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An Update on Revenue Service Evaluation of Premium Insulated Joints

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Summary

The average service life of conventional insulated joints (IJs) in heavy haul freight routes has increased to 500 million gross tons (MGT), compared to 200 MGT some years ago. The railroads next objective is to push service life to 1,000 MGT. Based on laboratory test results and preliminary results at the Facility for Accelerated Service Testing (FAST), several improvements have been successfully incorporated into conventional IJ designs. These improved IJs are termed as premium IJs.

Prototype premium IJs are being tested in BNSF Railway's Orin subdivision and Union Pacific Railroad's South Morrill subdivision. which is one of the heaviest coal routes in the world. Transportation Technology Center, Inc. (TTCI), with support from IJ suppliers and host railroads, is evaluating the performance of prototype premium IJs.

Although some of the IJs are still being tested, the following conclusions can be made:

- As opposed to laboratory shear strength test results that showed no benefit of Kevlar over fiberglass insulators, standard IJs equipped with Kevlar insulators have provided service lives of 1,000 MGT, which is significantly higher than similar IJs equipped with fiberglass insulators.
- A premium IJ system with 48-inch long joint bars, supported over wider ties and having a three-tie-plate configuration, is performing well. To date, the average tonnage on a sample of 15 IJs is 500 MGT. No failure indications have been observed.
- A group of six IJs with larger wraparound joint bars have accumulated about 600 MGT with no failures.
- Rail ends of many premium IJs show material chipping (i.e., fatigue cracking). This failure mode has become more prominent as IJ support and structural issues have been addressed. Adjustments to joint slotting practices may mitigate this problem.
- Hybrid IJs have a double layer of insulation protection (i.e., bolts are insulated from joint bars and rail). Some hybrid IJs appear to have pulled apart, but as expected, they are still providing insulation.

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INTRODUCTION

Bonded IJs are the backbone of the current railway signal system. The IJs divide the track into 2-mile blocks. Each block has traffic control signals and IJs on both ends. The signal system is used to detect train presence within the block and to control traffic on the railway. Using the present IJ-based signal system, the presence of broken rails can be detected in many circumstances. Also, warning lights at railroad/highway crossings are controlled using train presence detection circuits and IJs.

On heavily used coal routes, the performance of conventional IJs was a significant economic and reliability problem due to their relatively short service lives. The average service life of an IJ was as short as 200 MGT.[1] As a result of improved quality control, the service lives of the same IJs are about 500 MGT.

To further increase the service life of IJs, several improvements were made to conventional IJ designs. These improvements include, but are not limited to:

- Stronger insulators
- Steel surface treatment
- Longer joint bars
- Hybrid designs with double insulation
- Wraparound joint bars and joint with center liners, etc.

Based on these concepts, several prototype IJs (premium IJs) were assembled and installed on BNSF Railway's Orin and Belen subdivisions and on Union Pacific Railroad's South Morrill subdivision. Figure 1 shows a comparison of the service lives of IJs.

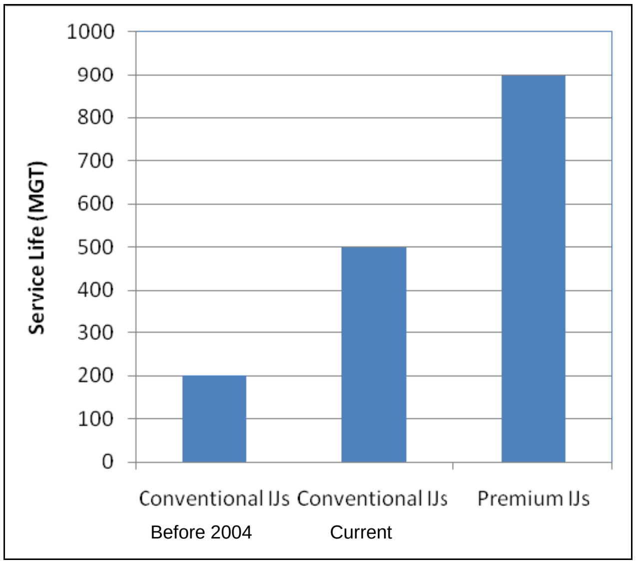

Figure 1. Comparison of Projected Service Lives by IJ Category

It appears that all suggested improvements provide some benefit in increasing the service life of IJs. However, the most benefit is likely to be achieved by the IJ system, which is a combination of 48-inch long joint bars, three-tie-plates, and wider ties, as Figure 2 shows.

Figure 2. IJ System Design: Supported IJ with Wider Ties and Three-Tie-Plate

IJ System

BNSF uses wood tie panels (in concrete tie track) for track transitions and high dynamic load components like IJs. The panels have wider ties (typically, 11-inch versus 9-inch standard ties) under the IJs and longer ties (9 1/2-foot versus 9-foot standard ties) on the whole panel. The panels provide additional track damping with a footprint similar to concrete ties. The change in tie size creates two new transition zones 20 feet away from the IJs. Fifteen prototype IJs are in test and their service tonnage to date ranges from 450 to 550 MGT. The effects of new ties and ballast versus IJ material improvements cannot be separated in these tests.

Stronger Insulators

Insulators come in different weave patterns, weights, thicknesses, and strengths. It is believed that of all of these properties, tensile strength has the highest effect on insulator performance in bonded IJs.

Kevlar is embedded in the adhesive layer of bonded joints and serves the functions of a spacer, an insulator, and an adhesive reinforcement. Conventional laboratory testing of joints fabricated with Kevlar showed them to be no stronger, and only marginally more durable, than joints fabricated with fiberglass cloth. However, revenue service testing shows that they provide a significantly longer service life. Many prototype joints fabricated with Kevlar have been removed from track with about 1,000 MGT of service (Figure 3). It is speculated that Kevlar performs better in the more complex load environment of revenue service (where wheel impact loads and multi-planar stresses occur) than in the single-direction loading environment used in laboratory tests. Also, joints fabricated with Kevlar may be less subject to environmental degradation.

Figure 3. Conventional IJ with Kevlar Insulators in Track Removed after 1,000 MGT

Higher Modulus Joint Bars

Higher modulus joint bars are designed to match the vertical stiffness of the IJs to the surrounding rail. They can be either cast or machined. This type of joint distributes the wheel loads to at least three ties, reducing ballast degradation. Due to higher section properties, the stresses in the adhesive layer in these IJs are lower than in standard IJs. However, the larger cross section results in a stiffer joint, which is likely to increase wheel impact loads. Higher modulus IJs perform satisfactorily in revenue service.

Wraparound joint bars (Figure 4) have almost double the bonded surface area with the rail compared to standard joint bars. Logically, the ratio of adhesive strength to longitudinal forces should be higher.

Figure 4. An IJ with Wraparound Joint Bars (top) In Service, (bottom) View of the Rail Base

However, one joint failed after 300 MGT of service, which may be attributed to variations in tolerance, because the joint bars are machined and not rolled. This failure was not representative of other test samples of similar design, which have average service lives of about 550 MGT.

Cast joint bars have a larger cross section in the center of the joint, where rails have a discontinuity and taper to a smaller cross section at the end of the joint. These are likely to have lower stresses, but their higher mass may result in higher wheel impact loads.

Tie Plates

Generally, three types of insulated plates are used under IJs: single tie plates for supported joints, two-tie-plates for suspended joints, and three-tie-plates for supported 48-inch long joints. Figure 5 shows the different types of tie plates.

Figure 5. Clockwise from top left corner: Two-Tie-Plate, Three-Tie-Plate for Timber Ties, Three-Tie-Plate for Concrete Ties, and Single Tie Plate

Single tie plates are used for insulation and do not add strength to the joint. The two-tie-plate design is mainly used to reduce joint deflection. Modeling results for a beam on an elastic foundation show that single ties experience 40 to 60 percent of the wheel load (depending on track stiffness) when loaded directly. The three-tie-plate design reduces this load by making the track stiffer.

The two-tie-plate and three-tie-plate designs are usually 1-1/2-inches thick and add minimal stiffness to the track, as compared to rail. A lower strength material is used, as compared to high strength rail steel. Also, weld details and sharp radii are likely to initiate fatigue cracks, and insulation has a tendency to de-bond. Moreover, ties need to be lowered (dug down) to compensate for the additional plate thickness. The additional work to maintain tie plates outweighs the advantage of the slight increase in stiffness.

Railhead Chipping

Now that IJs have a service life greater than 500 MGT, chipping of metal from the top of the rail ends has become the predominant failure mode. As Figure 6 shows, metal flow at the rail ends can lead to small cracks that can grow larger with tonnage, resulting in chipping. If the metal flow is removed by grinding, no further cracking or chipping usually occurs. However, the wheel then has to jump a 1-inch-long dip formed during the grinding process instead of a 1/4-inch end-post gap. The resulting wheel impact loads can accelerate ballast deterioration.

Railhead chipping is likely to depend on joint stiffness as well. Joints made with very high modulus bars tend to develop cracks faster than joints made with lower modulus bars.

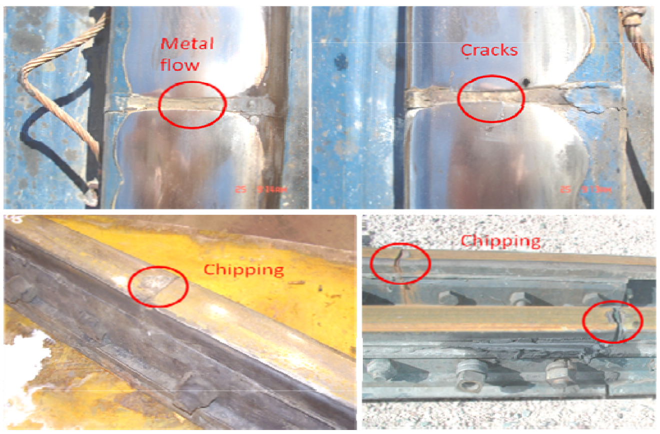

Figure 6. Clockwise from top left corner: Different Joints Showing Metal Flow, Crack Initiation, and Chipping

Conclusions

TTCI researchers have evaluated prototype premium IJs tested in revenue service and made the following conclusions:

- As opposed to laboratory shear strength test results that showed no benefit of Kevlar over fiberglass insulators, standard IJs equipped with Kevlar insulators have provided service lives of 1,000 MGT, which is significantly higher than similar IJs equipped with fiberglass insulators.
- A premium IJ system with 48-inch-long joint bars, supported over wider ties and having a three-tie-plate configuration, is performing well. To date, the average tonnage on a sample of 15 IJs is 500 MGT. No failure indications have been observed.
- A group of six IJs with larger wraparound joint bars have accumulated about 600 MGT with no failures.
- Rail ends of many premium IJs show material chipping (i.e., fatigue cracking). This failure mode has become more prominent as IJ support and structural issues have been addressed. Adjustments to joint slotting practices may mitigate this problem.
- Hybrid IJs have a double layer of insulation protection (i.e., bolts are insulated from joint bars and rail). Some hybrid IJs appeared to have epoxy failure manifested as rails pulling apart so that the bolts begin carrying longitudinal load. But as expected, they are still providing insulation.

Future Work

The premium IJs evaluated have improved performance and average service life by addressing the predominant failure mode of standard bonded IJs: epoxy failure. In delaying or eliminating the onset of this failure mode, other failure modes emerge. Once railhead chipping occurs, prevention and maintenance methods are needed. These research and development topics will be addressed to further improve the performance of premium IJs. Further investigation of the potential benefits of premium materials for metallic and insulator parts of the IJ will be conducted.

References

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