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Rail-Wire Interface Performance Issues

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Summary

Transportation Technology Center, Inc. interviewed signal maintenance personnel from a number of railroads regarding rail-wire interface (RWI) performance issues to gain a general perspective into the known or suspected root causes of RWI problems and failures, current RWI installation and maintenance practices, and to identify potential improvements to current RWI technology.

Responses to the survey were somewhat varied, but key suggestions of problems and issues taken from the interviews were:

- Improve the quality of rail surface preparation with grinding processes that are not highly dependent on operator skill
- Define preheating rail temperature specifications for exothermic rail bond installations
- Define a maximum number of exothermic mold applications, improve mold designs and clamping fixtures
- Define pull-strength specifications and provide calibration equipment to improve quality of crimped connections
- Provide better surface preparation and premeasured flux for better adhesion beneath exothermic weld nuggets and pin-brazed cable lugs
- Develop RWI designs that are less prone to damage from track maintenance activity and rail motion under traffic
- Use longer signal bond pigtails to increase the number of detachment/reattachment cycles before the RWI needs to be replaced

Signal system reliability is essential for safe and efficient rail operations and integrity of the RWI is required for system functionality. A previous study performed under the Track/Signal Interface Strategic Research Initiative (SRI) indicated the RWI failures are a significant source of service disruptions, and that the opportunity exists to significantly improve operational performance through improved RWI performance. The intention of this investigation was to identify RWI performance issues and areas for potential improvements based on the collective knowledge and insights of experienced signal maintainers.

This work was performed as part of the Association of American Railroads' Track/Signal Interface SRI.

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INTRODUCTION

The rail connection of wires connecting wayside signaling and grade crossing warning systems or power bonds carrying electrified traction propulsion-current are referred to as the RWI. The RWI is an integral part of the operating system and RWI failures, particularly signal bond RWI failures, cause train delays that can effect operations over a large segment of the system.

A primary objective of the Track/Signal Interface SRI sponsored by the Association of American Railroads is to improve RWI performance and reduce the number of RWI failures. A previous study estimated that 10,000 or more RWI failures may occur annually industry-wide based on the trouble-desk records from two major North American railroads.[1] Assuming that the majority of these trouble-desk issues could result in train delays, the opportunity exists to improve operational productivity through improved RWI performance.

One of the problems with the referenced study was lack of specificity in the trouble-desk data. In other words, the failures or issues recorded generally could not be attributed to the type of RWI or a mode of failure. To gain better insight into the overall nature of the performance problems, a follow up study was undertaken to solicit information and gain the perspective of signal maintainers who deal with RWI performance on a daily basis. This *Technology Digest* describes the process and results of the survey.

INTERVIEW PROCESS

A number of maintainers were interviewed regarding known or suspected causes of RWI problems and failures, current RWI installation and maintenance practices, and to help identify potential improvements to current RWI designs. All of the participants were from freight railroads, with the exception of one maintainer from a transit agency. Several of the maintainers also worked on freight lines with occasional Amtrak passenger service. The size of the territories covered ranged from just over 20 track miles to over 1400 miles. On average, the maintainers had more than 10 years of experience.

The interviews were based on a list of core questions designed to stimulate discussion of relevant experiences, including:

- What types of RWI problems do you experience and what are the known or suspected root causes of the problems; e.g. vandalism, track maintenance induced, loss of conductivity, broken rails, fatigue, or other?
- What is the size of your RWI failure problem?
- What are the current RWI installation and maintenance practices?
- What are the pros and cons of current RWI methods and materials?
- What are the suggestions for improvements in RWI technology? In your opinion, what would be the characteristics of a perfect RWI?

In addition to these questions, general questions such as the type of territory covered and the types of RWI used were also asked.

INTERVIEW RESULTS

The types of RWIs in common use on freight railroads were identified as:

- exothermic welds (Figure 1), factory installed pin-brazing on prefabricated insulated joint plug rails, and
- field installed pin-brazing (Figure 2).

The limited use of mechanical tapered-pin plug bonds known as “chicken heads” (Figure 3) for specific applications where flammable materials were handled, such as signaled sidings, where locomotives are fueled and customer facilities handling flammable cargo, such as solvents and propane, was also mentioned. Chicken heads require the rail to be drilled and are no longer commonly used by most railroads.

Figure 1. Exothermic RWI

Figure 2. Pin-Brazed RWI

Figure 3. Tapered Pin RWI (i.e., Chicken Head)

RWI Failure Modes Identified

The survey identified the following failure modes according to RWI type:

- Failure of exothermic welds or pin brazed RWIs to adhere to the rail due to improper preheating and/or grinding
- Failure of exothermic molds to seal against the rail surface, due to degradation of the mold material when molds are used beyond their working lives
- Rail defects being detected adjacent to the exothermic weld
- Insufficient/improper factory or field crimping of the crimp sleeve on the pigtail
- Insufficient bond length (i.e., wire slack) causing failure due to thermal or train induced rail movement
- Insufficient tensile strength of the connection due to insufficient rail surface preparation allowing the cable lugs to be pulled off the rail due to tension on the track wire
- Excessive track deflections under heavy trains

Discussion of RWI Failures

The problem of improperly or inadequately crimped RWI pigtail connectors was a recurring theme in the interviews. RWI pigtails have a connector at the end of the pigtail that is factory installed, and the track wire is connected in the field (Figure 4). The pigtails are mass-produced, and the quality control of the crimped connection is generally not known. Some maintainers routinely re-crimp factory made connections in the field, but there was also the question of field-crimped connection adequacy. The crimping processes in general could be improved with a pull-test specification for the connection and the use of calibrated crimping tools.

Another recurring theme was insufficient adhesion beneath the exothermic weld nuggets and pin-brazed cable lugs. In the case of exothermic welds, this condition suggests inadequate rail surface preparation. However, in the case of pin-brazed connections, the insufficiency can be an indication of not enough flux. The availability of premeasured flux could alleviate this problem.

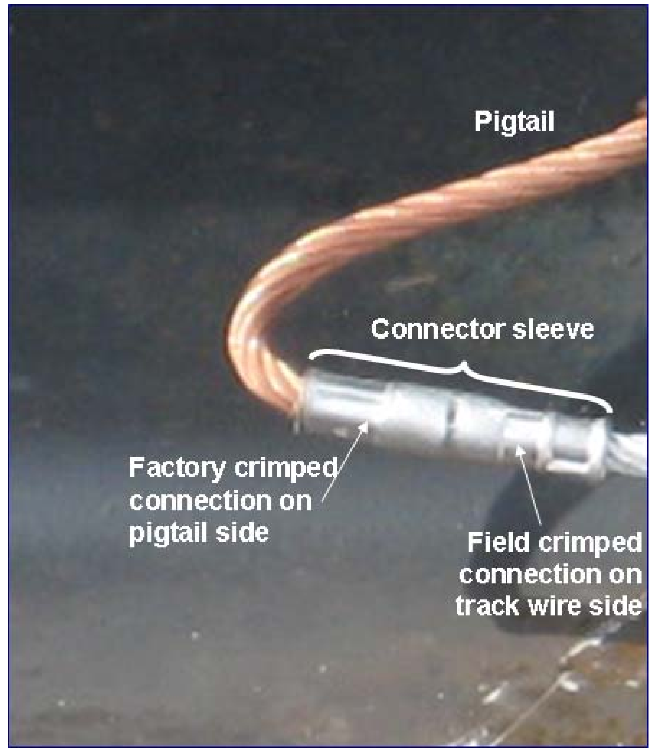

Figure 4. Typical Pigtail Crimped Connections

The quality of rail surface preparation using hand grinders and the operator dependency aspect of this procedure was mentioned. Some maintainers felt a grinding process that is faster and not as operator dependent would be beneficial.

Also noted was the practice of preheating the rail before installing an exothermic or pin-brazed RWI. Although several maintainers reported having been instructed to preheat the rail (usually with a propane torch) none were provided with a minimum temperature specification. Some maintainers expressed the concern of possibly damaging the rail by overheating and were, therefore, probably not providing an adequate preheat. A procedure specifying the minimum preheat temperature would provide a uniform and improved preheating process.

Several maintainers mentioned excessive track motion under heavy trains as being a problem for RWIs. This was noted for both head-bonds in jointed rail and track-wire connections at the rail web. In the case of the head bonds, additional bond-wire length, and/or a minimum slack specification would appear to be part of the solution. In the case of track wires, those surveyed felt that better protection of the wire where it emerges from underground and connects to the rail is warranted. Standard practices in this area seem to vary from one railroad to another and from one territory to another within the same railroad.

CONCLUSION

Several maintainers surveyed mentioned the length of RWI pigtails as being a problem. As the more replaceable component when disconnection of the track wire is required, the pigtail, rather than the track wire, is normally cut at the crimped connector sleeve. The pigtail becomes shorter each time it is cut. If the pigtails were longer initially, this process could be continued for a few more detachment/re-attachment cycles before the RWI would need replaced. Another approach would be to install a bolted connection, rather than a crimped connection, at the end of the pigtail to facilitate track wire removal and reconnection.

There was some frustration expressed concerning the sealing of exothermic molds to prevent the loss of molten metal. The molds do have a working life and the edges will degrade with repeated usage, as Figure 5 shows. Without a new replacement mold, the maintainer is forced to improvise a field fix such as using a duct seal putty around the edge of the mold. This improvised technique has yet to be tested to verify that it does not cause more harm than good. The real solution is to have the mold suppliers specify a maximum number of applications for the molds and train the maintainers to replace the molds once this point has been reached. Use of a sealing material would be discouraged and applied only as a last resort.

The last issue, but one that is perceived to account for as much as half of the RWI failures, is track maintenance. The present solution is to have a signal maintainer, with a track gang, removing RWIs in advance of the gang when and where possible, and following up to repair any damage behind the gang. Apparently, this approach still allows a high percentage of maintenance driven failures to occur. Designs that simplify and facilitate RWI removal and reinstallation can reduce the number of maintenance related failures.

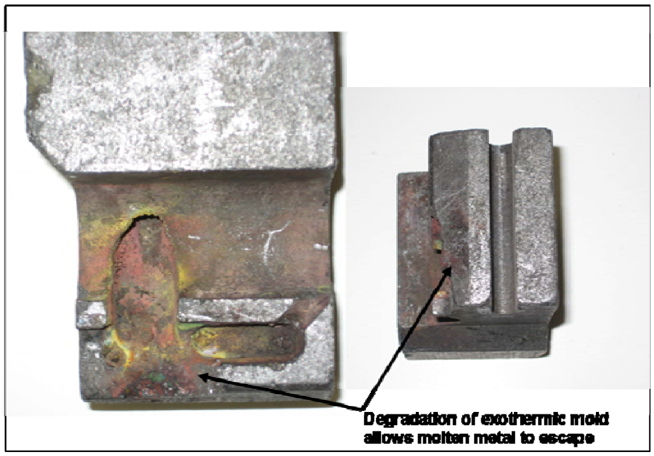

Figure 5. Typical Degradation of an Exothermic Weld Mold

RECOMMENDATIONS

If the RWI technologies currently in widespread use are not abandoned in some unanticipated wholesale manner, then the objective of improved RWI performance will likely be achieved through incremental improvements on all sides of the issue, such as improved methods and materials, enhanced training, and better quality control. In addition, new RWI technologies need to be pursued through research.

Based on the survey, improvements to current RWI technologies include:

- Defining requirements for exothermic weld rail preheating and optimized surface preparation techniques before installing pin-brazed or exothermic RWIs
- Implementing a comprehensive quality control process for the tools, materials, and training used by signal maintainers and signal construction gangs in the installation of RWIs
- Determining the amount of tensile or shear strength required of the RWI and setting a standard
- Determining the amount of wetted area necessary for each brazed/welded RWI process to achieve sufficient strength
- Determining the proper crimping pressure necessary to meet a tensile (wire pull-out) specification
- Setting a standard for the maximum number of mold applications and identifying improvements in mold designs, clamping fixtures, or additional sealing materials that may be necessary to ensure proper installation of exothermic RWIs
- Identifying better ways of protecting track wires where they make the transition from underground to the RWI's on rails

ONGOING WORK

TTCI will forward the results of the survey to the applicable RWI suppliers for their responses. As the next step in the research program, TTCI is in the process of installing an RWI test zone at the Facility for Accelerated Service Testing to monitor long-term performance of a variety of designs under heavy axle load traffic.

REFERENCE

1. Hawken, Ted, David Davis, and Michael House. April 2008. "Improved Signal Reliability: Rail-To-Wire Bonding," *Technology Digest*, TD-08-016. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.