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TTCI Rail Welding Workshop

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Transportation Technology Center, Inc. (TTCI) hosted a rail welding workshop on April 28, 2015 in Harrisburg, Pennsylvania. The purpose of the workshop was to allow rail welding users (railroads), suppliers, and researchers to discuss the current state of the practice, to identify needs for improvement and disseminate information on current work to meet those needs, and to facilitate discussions between the groups. The workshop, held just prior to the spring meeting of American Railway Engineering and Maintenance-of-Way Association (AREMA) Committee 4–Rail, featured 17 presenters from organizations associated with rail welding who offered their perspectives to over 50 industry representatives.

The workshop allowed the participants to give their perspectives on rail welding: some took a broad industry view, some were more focused on specific issues. Railroads identified factors that could negatively affect thermite weld performance, including:

- Improper rail alignment
- Flashing and cold laps at the weld collar
- Inclusions in the weld and at the weld collar
- Effects of rail chemistry on weld chemistry and performance
- Welder training and retention

Similarly, railroads discussed key issues regarding Electric Flash Butt (EFB) welds, including:

- Effects of rail chemistry on weld performance
- The presence of, and acceptable levels of, untempered martensite in welds
- The suitability of current AREMA slow bend test recommendations

Rail welding suppliers presented their work that is intended to address railroad needs; including:

- Improved mold design to reduce flashing and cold laps
- Alloying the head of the weld to better match the hardness of premium rails
- Improving quality control during the manufacture of thermite weld products
- Improved rail end polishing and preparation prior to EFB welding
- Improved (electric) welders and welder control systems

The ultimate performance objective for rail welds should be that they match the performance and life of their parent rails. EFB welds are currently closer to meeting that objective than thermite welds are, but improvements are need for both methods. Avenues for meeting this objective could include:

- Thermite weld metallurgy that more closely matches the metallurgy of rails
- Significantly reduced soft heat affected zones
- Weld processes that improve overall weld performance and reduce performance variability

Railroads, rail suppliers, rail welding suppliers, and researchers are making progress toward better performing rail welds. Communication and cooperation will facilitate their efforts.

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INTRODUCTION

To facilitate discussion between rail welding stakeholders: railroads, suppliers, and researchers, Transportation Technology Center, Inc. (TTCI) sponsored a rail welding workshop on April 28, 2015 in Harrisburg, PA. Over 50 attendees heard 17 presenters give their perspectives on the current state of rail welding, what improvements are needed, and what is being done to meet the needs for improvement. This *Technology Digest* summarizes the material that was presented, and the discussions that followed the presentations.

As rail traffic continues to grow, the need for improved rail welding processes also grows. Electric flash butt (EFB) and aluminothermic welding methods, the most commonly used in North America, are generally far superior to bolted rail joints for joining rails. But, neither method produces a bond that matches the properties or performance of the parent rail. With many tens of thousands of rail welds made by railroads and contractors every year, improvements in performance could provide a significant benefit to the industry. The need for improvements in rail welding is typically near the top of the list when TTCI asks railroads to define their research priorities.

Industry Perspectives

The workshop allowed railroaders to give their perspectives on rail welding: some took a broad industry view, and some focused on issues more specific to their railroad. The group reviewed the factors that have helped increase expected rail lives from double-digit MGT a century ago to multiple thousands of MGT today. Many cited improvements in production practices and metallurgy, improved rail sections, longer rails, and advancements in rail welds. Some common themes emerged in the presentations and in the discussions that followed. Factors that could negatively affect thermite weld performance were identified as:

- Improper rail alignment
- Flashing and cold laps at the weld collar
- Rail movement during the weld process
- Inclusions in the weld and at the weld collar
- Improvements in rail welds are not keeping up with advances in rail metallurgy
- Mechanical properties of the cast-like weldment are generally inferior to those of rail
- Effects of rail chemistry on weld chemistry and performance
- Time required to make a good weld is sometimes in conflict with available track time
- Improper post-weld shearing and/or grinding
- Variability of installation procedures and conditions, and resulting variability in weld performance
- Welder training and retention

Figure 1 shows an example of a broken, conventional thermite weld; thermite weld failures were a major topic of discussion. Non-traditional applications for thermite welds were also discussed. There was wide variability between railroads regarding their use of wide-gap thermite welds, and head-repair thermite welds. One railroad uses wide-gap welds regularly, and is generally satisfied with their performance. Advantages of wide-gap welds include the ability to remove larger defects with a single weld instead of a plug rail and two welds. Other railroads reported limited use of the product; they cited the need to precisely locate defects and ensure complete defect removal, as well as the need for extra inventory with slightly different installation practices, and performance issues (more weldment to fail than with a traditional gap thermite weld) as reasons for non-use.

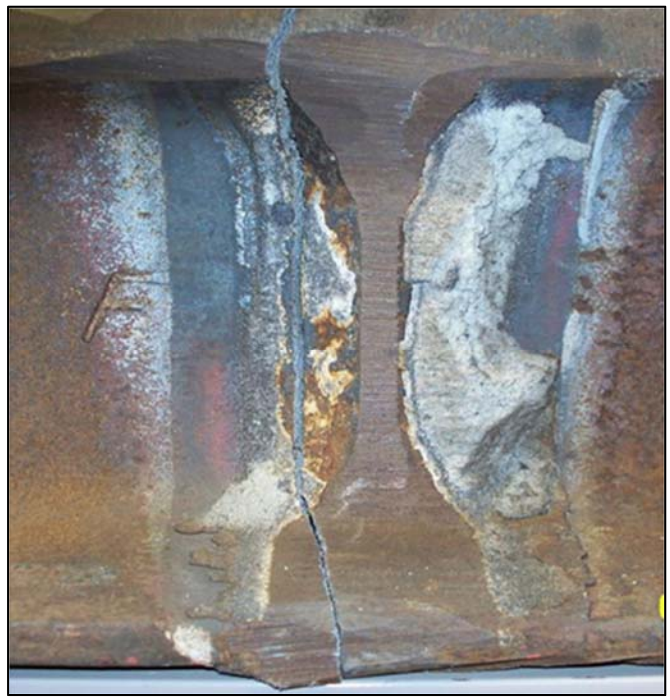

Figure 1. Common Type of Thermite Weld Break

Regarding head repair thermite welds, there was once again a range of opinion and utilization. This type of weld, where only the head of the rail is removed, is earlier in the development phase than wide gap welds. Most railroads expressed interest in the concept; the benefits of leaving the web and base of the rail intact are attractive. Some railroads are evaluating the performance of these welds in track and results have been mixed. One railroad reported good results in 136-pound rail, but less positive results in 115-pound rail. Similarly, defect location, extra inventory, and varying installation practices were mentioned as impediments to implementation.

Railroad representatives were unanimous in their opinions that welder training and retention had a significant effect on weld performance. The position of rail welder is viewed as a difficult, physically demanding position, and worker turnover is an issue. Retaining a well-trained crew is challenging, and the constant need to train new welders can result in inconsistent weld procedures and weld performance.

The generally expressed view is that EFB welds typically outperform thermite welds, but there were still common concerns regarding the performance of EFB welds, including:

- The effects of rail chemistry on weld performance
- The presence of, and acceptable levels of, untempered martensite in welds
- The suitability of current AREMA slow bend test recommendations
- Improper post-weld shearing and/or grinding
- Weld surface degradation, usually after high tonnage
- Weld alignment; especially for high-speed rail

The group discussed extensively the effects of rail chemistry on weld performance, and adequacy of current AREMA slow bend tests for assessing weld performance. One railroad described how a slight change in their rail hardness specifications (and the rail chemistry change that produced the increased hardness) had a detrimental effect on EFB welds. The change in rail chemistry resulted in an increase in untempered martensite at the weld fusion line. One of the welds initially made in the new rail failed during rail handling. Subsequent lab tests showed poor results in slow bend testing, and revealed the untempered martensite (Figure 2).

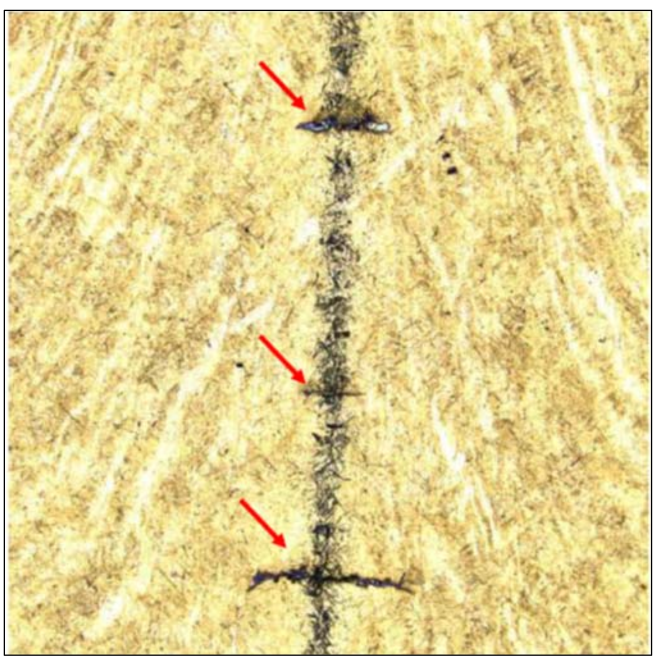

Figure 2. Untempered Martensite at Fusion Line with Longitudinal Cracks (red arrows)

Modifications to the weld procedure reduced, but did not completely eliminate, the martensite; however, welds with small amounts of martensite still met AREMA slow bend test recommendations. This topic led to a discussion of whether the slow bend test procedures and/or limits should be revised. The issue will be raised at an upcoming AREMA meeting.

Another issue related to EFB welds has manifested itself as rail life length continues to increase. With rails lasting for over 1 billion gross tons in some applications, lives of EFB welds can fall short of that timeframe. Railroads have reported having to remove rails because of the type of surface degradation shown in Figure 3. Preventive rail grinding mitigates, but does not eliminate the occurrence of this type of damage. Research into ways of reducing its likelihood will be discussed later in this *Technology Digest*.

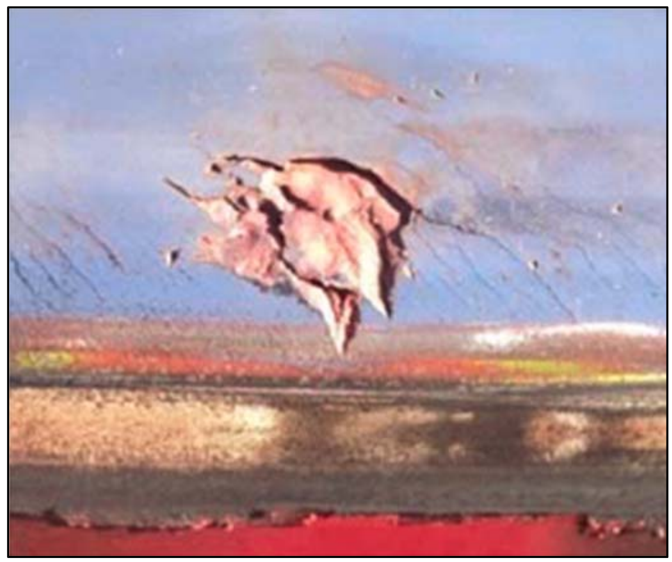

Figure 3. Electric Flash Butt Weld Surface Degradation

Recent emphasis on increasing the utilization of higher speed passenger train service in North America has increased the importance of rail end straightness and proper weld alignment. One railroad reported on how even slight deviations in these parameters resulted in impacts at welds. AREMA Committee 4 has been addressing the issue.

Supplier Perspectives

Suppliers of thermite weld products and electric flash butt welding services presented background on their products, and discussed their efforts to meet industry needs. Thermite weld suppliers noted the benefits of thermite welds: low cost, relatively fast installation, zero rail consumption, and equipment portability. They also discussed means of improving weld performance, including:

- Improved mold design to reduce flashing and cold laps.
- Improved weld ignition systems to improve consistency and reliability.

- Alloying the head of the weld to better match the hardness of premium rails.
- Improving quality control during the manufacture of weld products.
- Assisting in training of welders.

These incremental improvements in thermite welds are important and valuable, but fall short of providing the "step improvement" in weld performance that railroads have said that they need.

Rail manufacturers and EFB weld service providers also presented information on steps that they are taking to improve EFB performance, and to improve rail system performance in revenue service. Those steps include:

- Improved rail end polishing and preparation
- Improved (electric) welders and welder control systems
- Process automation
- Post-weld heat treatments to mitigate negative effects of weld heat affected zones, and to reduce weld surface degradation
- Reducing the number of rail welds in track by welding longer rails (up to 480 feet) into strings

As with thermite welds, these improvements tend to be incremental.

Rail Welding Research

TTCI researchers provided an overview of recent weld research conducted under the AAR's Strategic Research Initiative program aimed at improving weld performance. Some of the research has contributed to changes in weld designs and practices, with varying degrees of implementation. Examples include:

- Effects of pre-heat
- Optimization of mold flank angles
- Thermite head repair welds
- Wide gap welds
- Head alloyed welds
- Effects of rail offset, flashing, and cold laps

Some research is ongoing:

- Post-weld treatments to mitigate negative effects of weld HAZ and to reduce weld surface degradation
- Effects of molten metal flow in thermite welds
- Electric flash head repair welds
- Effects of cooling rates

And, some research showed that ideas which seemed to have promise could not yet be shown to be beneficial:

- Post-weld vibration treatment
- Electro-slag welding.
- Bottom fed thermite welds

Other researchers discussed the effects of rail and weld problems on track safety, and research that is addressing rail and weld failures. That research includes rail defect detection and sizing, rail neutral temperature measurement and management, rail base corrosion prevention, and rail joining technologies.

One of the more innovative and experimental rail joining (welding) technologies being evaluated is linear friction welding. This process uses large oscillators to move the rail ends, and the resulting friction between those rail ends generates heat. The rails are forged together to produce a solid-state weld once sufficient heat is generated. Feasibility studies have shown that rails can be welded with this process, and equipment size and capacity are undergoing further development. In addition, the properties of welds produced with this process are being evaluated.

The most theoretical presentation included information on fatigue-informed decision making. Modeling and testing to assess the effects of: position in the rail, track support conditions, number of fatigue cycles, rail/weld grinding, and material properties on fatigue accumulation were presented. The information could be used to identify fatigue critical weld locations, and assist in focusing efforts to improve weld properties.

Although, no "cure-all" was revealed during the workshop, there was general agreement that the sharing of information was valuable. The organizations represented at the workshop heard a wide range of perspectives and opinions on problems and potential solutions. Those same organizations will continue their efforts to improve the quality and performance of thermite welds.

Acknowledgements

Special thanks to all presenters, and to those who participated in the workshop.

Topical Agenda for the Meeting

The Never Ending War – Rail Life Extension	Dave Staplin, Amtrak
TTCI Research Overview and Objectives	Joe LoPresti, TTCI
Industry Perspective	Brad Kerchof, Norfolk Southern
BNSF System Welding	Ron Adler, BNSF
Thermite and EFB Welds on UP	Dan Torres, Union Pacific
Slow Bend Testing of Welds	Steve Lakata, Norfolk Southern
CSX Perspective	Mark Austin, CSX
CN Track Welding	Dan Bjork, CN
Welding of Rail, the Amtrak Experience	Joe Smak, Amtrak
Panel Discussion	
Railtech Boutet Aluminothermic Welding	Frederic Delcroix, Railtech Boutet
Overview of the Thermit® Welding Process	Frik Heffer, Orgo-Thermit, Inc.
Heavy Axle Load Effects, and Long Rails	Richard Kral, Holland
Improved Welding Plant Features	Chuck Battisti, Chemetron (Progress Rail)
Rail Weld Performance Improvement	Joe Kristan, Evraz NA
Panel Discussion	
Improved Rail Welding, TTCI Research	Joe LoPresti and Megan Archuleta, TTCI
FRA Safety Research – Rail	Cameron Stuart, FRA
Linear Friction Welding of Rail	Seth Shira, EWI
Fatigue Performance of Rail Welds	Gary Fry, Texas A&M University
Panel Discussion	

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