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Maintenance Resistant Track Wire Connections

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Summary

As part of the Association of American Railroads Strategic Research Initiatives Program, Transportation Technology Center, Inc. (TTCI) conducted a series of laboratory and field tests to determine the strengths and weaknesses of currently used and proposed track wire/rail connections to investigate the potential reduction of train delay by reducing the rail/wire interface failure frequency.

Currently, there are an estimated 25,000 train stops per year due to track wire connections in North America. Previous studies of signal trouble calls attempted to attribute causes to track wire connection failures. While most were unattributed, track maintenance and vandalism were among the most common causes identified.¹ Both of these failure causes have a common failure mode: the track wire is snagged and broken in tension. Laboratory results from this study show that about 35 percent of track wire connections failed at the rail/wire interface.

To avoid damage to the rail, TTCI recommends that a maximum strength be considered, with the connection (from signal bungalow to rail) allowed to break at a “fusible link”; that is, a connection that can be easily reconnected/repared without damaging the rail. This would allow the reuse of the same location along the rail when reconnecting wires, an important issue at interlockings and signals where track wire locations, are fixed.

Laboratory results suggest that the rail bond (rail/wire interface) pull strength is above 500 pounds. At forces higher than 500 pounds and up to approximately 1,000 pounds, there is no damage to the rail when connections are pulled off the rail. Thus, a repairable track wire crimp (aka fusible link) that does not break below 400 pounds yet releases at 550 pounds, would in most cases, allow the rail bond to remain intact yet permit a pull apart to be reconnected and repaired at the same location. A track wire crimp is a mechanical connection between two wires. In the laboratory tests, track wire crimps have a wide range of strengths. This information will be provided to the appropriate AREMA committee for discussion and further evaluation as a suggested recommended practice or guideline.

As damage from track maintenance cannot always be avoided, making connections with a fused link suggests a possible improvement supporting rail operations. By providing a breakaway location whereby the connection to the rail is not damaged, but sufficient wire remains to allow reattachment, it is feasible that the industry could save considerable track time during the repair processes and ultimately reduce track wire-caused broken rails..

A companion digest will describe results from field testing of signal track wire connections for environmental and fatigue durability testing.



INTRODUCTION

Railroad signaling systems are a vital part of the national railroad system, supporting industry productivity and profitability. Based on the closed circuit principle and fail-safe characteristics, signaling systems have expanded the founding principles included in William Robinson's original 1872 patent for "Improvements in Electric Signaling Apparatus for Railroads" (U.S. Patent 130,661) into a wide variety of systems.

Modern railroads use various types of electrical and electronic signaling equipment, which require dependable and rugged electrical interconnection to support efficient and competitive train operation. By incorporating the track components with the circuits used to detect the presence of trains, wayside signaling and grade crossing warning systems have effectively overcome one of the major drawbacks of many signaling systems proposed earlier; i.e., it is possible to detect failures in almost any single vital component of the system. But this came at a price. In order for the signal equipment to function reliably, each individual component now had to be extremely reliable. The reliability of the system as a whole could not be better than the individual reliability of each component.^{1,2}

Based on information from two major North American railroads, a previous study estimated that 10,000 or more signal system rail/wire failures may occur annually industry-wide.¹ Assuming that the majority of these issues result in train delays, a significant opportunity exists to improve operational productivity through improved rail/wire interconnect performance.

APPROACH

Reliable track wire connects are a significant issue in train delays and are blamed on signal failures.¹ One approach to reduce delays is to strengthen the rail/wire connections. Ongoing tests at the Facility for Accelerated Service Testing and in revenue service are evaluating the reliability of alternative connections.

A factor being addressed is that if a connection is too strong, a large force, such as dragging lading or equipment, could damage the rail by ripping metal from the contact area.

To avoid damage to the rail TTCI suggests that a maximum strength should be considered, with the connection allowed to break at a "fusible link"; that is, a connection that can easily be reconnected/repared without damage to the rail. This would allow the reuse of the same location along the rail when reconnecting wires, an important issue at interlocking and signals where track wire locations are fixed.

To ensure that such a repairable link works properly, the minimum bond strength of the rail/wire connection will need to be identified. As such TTCI conducted pull tests on new connection samples to determine the strength range of new connections.

Another approach to consider is improving the routing of cables to avoid breaking the wire and bond, thus reducing the chance of damage. A procedure, which is followed by The Kansas City Southern Railway Company (KCSR), has been identified as a method that addresses this approach.

LABORATORY

Track Wire Pull Test

To determine minimum wire pull apart strength (crimp or rail attachment strength), the break point of existing wire connections was evaluated. To conduct this test, a fixture was fabricated (Figure 1) to allow pulling of wires longitudinally or perpendicular to the rail.

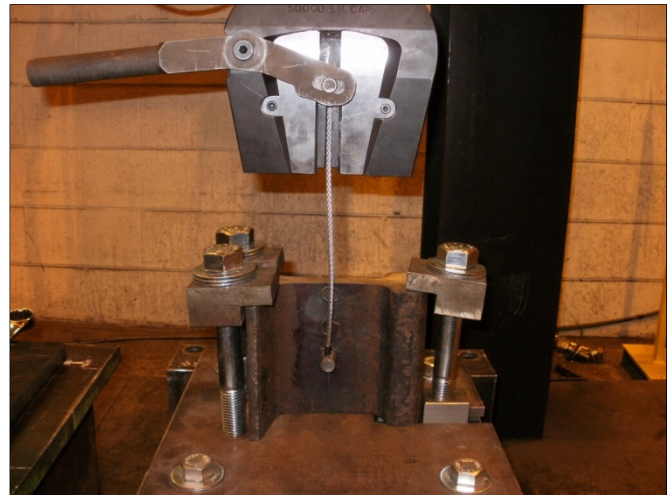


Figure 1. Test Jig for Longitudinal Pull

Individual fasteners, attached to rail specimens approximately 6 inches long, were installed in the fixture and tested in perpendicular and longitudinal positions. Increasing values of force were applied (25 lbs/sec) to the rail/fastener assembly, until the fastener system physically failed (pulled apart). Additionally a perpendicular "snag test" was performed, in which the test specimen was loaded at a rate of up to 50,000 lbs/sec. These two scenarios were established to simulate slow and rapid occurrences that the track wires may be subjected to when caught by machines, dragging equipment, or when track is raised for tamping.

Multiple samples of all track wire fastener technologies were evaluated, which included bolts through the rail, different epoxies, brazing, welds, wedge-pins, base clamps, and base welds. Figure 2 summarizes the results and suggests bolted connections have the highest strength, with epoxy showing the lowest snag and perpendicular pull strength. These samples were all new, unused, and tested without being subjected to traffic or weathering.

The failure mode varied by the type of connection with the most number of failures associated with crimp strength, followed by separation of the connection from the rail. Figure 3 shows these results.

Force (lbs) Required to Separate Fastener/Rail Connection

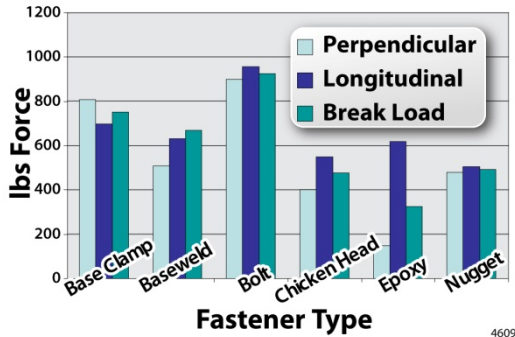


Figure 2. Average Forces Needed to Fail Connections by Perpendicular, Longitudinal or Snag Motion

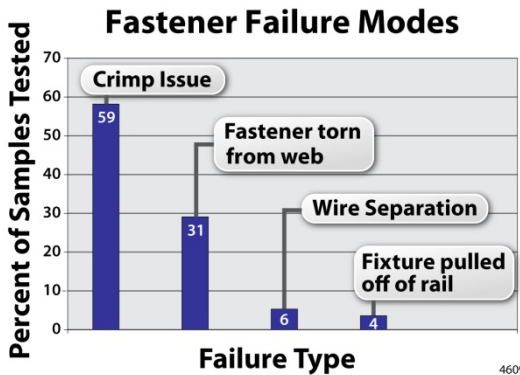


Figure 3. Summary of Failure Modes Observed in Laboratory Tests

Laboratory results suggest that crimp strength of 500 pounds is above the breaking strength of most connections. At forces higher than 500 pounds and up to approximately 1,000 pounds, there was no damage to the rail when connections were pulled off the rail. Thus a repairable crimp (aka fusible link) that does not break below 400 pounds, yet releases at 550 pounds, would in most cases, allow the rail bond to remain intact yet permit a pull apart to be reconnected and repaired at the same location, as Figure 4 depicts. This information will be provided to the appropriate AREMA committee for discussion and further evaluation as a suggested recommended practice or guideline.

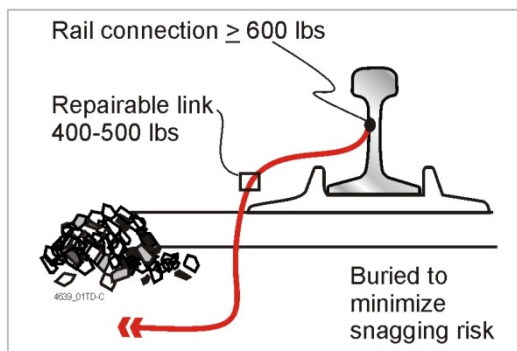


Figure 4. Detail View Showing Rail Connection and Proposed Fusible/Repairable Link

FIELD Bond Strength

Soon after installing the track wire test at one railroad field site, a tie maintenance gang went through the zone, damaging or destroying many of the connections. Most of the surviving connections had damage to the wires, and several that were destroyed had the rail attachment connection still attached to the web. However, the wire had been broken or had been pulled apart. Figure 5 shows one example.

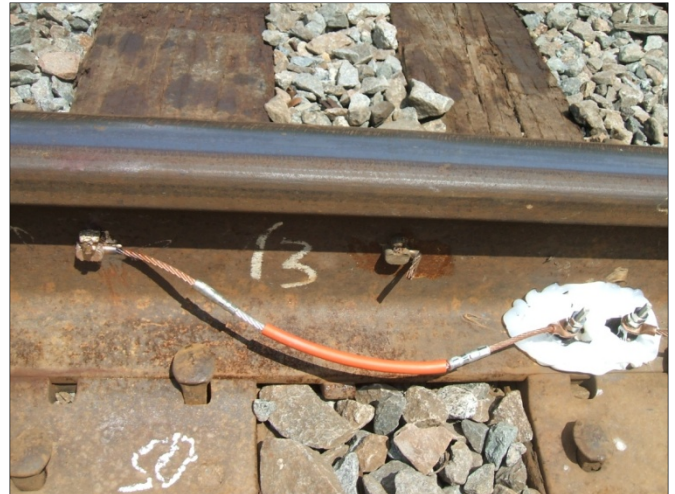


Figure 5. Replacement Wire Connection (left) and Original Damaged Rail Attachment (middle) after Passage of a Ballast Regulator (Note: The connection to the rail was undamaged, but the wire was broken making the connection unusable.)

While this maintenance activity resulted in the reinstallation and restart of this test, the resulting damage to many of the test connections identified a need for developing damage resistant track wire attachments. Previous studies also showed that track maintenance was attributed as a failure cause for many track wire connections.¹ As damage from track maintenance cannot always be avoided, making connections with a fused link suggests a possible improvement supporting rail operations. By providing a breakaway location whereby the connection to the rail is not damaged, but sufficient wire remains to allow reattachment, it is feasible that the industry could save considerable time during the repair processes. Figure 6 shows a schematic of the concept for routing wires to avoid damage.

Additional savings in reduced risk of a rail defect caused by track wire attachment methods that heat the rail are likely. As discussed earlier, TTCI conducted a number of pull tests in the laboratory to determine what the typical wire breakaway strength was on new, unweathered samples. This information can be used to determine minimum strength needed at the rail connection and maximum pull apart strength of any future fusible link designs.

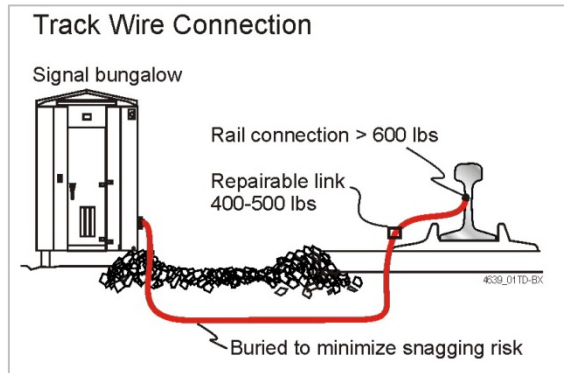


Figure 6. Schematic of Fused link Track Wire and Proposed Strength Requirements

Alternative Field Techniques

One simple, low-cost approach to improving field performance of track wire connections has been implemented by KCSR, in which KCSR reduced failures by changing the installation procedure. The KCSR routes wires vertically from underneath the rail and limits exposure to pass items that could catch and rip wires, as Figure 7 shows. Figure 6 shows how this feature, in concert with the proposed fusible link, can improve track wire connection performance.

While this approach requires more up front time and effort during installation, it has been shown to reduce chances of damage during most routine track maintenance tasks.



Figure 7: Example of Damage Resistance Installation on KCS, Where Wire is Routed Under the Rail and Buried in the Crib, Limited Snagging or Other Damage from Passing Vehicles and Maintenance Equipment (Note: Small clamp on rail base holds wire in position.)

CONCLUSION

A number of new technologies for connecting signal wires to rail are under investigation for in track performance. Results of laboratory testing examples of these connections suggest that minimum and maximum crimp strength may be a viable standard to develop for future connection technologies. With a properly designed crimp connection, a breakaway could occur at a location on the wire where it can be easily reconnected (or cut and recrimped) rather than requiring reattachment of the rail interface. Currently, there is a major issue with reattaching many of the connector technologies to the same location of the rail because it is either not feasible or advisable because of surface preparation and/or heat damage issues.

A wire connection with a breaking strength of at least 400 pounds, but not exceeding 550 pounds would allow the rail to wire bond to remain attached to the rail without damage, yet provide reconnection capability. Recrimping tools and connectors need to be developed to ensure reliable and consistent results in this range.

Future work to investigate improved reliability of low or “no heat” connections, such as base clamps and epoxy based rail connections, is recommended. Alternative connection technologies are also currently being evaluated, and performance will be reported in separate TDs.

The use of low or “no heat” connections is of special interest to railroads operating in high fire danger zones (usually in western states), when extended drought results in high risk of fires due to sparks and flames that are generated during the application of conventional attachment methods.

REFERENCES

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, Colorado.
2. Read, David, Michael House, and David Davis. December 2008. “Rail-Wire Interface Performance Issues,” *Technology Digest* TD-08-058, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado