ABSTRACT

Results from heavy axle load revenue service testing have shown that the implementation of top-of-rail (TOR) friction control has delayed the occurrence of rolling contact fatigue (RCF) in premium-grade rail (about four times as long as when TOR was not implemented) and resulted in a significant reduction in rail wear. Transportation Technology Center, Inc. has been investigating practices at two mega sites in an effort to optimize rail life extension strategies.

With the wear life and overall performance exceeding previous expectations, the life of plant welds have become a limiting factor in the actual service life of continuous welded rail in curves, especially after 1,500 MGT. As such, improved rail welding strategies are being developed to improve weld performance and bring the life of such welds closer to that of the parent rail.

With more than 2,000 MGT accumulated to date at the western mega site and more than 450 MGT at the eastern mega site, premium rails in both locations continue to show excellent wear performance and resistance to internal defects. Although TOR friction control has been effective with regard to wear reduction and prevention of RCF in premium rail, the rate of electric flash-butt (EFB) weld degradation in the test curves suggest preventive grinding, with improved welding practices, may be necessary to mitigate severe weld degradation later in the life of the rail. Independent of TOR friction control, the implementation of preventive grinding has been effective in managing RCF as well as surface degradation of EFB welds.

INTRODUCTION

Rail performance testing has been integral part of the heavy axle load (HAL) revenue service program at the mega sites since 2005. The initial objective of this testing at the mega sites was to supplement the testing at the Facility for Accelerated Service Testing (FAST) in Pueblo, Colorado, to provide more diverse operating and climatic conditions to further investigate the performance of the premium rails available to the industry, featuring improved metallurgical properties and cleanliness. In 2008, Transportation Technology Center, Inc. (TTCI) extended the scope of testing to investigate the long-term benefits associated with rail life extension strategies, namely gage-face lubrication, top of rail (TOR) friction control, and preventative grinding practices.

Results from the mega sites have shown as rail life continues to increase because of improved rail performance and rail life extension strategies, electric flash-butt (EFB) welds previously expected to last
for the life of the rails are experiencing breakdown at the running surface. This degradation prevents EFB welds from achieving the same longevity as rails and, in turn, prevents rail from realizing its extended service life in track. This insight has prompted an initiative into improved welding strategies to mitigate running surface degradation initiating at the softer heat-affected zones (HAZ) of the welds, beginning with thermite welding. Following successful testing at FAST, a number of thermite welds featuring a revolutionary HAZ treatment are currently being monitored at multiple revenue service locations, including the western mega site.

This paper presents the most recent results from this ongoing study being conducted in the North American HAL revenue service environment. It includes recent discoveries made with regard to the effect of EFBW degradation on service life of rails in HAL revenue service as well as results of strategies to mitigate this new issue affecting service life of premium rail steels in this environment.

RESULTS FROM THE EASTERN MEGA SITE

The evaluation of the long-term performance of premium rail in the HAL environment of the eastern mega site has been ongoing since the fall of 2005. The eastern mega site is located on a major heavy haul coal route through the mountains of West Virginia. This line typically sees between 40 and 50 MGT of traffic annually consisting of approximately 60–70 percent 286-kip gross car loads, operating at speeds between 15 and 25 mph over grades as steep as 1.4 percent in some areas. Four test curves were installed, including two 6.8-degree curves and two 10-degree curves, all employing timber ties with a combination of elastic fasteners and cut spikes. Given the high degree of curvatures in this region, the test curves within the eastern mega site have incorporated a combination of gage face lubrication and TOR friction control since the installation of the rail, and rail grinding on an as-needed basis (i.e., corrective grinding) beginning after 272 and 356 MGT for the 10- and 6.8-degree curves, respectively. With more than 515 MGT accumulated to date, the premium test rails within the eastern mega site continue to show excellent wear performance and resistance to internal fatigue. Corrective grinding was employed on four separate occasions to remove RCF and plastic flow during the course of testing.

The surface condition of the rails within the test curves was in excellent shape until approximately 250 MGT when the low rails within the two 10-degree curves began to show signs of RCF. An additional 100 MGT was accumulated before the 6.8-degree curves began to show similar signs of RCF growth on the low rail. A corrective grind to address RCF was performed at 275 MGT and 365 MGT for the 10- and 6.8-degree curves, respectively. Figure 1 shows the average rail wear test results attributed to both traffic and grinding on the high and low rails for one each of the 10- and 6.8-degree curves. The figure depicts the corrective grinding events as nearly vertical shifts in the rate of wear for each of the test curves.

For the 10-degree test curves under normal traffic, the median area railhead loss per 100 MGT is more than twice that of the 6.8-degree test curves for both rails. The median area railhead loss per 100 MGT is 0.09 in\(^2\) and 0.11 in\(^2\) for the high and low rails, respectively, for one of the 10-degree curves. The 6.8-degree curves, on the other hand, typically wear at a median rate of approximately 0.04 in\(^2\) per MGT for both rails. The higher rate of wear for the low rail of the 10-degree curves could be attributed to a combination of (1) the traffic operating at underbalance speeds through these curves and (2) more rapid deterioration of the running surface due to these operating conditions, resulting in more frequent grinding cycles. It should be noted that the measurement of rail wear conducted at the eastern mega site does not account for such uncontrolled variables as changes in operation, differing TOR friction control applicator configurations, and effects of freezing temperatures on the effectiveness of TOR friction control application.
RESULTS FROM THE WESTERN MEGA SITE

Although the scope of testing has since expanded to include an evaluation of rail life extension strategies, rail performance in the heavy haul environment of the western mega site has been continuously monitored since the fall of 2005. The western mega site, located on a 120-mile stretch of a major heavy haul coal route in Western Nebraska, started with three separate test curves containing seven grades of premium rail from six manufacturers (1). This line typically sees between 200 and 240 MGT of traffic annually from 286-kip gross car loads with operating speeds on this heavy haul coal route ranging between 40 and 50 mph over near-flat grades. The test curves themselves are comprised of two 2-degree curves and one 1-degree curve, all employing standard concrete ties with elastic fasteners.

For all three test curves, no rail life extension strategies, except for the application of lubrication to the gage face, were implemented during the early stage of the experiment. For the 2-degree test curves, RCF began to appear on the low rails after approximately 300–350 MGT. As a result, two corrective grindings were implemented before 700 MGT to remove the RCF and improve the condition running surface. In 2008, the subject of this testing shifted from rail performance to the evaluation of life extension practices using two different methods to control RCF growth and wear rates. After 700 MGT, TOR friction control was implemented for one of the 2-degree curves and the other one began receiving scheduled preventive grinding every 70 to 90 MGT (2). Figure 2 shows the average rail wear test results attributed to both traffic and grinding on the high and low rails for the 2-degree curves.
FIGURE 2. Left – Rail Wear (2-Degree Curves) from Traffic and Grinding at the Western Mega Site; Right – Current Condition of the Rail within Each Curve

After TOR friction control was added, a corrective grind was not required to remove RCF until 1,650 MGT of accumulated tonnage, and it took much longer for RCF to recur (i.e., 950 MGT; see Figure 2). Preventive grinding has also been effective in maintaining a smooth running surface because it removes RCF periodically and prevents severe surface damage from developing. Following the implementation of preventive grinding, corrective grindings were conducted in intervals of 410-470 MGT to (1) remove deep-seated RCF that was not fully addressed from the preventive grinding cycles and (2) address running surface degradation at the plant welds within the curve. These corrective grinds were not as extensive as grinds conducted prior to implementation of preventive grinding, which suggests preventive grinding is successful in reducing the potential for significant running surface damage.

The 1-degree curve did not incorporate either of the rail life extension strategies seen at the 2-degree curves at the western mega site; only gage-face lubrication has been implemented since the initiation of the test in 2005. As such, this test curve developed moderate yet isolated areas of RCF after approximately 960 MGT and multiple corrective grinds were undertaken subsequently to prevent further progression of these spots. Though no internal fatigue defects were identified, severe sporadic running surface degradation developed at multiple locations on the high rail, which led to the eventual removal of the test rail after 1,782 MGT (1).

To date, the premium rails in the remaining test curves within the western mega site have accumulated more than 2,300 MGT of traffic and continue to maintain excellent wear performance. A statistical analysis was conducted to compare the rate of wear before and after implementation of TOR friction control within the 2-degree curve. Results show that there was a statistically significant reduction in the rate of natural wear (i.e., wear resulting from traffic, excluding the effects of grinding) after TOR friction control was implemented for both the high and low rails. Moreover, results of the statistical analysis show that railhead area loss through grinding per 100 MGT was also reduced for both the high and low rails following the implementation of TOR friction control. As with the eastern mega site, the measurement of rail wear conducted at the western mega site does not account for such uncontrolled variables as.
changes in operation, differing TOR friction control applicator configurations, and effect of freezing temperature on the effectiveness of TOR friction control application.

The average rail wear life (including the loss of materials due to grinding operations) was estimated based on the host railroad’s limits regarding railhead wear (i.e., top and gage-side wear). The resulting estimation of average wear life associated with the 2-degree curve utilizing TOR friction control exceeded 5,700 MGT, while the 2-degree curve with preventive grinding is predicted to exceed 4,300 MGT. Even within shallower curvatures, these results provide strong support toward the contribution of these rail life extension strategies in the continued performance of premium rail in the heavy haul environment. As rail life continues to increase because of improved performance due to high-strength rail steels and implementation of rail life extension methods, plant welds, which combine the various lengths of rolled rail into a single string for installation in track, are now reaching the point of failure at the running surface prior to achieving the same longevity as the parent rails.

**EFB Weld Degradation at the Western Mega Site**

In the summer of 2014, the high rail of the 2-degree curve utilizing TOR friction control (i.e., Mile Post 45) in the western mega site was removed due to persistent and severe EFB weld degradation at the running surface, despite the excellent condition of the parent rail adjacent to the welds affected. Prior to the removal of the high rail, nine welds (i.e., five from the high rail and four from the low rail) were removed from the 2-degree curve utilizing TOR friction control, whereas the 2-degree curve implementing preventive grinding has had two welds removed to date from the high rail. These results suggest that regular, preventive grinding is effective in mitigating the EFB weld degradation issue by addressing shallow fatigue cracks and discontinuities before they become severely problematic.

As the rail performance testing in the western mega site progressed, the running surface of the EFB welds began to deteriorate. At approximately 1,500 MGT, the condition of some welds had deteriorated to the point where a remediation effort was implemented by the host railroad to remove and replace the EFB welds that exceeded ultrasonic inspection criteria. Running surface degradation of EFB welds is not only evident at the western mega site but is found in various heavy haul environments worldwide.

Initial crack damage tends to follow the edges (i.e., metallurgical transitions) of the EFB weld HAZ. These initial cracks may occur on the leading or trailing edges of the softer HAZ. Subsequent surface damage and crack growth tend to occur on the trailing edges of the HAZ.

Beginning in 2012, with an accumulated tonnage in excess of 1,500 MGT, 12 EFB welds within the test curves were selected for ongoing monitoring (3). These welds showed little observable damage and generally represented the early stages of running surface degradation. Researchers from TTCI examined these welds periodically, both visually as well as with dye penetrant inspection, to assess the extent and growth of fatigue cracks at the running surface.

Figure 3 shows one of the welds before rail grinding at 2,080 MGT and again shortly after rail grinding at 2,112 MGT. The grinding operation occurred at 2,089 MGT and removed approximately 0.04 inch of material from the top of the rail. The grind was insufficient to fully remove the RCF that had developed on the welds, even after nine passes. The examination with dye penetrant inspection revealed that the grind failed to remove deep-seated fatigue cracks, as indicated by the heavier penetrant bleed (Figure 3).
In addition to the visual observations, longitudinal profiles of the welds were collected on the running surface at the center of the railhead. Figure 4 shows longitudinal profiles taken for another weld before and after a corrective grind at several MGT levels. The longitudinal profiles are aligned at the ends in the parent rails. This method of aligning the profiles does not show the amount of rail removed as a result of grinding, but rather shows the variation of the weld from the overall rail running surface. Before the grind, the profiles had concavities at the HAZ, around the ±1-inch mark from the weld centerline (i.e., 0 inch), and also had longer shallower depressions in the adjacent parent rail leading into the weld (see the region between 1.5 and 3 inches from the weld centerline). The grinding conducted was sufficient to remove both the longer depressions in the rail as well as the majority of the concavities present in the weld HAZ. Note that the concavities in the weld HAZ at 1,652 MGT had already started to form after the grind 32 MGT prior (i.e., 1,620 MGT).
Prior to the grind, the observed rate of batter for the weld depicted in Figure 4 at +1 inch from the weld centerline was approximately 0.00367 inch per 100 MGT. Following the grind, the rate of batter increased to approximately 0.00413 inch per 100 MGT, an increase of about 12.5 percent. This value is calculated based on the total depth of the concavity from the running surface of the rail (represented by the ends of the profiles). This change is primarily due to the removal of work hardened material from the grinding operation.

In order to determine the most efficient grinding schedule for curves that utilized gage face lubrication and TOR friction control, intervals between grinding cycles for the 2-degree curve with TOR friction control were extended based upon the condition of the running surface of the rail during periodic visual inspections. In this way, TTCI and the host railroad sought to achieve an optimum grinding schedule that would minimize grinding cycles and, in turn, unnecessary removal of additional material. While this proved to be beneficial for the performance of the premium rail with regard to RCF and natural wear, it permitted the unhindered growth of surface and subsurface fatigue cracks at the welds, which became sufficiently engrained in the HAZ of the weld and substantial corrective grinds did not remove the damage. These corrective grinds ended up removing more of the work hardened layer, allowing the rapid degradation of the running surface through the weld and, in turn, developing a discontinuity that could adversely affect vehicle/track interaction through the welds in the curve. Thus, increased dynamic responses due to the discontinuities may result in increased degradation of the weld.

IMPROVED WELDING STRATEGIES TO MITIGATE WELD DEGRADATION

TTCI has addressed the surface degradation of the soft HAZ, thereby mitigating the issue of rapid weld degradation and improving the integrity of the weld along the running surface. Studies, including those conducted at the western mega site, have shown that the soft HAZ on either side of the weld degrades faster than the adjacent rail (4). The increased rate of degradation is more pronounced in high-hardness, head-hardened rail and increases the fatigue environment of welds. TTCI has developed an overlay treatment for the HAZs of thermite welds to help mitigate this issue. Initial efforts have been primarily focused on applying this strategy to thermite welding, but efforts are underway to apply this to EFB welding as well.

In 2011, TTCI began testing the effectiveness of altering the original HAZ of a thermite weld, which is composed of a low-hardness spheroidized crystal structure, by way of a manually applied stick weld overlay on each of the two HAZ. The overlay process consists of positioning the weld bead directly over each of the soft HAZ of the thermite weld while the weld and adjacent rail are still hot. This process immediately follows the shearing of the thermite head riser, which is a standard procedure for thermite weld installation. After cleaning the surface to be welded with a wire brush, the weld boundaries are marked between 0.25 and 1.0 inch from outside the edge of sheared thermite weld. A stick weld is applied in a weave pattern between the two boundaries progressing from gage corner to field side (Figure 5). The heat from the overlay treatment reduces the width of the original HAZ and pushes it farther outward from the weld centerline and reduces the width of the HAZ by up to 75 percent in thermite welds (5). A rough and finish grind of the overlay treatment of the HAZ and the rest of the thermite weld, again in line with the standard procedure for a thermite weld installation, completes the process. From start to finish, the application of this overlay treatment can be completed within approximately three minutes following the shearing of the head riser.
Laboratory and in-track testing at FAST have demonstrated that the overlay of the HAZ can mitigate the metal flow in the softer HAZ of thermite welds, including head-alloyed welds (HAW), and potentially serves as a mitigation treatment for running surface degradation (3,5). The combination of a HAW and overlay treatment of the HAZ resulted in the lowest percentage of shelled welds and provided the best running surface (3). Using these test results, TTCI began working with two Class I railroads to conduct revenue service testing of overlay-treated thermite welds. Initial results show decreased unwanted metal flow and surface degradation with little or no increase in the start-to-finish time for thermite weld production.

Installation of Test Welds on a Northern Railroad

At three revenue service sites in the northern United States (Superior, Wisconsin) and southern Canada (Winnipeg, Manitoba, and Toronto, Ontario), TTCI is monitoring nine overlay-treated thermite welds and three untreated (control) welds. In fall 2012, host railroad welding crews installed all 12 test welds in tangent mainline track at three different locations to expose the test welds to varying climatic conditions. Unlike the overlay-treated welds tested at FAST, the thermite welds installed at these revenue service locations as well as the stick welding for the overlay treatments themselves were completed by the railroad’s welding crews within 136RE rail. To date, these welds have accumulated 169, 175, and 158 MGT of HAL traffic at the Superior, Winnipeg, and Toronto locations respectively.

Installation of Test Welds at the Western Mega Site

In July and August 2014, 11 thermite welds were installed at the western mega site in Nebraska. Seven welds (including one HAW) featured the overlay treatment for the HAZ, and the remaining four welds (including one HAW) were untreated control welds for this test. The untreated HAW allows for a direct comparison with the HAW weld featuring the overlay treatment. TTCI researchers will compare the performance of these thermite welds in revenue service to welds formerly tested in the controlled test environment at FAST.

The overlays at the mega site were made with commercial welding electrodes designed for rail-end build-up, and all of the test welds were made in 136RE rail. The thermite welds in the western mega site were installed by the host railroad’s welding crews, but the overlay treatment of the HAZ was completed by a TTCI welder. To date, these welds have accumulated approximately 147–165 MGT.

Current Results

On a biannual basis, TTCI engineers visit these test locations to collect rail and weld surface hardness and longitudinal profile measurements. Profile measurements are taken longitudinally along the center of the running surface of the weld and include the full length of the thermite weld, including each of the HAZ, as well as 4 inches of parent rail on each side of the weld. Analysis of the hardness measurements at these locations suggest that the overlay treatment described here is effective in modifying the hardness of
the HAZ. Figure 6 depicts the running surface condition for the untreated and treated thermite welds at the northern test sites and at the western mega site.

**FIGURE 6. Current condition of the running surface for treated and untreated welds at the northern test sites and western mega site**

Figures 7 shows the longitudinal profiles collected on the test welds at the three northern test locations. The uniquely shaped profile of the untreated thermite weld at 21 MGT is due to excess weld material left following shearing and grinding of the weld at installation. After 38 MGT, the weld material levels off and the dipping of the soft HAZ starts to increase with increasing tonnage. All of the welds in the northern locations are within sections of the track that receive grinding on a semi-annual basis, and the wear and batter of the running surface of the welds relative to the rail is minimal due to the frequent grinding reducing the effects of the overlay. The running surface photographs of each weld, however, show how the overlay treatment of the HAZ has mitigated the metal flow in the softer HAZ of the untreated welds.

Since the welds at the western mega site are fairly new installations, the assessment of longitudinal profiles cannot be completed at this time, though the difference between the treated and untreated welds via visual observation is clear. The welds in the western mega site are exposed to a higher tonnage per annum of 180–190 MGT and have a grinding schedule similar to that implemented at FAST, so the test welds will be closely monitored.
FIGURE 7. Longitudinal profiles representing the untreated (control) thermite welds and thermite welds with the overlay of the HAZ treatment at each location.

CONCLUSIONS

The service life of rail in curves continues to increase, even in the heavy haul environment, where the industry is presently seeing increased wheel loads and traffic volumes. This is due in large part to innovations in materials, design, and maintenance strategies, such as higher-strength rail steels with improved metallurgy and cleanliness, advances in lubrication and friction control, and scientific approaches to grinding operations to improve effectiveness and efficiency.

Results from a long-term study of premium rail performance with rail life extension strategies, such as TOR friction control, have provided valuable insight into the benefits such strategies can have on the service life of rail in curves. Among the most influential of these benefits in terms of extending rail life are the improved resistance to wear, reduction in the severity, and delay in the development of RCF.

As rail life continues to increase because of the benefits associated with improved rail steels and maintenance strategies, EFB welds that previously lasted for the life of the rail are now reaching the point of breakdown at the running surface prior to achieving the same longevity as the rails. Ongoing monitoring of EFB welds in revenue service has shown that the service life of rail in curves can be ultimately impacted by the performance of these welds if they are not properly maintained. As such, it may be appropriate to consider the condition of EFB welds in addition to the condition of the surrounding rail when establishing a grinding schedule for a particular area. Results suggest that regular preventive grinding cycles may be necessary to maintain surface condition through welds in curves.

An overlay treatment of the HAZ currently being developed and tested by TTCI can potentially serve as a viable mitigation treatment for running surface degradation and may increase the life of a thermite weld depending on the thermite weld composition, dynamic loading conditions, and maintenance practices. The benefit of the treatment related to various grinding schedules and climates will serve as additional information that will be recorded throughout this study.
FUTURE WORK

With the support of two Class I railroads, TTCI will continue to monitor the long-term performance of these welds. Research on the overlay treatment of the HAZ for thermite welds 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. The application of this treatment is already being considered for EFB welds to combat the running surface degradation observed within the western mega site.

Further investigation into optimized rail maintenance strategies is already underway. Results of testing suggest that TOR friction control and preventative grinding were found to be effective in addressing the development and growth of RCF in revenue service \((2,6,7)\). As such, armed with the knowledge gained from the long-term performance testing presented in this paper, TTCI and host railroads are monitoring additional test curves at both mega sites with the goal of evaluating a hybrid maintenance strategy that combines the benefits of TOR friction control and some preventative grinding on an optimized schedule. Furthermore, an additional test curve was established in the eastern mega site to evaluate the long-term effects of similar rail maintenance strategies on intermediate strength rail in high-degree curves. To date, these curves have accumulated more than 350 MGT and 50 MGT at the western and eastern mega sites, respectively. Future publications will present results from these experiments as more tonnage is accumulated.

Similar testing using the overlay treatment of the HAZ is currently underway for EFB welds at the Transportation Technology Center in Pueblo, Colorado. Laboratory tests on these EFB welds have been completed with encouraging results and overlay of the HAZ EFB tests welds were recently installed in-track at FAST.

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Rail Life Extension and Improved Welding Strategies in Heavy Axle Load Revenue Service

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Rail Performance & Rail Life Extension

- **Background**
  - Improve resistance to Wear ● Internal Defects ● RCF
  - Result
    - High-strength rail steels
    - Gage-face (GF) lubrication
    - Top-of-rail (TOR) friction control
- **Objective**
  - Evaluate the long-term effect of rail life extension strategies on premium rail performance

Key Characteristics of the Mega Sites

- **Western Mega Site**
  - Annual Tonnage: 200–240 MGT
  - 80% 286-kip traffic @ 40–50 MPH
  - Track Structure
    - Concrete Crossties
    - Elastic Fasteners
- **Eastern Mega Site**
  - Annual Tonnage: 40–50 MGT
  - 60% 286-kip traffic @ 20–40 MPH
  - Track Structure
    - Hardwood Crossties
    - Elastic Fasteners & Cut Spikes

Testing at the Eastern Mega Site

- **Features**
  - Installed: September 2005 | 500+ MGT to date
  - 8 grades of high-strength (HS) rail from 4 manufacturers
  - Four test curves: 10- and 6.7-degree curvatures
  - GF Lubrication & TOR Friction Control

Results from the Eastern Mega Site

- Corrective Grindings
  - Start Corrective Grindings
  - Results from the Eastern Mega Site
Testing at the Western Mega Site

- Features
  - Installed: September 2005 | 2,300+ MGT to date
  - 7 grades of high-strength (HS) rail from 6 manufacturers
  - Three test curves: 2- and 1-degree curvatures
  - GF Lubrication · TOR Friction Control · Preventive Grinding

One-Degree Curve

- Gage-face lubrication ONLY
- No internal defects
- Isolated areas of RCF
- Removed after 1,782 MGT

Results from the Western Mega Site

- Significant reduction in rate of wear following implementation
- Benefit observed for high rail as well as low rail
Results from the Western Mega Site

• Welding: A Life-Limiting Factor
  – Electric Flash-Butt Welds (EFBW)
  – Rapid degradation after 1,500 MGT
  – Initial cracking begins in heat-affected zones (HAZ)

• Recent Findings
  – High rail removed from 2-degree curve (TOR FC)

Conclusions

• TOR friction control can significantly reduce rate of wear & delay development of RCF in premium rail steels

• With TOR friction control, wear life of rail is exceeding previous estimates; EFB degradation can become an issue

• Periodic preventive grinding removes less material than corrective grinding; maintains running surface by removing the initial RCF and EFB degradation

Improved Welding Strategies to Mitigate Weld Degradation

Metal flow in soft heat affected zone is major cause of running surface degradation of welds

Tear Drop Shapes Observed
Improved Welding Strategies to Mitigate Weld Degradation

Installation of Test Welds on a Northern Railroad
Superior WI, Toronto ON, & Winnipeg, MB

Superior, WI – 169 MOT
Overlay of the HAZ Treated Weld
Untreated Weld

Longitudinal Profiles of HAZ Treated/Thermite Weld

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Installation of Test Welds at a Western Mega Site

Future Testing
HAZ Treatment of Mobile EFB Weld

Future Testing
HAZ Treatment of EFB Plant Weld

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