are the main findings from this test:

- WGW is a viable rail joining practice for heavy axle load operating environments. Even without the benefits of regular preventative grinding, these welds showed a minimum fatigue life of 265 MGT, with an estimated average life of 490 MGT. This is comparable with expected rail life in 7- to 10-degree curves in North American heavy haul environment.[1] WGWs are expected to last considerably longer when preventative grinding is used to remove minor shelling and plastic flow.
- WGWs exhibited running surface degradation consistent with that observed in standard gap thermite welds, but the degree of degradation was greater and occurred faster for WGWs compared to standard gap welds. This observation is consistent with observations of weld degradation at the Facility for Accelerated Service Testing in Pueblo, Colorado.[2]
- Two Railtech Boutet WGWs were removed because of internal porosity defects detected by ultrasonic inspection. The first defect was found upon installation, and the weld was replaced. The second defect was found after 209 MGT, and the weld was removed from the test.
- Two Orgo-Thermit WGWs were removed. One weld experienced a fatigue fracture at 265 MGT that initiated at flashing under the base. The fracture occurred shortly after the weld developed a shell on the gage corner of the weld. The second weld was removed by NS when inspection revealed a similar gage corner shell.

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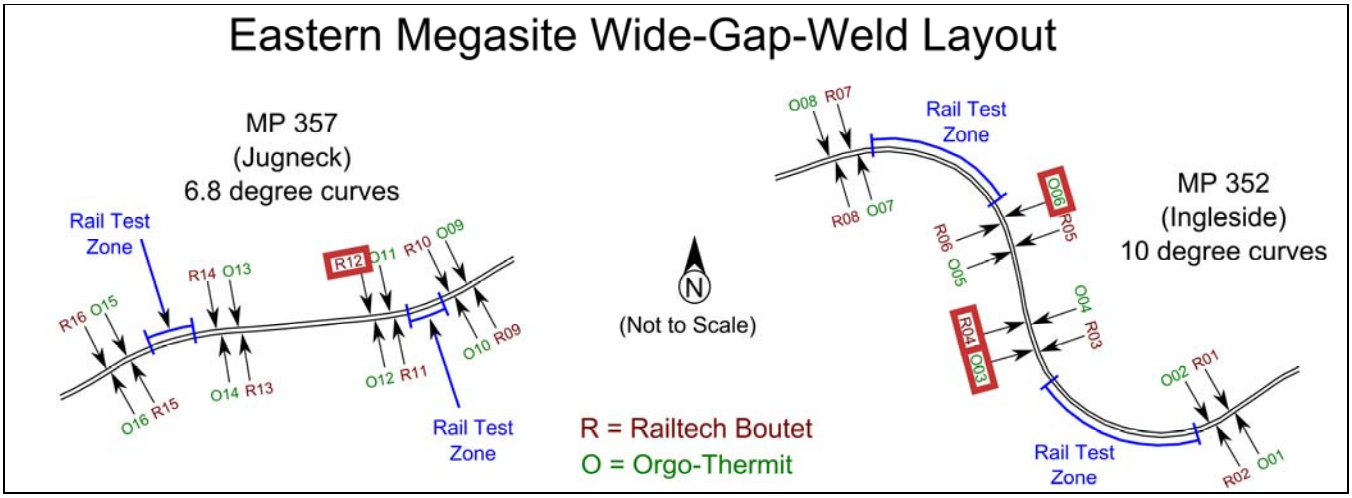

Figure 1. WGW Layout at Eastern Mega Site ─ Red Boxes Indicate Welds Removed during the Test as Described in this Report

INTRODUCTION

In 2005, TTCI and NS initiated a WGW test at the eastern mega site near Bluefield, West Virginia. Welds from two manufacturers were installed approximately one year apart. In October 2005, 16 Orgo-Thermit welds were installed in the spirals adjacent to premium rail test curves. The welds were staggered between low and high rail, and provision was made for later installation of additional welds. One year later, 16 Railtech Boutet welds were installed in the reserved locations.

Figure 1 shows the locations of the welds. In 2009, TTCI reported on the preliminary results of the testing and in 2010, provided an update.[3,4] During the test, four welds were removed for various reasons. One weld fractured in service, two welds were removed because of ultrasonic indications, and one weld was removed because of shelling at the gage corner of the railhead.

WGWs are thermite welds that incorporate a wider gap (2.75 inches) between rail ends than standard thermite welds (1 inch). WGWs were developed as an alternative repair process to the conventional plug and weld procedure. The wider gaps enable the use of a single weld to repair railhead defects. Welds or rails with defects or transverse breaks limited in the longitudinal direction to less than 2.75 inches in length can be repaired by the use of a single WGW, reducing labor and out of service time for the track.[3]

The NS mega site averages 55 MGT of mixed traffic per year, of which approximately 50 percent is heavy axle load (HAL) coal trains. The track in the weld test zone consists of 141 RE rail with cut spikes and wood ties.

TEST OVERVIEW

TTCI conducted semiannual inspections and measurements of the welds throughout the test period. Inspections were conducted visually and ultrasonically, and longitudinal profile and surface hardness measurements were taken.

In a previous *Technology Digest*, TTCI reported on metal flow observed on the gage corner of several of the welds.[3] In May 2009, manual grinding was performed on 10 of the Orgo-Thermit welds and on 11 of the Railtech Boutet welds. Grinding removed flow on the gage face of the welds. In April 2010, two Orgo-Thermit welds and one Railtech Boutet weld were ground to remove metal flow on the gage face.

WELD HARDNESS

TTCI conducted surface hardness measurements along the center of the running surface at five locations for each weld. Measurements were taken from east (-) to west (+). The locations were -12 inches (parent rail), - heat-affected-zone (HAZ), weld centerline (CL), +HAZ, and +12 inches.

Figures 2 and 3 show how the welds and HAZs work hardened with accumulated tonnage. The majority of hardening of the weld and HAZ running surfaces occurred within the first 50 to 60 MGT of traffic, and then the rate of hardening decreased. This pattern of rapid initial hardening is normal for thermite welds.

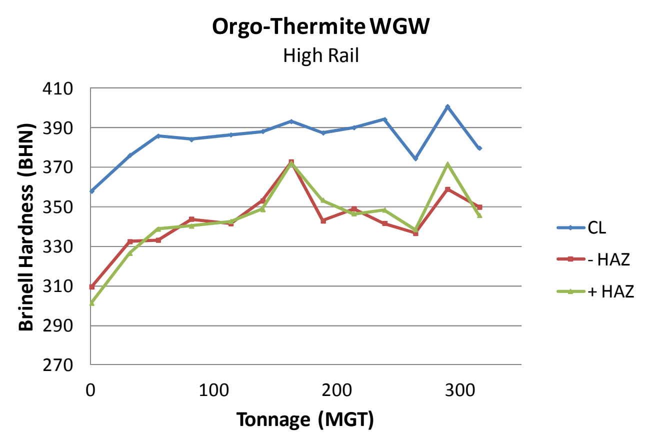

Figure 2. Average Running Surface Hardness in the Weld and HAZ for Orgo-Thermit WGWs Installed in High Rail

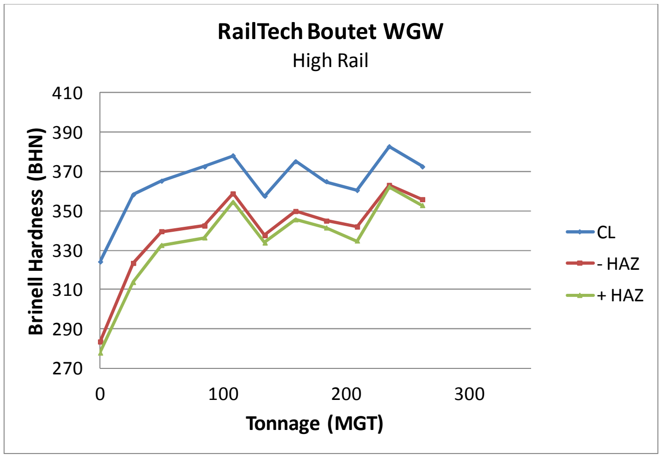

Figure 3. Average Running Surface Hardness in the Weld and HAZ for Railtech Boutet WGWs Installed in High Rail

WELD PROFILE

Figure 4 shows longitudinal running surface profiles for one WGW. The WGWs followed a typical wear/batter pattern for thermite welds. The soft HAZs quickly battered as the running surface work hardened, but then the rate of batter slowed in comparison to the adjacent rail wear. (Batter is metal deformation and flow at the rail running surface in the HAZ and weld that results from high contact forces at the wheel/rail interface.) The WGWs followed the same pattern observed in work hardening of the HAZ. The result was a rapid formation of HAZ dipping on both sides of the welds. The thermite weld metal experienced a steady batter rate resulting from wheel impacts as they traversed the HAZ.

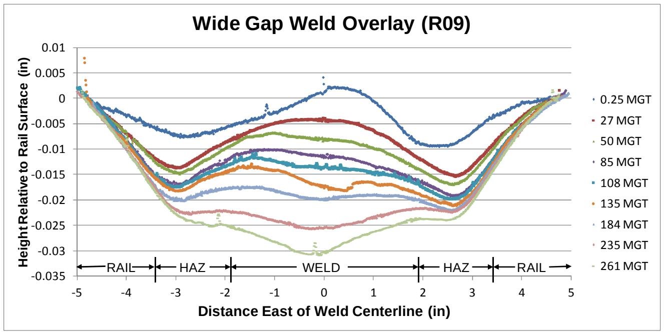

Figure 4. Weld Profile Degradation ─ Primary Direction of Loaded Traffic is Left to Right

WELD REMOVALS

During the course of the testing, several WGWs were removed or failed. Table 1 summarizes the removals and provides the tonnage accumulated.

Table 1. Summary of Weld Removals

Weld ID	Reason Removed	Defect	Date	MGT
WGW R4(initial)	Ultrasonic Indication	Gas Hole in Web	10/2006	0
WGW R12	Ultrasonic Indication	Gas Hole in Web	10/12/2010	209
WGW O6	Service Failure	Runout, Bottom Base	10/17/2010	265
WGW O3	Surface Condition	Shelling of Gage Corner	11/2011	321

TTCI performed a Weibull analysis based on the test results shown in Table 1 to estimate the time to failure, or expected life, for the welds under similar HAL revenue service operating conditions. It should be noted, however, that there were too few failures to provide a reliable result using the Weibull distribution due to wide confidence limits. Despite this, a survival analysis shows that 50 percent of the welds in the test will fail by 490 MGT. The minimum observed survivability of these welds is 209 MGT.

As part of the initial installation inspection, all welds were scanned ultrasonically by NS technicians. The Railtech Boutet weld R4 was identified as containing a defect and was removed. A new WGW was installed in its place and was also labeled as R4. The first weld was sectioned by NS and found to contain a gas pore. In October 2010, a second Railtech Boutet weld (WGW R12) was identified by ultrasonic inspection to have a defect. Laboratory evaluation revealed porosity similar to that found in the initial WGW R4. Figure 5 shows the transverse cross sections of WGWs R4 and R12.

Figure 5. Gas Holes in Railtech Welds R4 (left) and R12 (right)

Two Orgo-Thermit welds were removed during the test. In September 2010, a large shell was observed on the gage corner of WGW O6. In October 2010, the weld fractured due to fatigue that initiated at runout flashing under the base of the rail. Figure 6 shows WGW O6 and the fracture surface. One year later a second weld, WGW O3, developed a large shell on the gage corner, and NS removed the weld. Figure 7 shows the shell on WGW O3.

Figure 6. WGW O6 with Shelling on Gage Corner and Fatigue Fracture from Base of Weld ─ Inset Shows Fracture Face ─ Fatigue Initiated at Runout at Base of Weld

Figure 7. WGW O3 Shelling on Gage Corner

COMPARISON TO STANDARD GAP WELDS

In August 2005, approximately 14 thermite welds with standard 1-inch gaps were used to install the rail test at the eastern mega site. In 2007, two welds were removed for maintenance purposes when a timber bridge in the rail test zone was converted from open deck to ballasted deck. None of the remaining 12 welds experienced service failures.

The standard gap welds experienced running surface degradation similar to the WGWs, but to a lesser degree. The welds developed metal flow at the HAZ and at the weld. One weld developed a shell at the gage corner. Similar to the WGWs, standard gap welds that received rail grinding had reduced running surface degradation.

CONCLUSIONS

In October 2011, the profile and hardness monitoring of WGWs at the eastern mega site concluded, and final measurements were taken; however, semiannual visual inspections will continue, and any future failures will be noted and investigated by NS Research and Test Department and TTCI as needed.

The test results show that WGW is a viable rail joining practice for HAL operating environments.

Several 1-inch gap standard welds were located near the WGW test zones. The welds were installed in August 2005 and received the same traffic as the WGWs. Both the standard welds and WGWs demonstrated similar running surface degradation patterns (i.e., batter and chipping of the gage corner), but the WGWs did so to a greater degree and at a faster rate. This is in agreement with general observations of both types of welds at the Facility for Accelerated Service Testing.[2] Both standard welds and WGWs displayed a positive response to rail grinding.

Rail grinding improved the running surface profile and reduced the difference in batter between rail, HAZ, and weld metal. Welds installed in rail that receives periodic rail grinding should perform better than welds observed in this test, because rail grinding was only implemented as the rail condition necessitated it.

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