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# Prototype Next Generation Insulated Joints

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## Summary

Under the Association of American Railroads' Strategic Research Initiatives Program, significant progress has been made to increase service life of insulated joints (IJ) in the heavy axle load environment. Railroads, suppliers, and researchers working together have greatly improved the performance of conventional IJs to the point where a 500-million gross ton service life is expected.

While this doubles service life for heavy axle load service applications from 10 years ago, it remains far short of the railroads' goal of having IJ service life match that of the surrounding rail. Consequently, Transportation Technology Center, Inc., with support from industry, is looking at more revolutionary changes in IJ design and has designed, developed, and tested several next generation prototype IJs. Below are some features of these designs:

- Keyed IJs — Longitudinal load is transferred through partially embedded metal keys in the rail and the joint bars. Unlike when using epoxy, which experiences steep reduction in strength when heated beyond room temperatures, severe environmental conditions do not affect the strength of keyed IJs.
- Taper cut IJs — Provides smooth wheel transition due to the taper cut at the rail ends. Additional epoxy layers and a thicker web have almost doubled the stiffness compared to conventional IJ designs. Impacts from wheels have reduced to near zero.
- Durable epoxy and surface treatment — Addresses the major IJ failure mode of epoxy shear failure. More durable epoxy has been used. Rail and joint bar surfaces have been treated to increase epoxy-rail bonding and to inhibit corrosion.

While the long-term service performance of these prototype IJs is yet to be determined, laboratory testing and short-term service performance suggest a better service life than conventional IJs.

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## INTRODUCTION

IJs in mainline rail are installed as dividers for track circuits used for train control. Rail joints are known weak points in track, being less reliable and requiring more maintenance than continuous rail. A considerable industry effort has been expended to improve IJ performance by both evolutionary and revolutionary design changes. Significant improvement has been made in increasing the average service life of IJs over the past 5 to 7 years.

This *Technology Digest* (TD) describes the performance of more revolutionary IJ designs (i.e., Next Generation IJs) in revenue service. Another TD describes the performance of evolutionary IJ design (i.e., Premium IJs) in revenue service.[1] These changes result in an IJ that is conventional in appearance (i.e., a butt joint that has two axes of symmetry).

Several prototype IJs were evaluated at the Facility for Accelerated Service Testing (FAST), Pueblo, Colo., and in revenue service testing conducted by Association of American Railroad member railroads. The test designs are intended to develop an IJ that will have a service life equal to the surrounding rail. To accomplish this, the following failure modes were addressed:

- Fatigue of joint bars and fasteners
- Environmental degradation of epoxy
- Overstressing and fatigue of epoxy
- Rail running surface deformation
- Differential settlement of IJ

## Next Generation Insulated Joints

Prototype IJs were developed to address the above failure modes. Each design is described briefly below. In addition, Table 1 lists the failure modes addressed by each prototype.

- Taper cut IJ: This design has a lapped joint between the two rails. The taper cut joint is stronger than a butt joint.
- Keyed IJ: This design uses mechanical keys to transfer load from the rail to the joint bar, instead of the epoxy.
- Epoxy: More durable epoxy and rail/bar surface preparation. These can be applied to any bonded IJ design.

**Table 1. Design Features of Next Generation IJs**

| Design | Taper Cut | Keyed IJ | Epoxy |
|---|---|---|---|
| Component Fatigue | X | | X |
| Environmental Degradation | | | X |
| Epoxy Stress | X | X | |
| Running Surface Degradation | X | | |
| Deflection | X | X | |

## Keyed Insulated Joints

The keyed IJ transfers load from one rail to the other through partially embedded keys in the rails and the joint bars. This joint is capable of resisting four times the design load of a conventional IJ, and its strength is not affected by environmental factors . Figure 1 demonstrates how the keyed IJ concept works.

The size and number of the keys can be varied to provide the shear capacity required for a given service environment. Keys are press fitted in the joint bars. There is 1/16-inch tolerance between the keys and the counter bores in the rail, which is an allowance for the epoxy and the insulation.

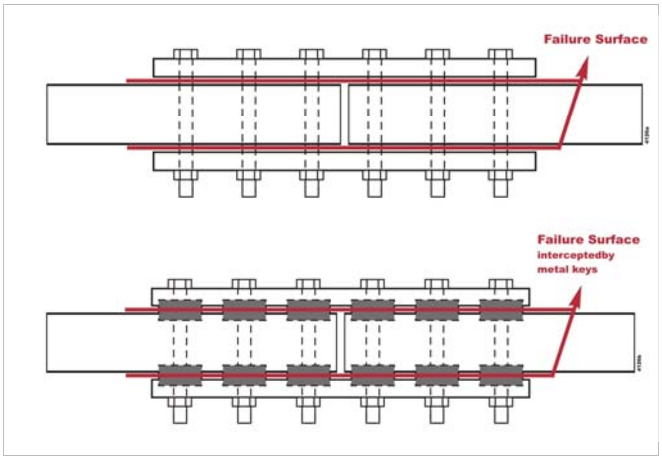

**Figure 1. Longitudinal Load Transfer in a Conventional IJ (top), and a Keyed IJ (bottom)**

Each key is capable of resisting an 800,000-pound load without breaking, virtually eliminating the need for epoxy to carry shear loading; however, epoxy may still be used for filling spaces and insulating between parts.

Three different keyed IJ samples were prepared with different types of insulation. Insulation failed during the test, but each sample resisted beyond 1,000,000 pounds, which is the capacity of the test machine. For comparison, the conventional epoxy IJ failed at 700,000 pounds. The test results suggested that keys may not be needed at all bolt-hole locations, because the strength is far beyond what is required (Figure 2).

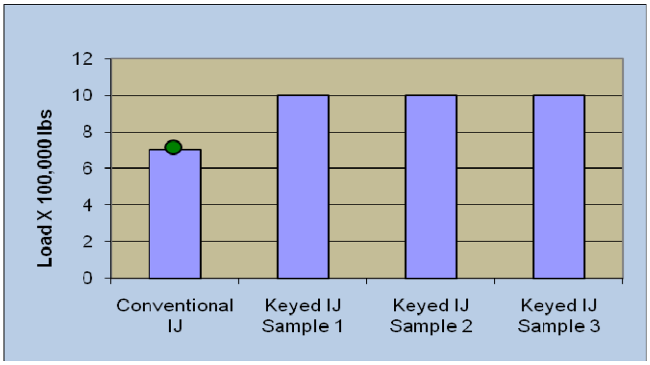

**Figure 2. Laboratory Test Results under Compression Load**

The first iteration of this design used two 3-inch diameter keys at each bolt location, one on each side of the rail. This configuration requires using thick web rail to accommodate the two keys at each bolt location. Two joints were manufactured: one was installed at FAST and the other on BNSF's Belen subdivision. These keyed IJs have accumulated 220 MGT and 160 MGT of 39-ton axle load and intermodal traffic, respectively, with good performance to date.

In the second design iteration, the keys were eliminated at the two middle bolt locations, reducing the amount of machining and assembling. Also, larger tapers were used on the keys and counter bores to reduce possible stress raisers. The third design iteration will use standard web thickness rail and half as many keys.

## Taper Cut Insulated Joints

The objective of this design (Figure 3) is to reduce epoxy shear stress, increase longitudinal strength, and provide smooth wheel transition. Initially, TTCI made the joint from thick web rail. Later a supplier modified the design and used bent standard rail.

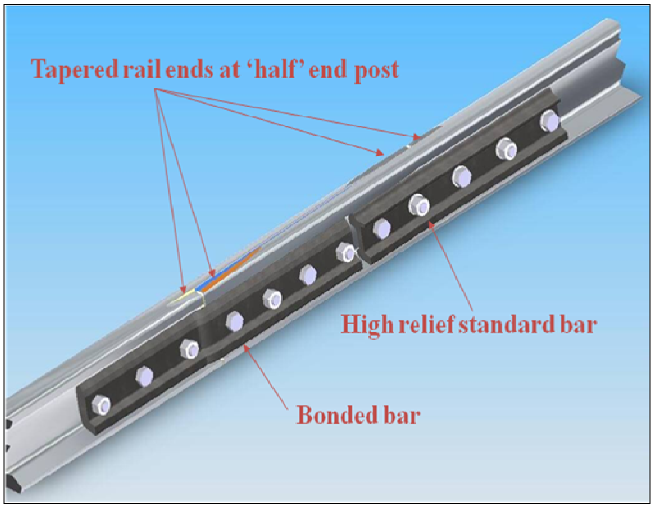

Figure 3. Taper Cut IJ

The main feature of this design is a full-section angle cut through the rail. The angle of the cut is very small with respect to the centerline of the track. Whereas, a conventional butt joint has a 90-degree cut with respect to the centerline of the track. The angle cut allows for smooth transitions of wheels from one rail to the other. This joint virtually creates no wheel impacts. It also provides higher resistance to longitudinal forces due to three layers of epoxy impregnated fiberglass.

Figure 4 shows acoustic analysis of sound recorded from a location before and after installation of a taper cut IJ. The conventional joint experiences a 12-decibel spike at about 9,300 Hz. This frequency is typically associated with wheel/rail impacts. In this case, it likely happens when the wheel jumps the end post gap and hits the downstream side of the rail. The taper cut joint does not have this spike, suggesting that the wheels have smooth transition from one rail to the other, and unlike the butt jointed conventional IJ, the taper cut IJ does not create wheel impacts.

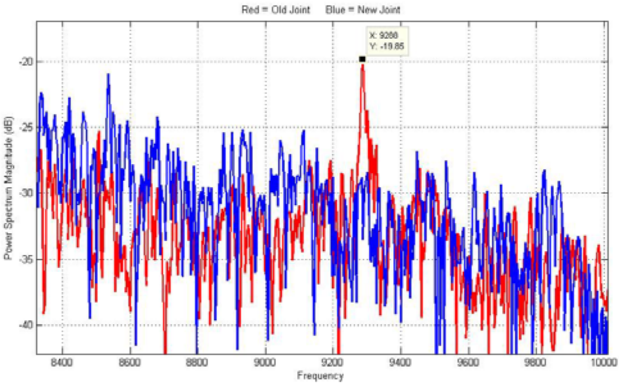

Figure 4. Acoustic Analysis of Sound from a Conventional and a Taper Cut IJ

As with butt joints, maintaining an open gap between the two rails is imperative for taper cut IJs. Here, the length of the joint is longer, but the requirement to minimize the gap (to reduce wheel impacts) has been removed. With the initial tests at FAST and in revenue service, the rail corner radii were optimized to allow for some metal flow.

There are currently six taper cut IJs in revenue service. Figure 5 shows one installed at a revenue service location. Two are installed on the South Morrill subdivision of Union Pacific with 150 MGT of 39-ton axle load traffic, and four are installed in BNSF's track in Belen, New Mexico. Tonnage ranges from 250 to 300 MGT of predominantly intermodal cars.

Figure 5. Taper Cut IJ in Revenue Service

## Durable Adhesives and Surface Treatment

One IJ failure mode is a "pull apart," which results from adhesive failure. The likely reason for failure is poor performance of adhesives under extreme temperatures.[2]

A study of commercially available adhesives showed that most of the adhesives lose strength sharply when heated beyond room temperatures, up to 75 percent, as Figure 6 shows.

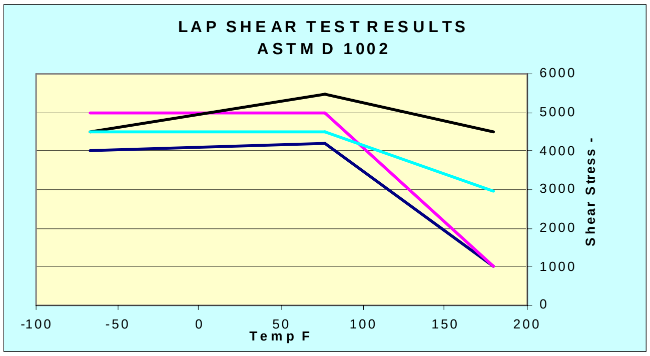

**Figure 6. Lap Shear Tests on Adhesives at -70, 70 and -170 Degrees F**

On the basis of a series of laboratory tests on materials, Virginia Polytechnic Institute (Virginia Tech) recommended certain adhesive and surface treatment for revenue service testing. The adhesive maintained its original strength during a freeze and thaw test and is expected to be more durable than existing adhesive used in IJ assembling. Saline based surface treatment provides better adhesion between steel and adhesive and might inhibit corrosion.

Eight IJs were assembled using the recommended adhesive and surface treatment (see Figure 7). Four IJs were recently installed in BNSF's track near Belen, New Mexico. Four more were installed in Union Pacific's track near Topeka, Kansas. None of them has shown any signs of degradation.

**Figure 7: Side by Side IJ Evaluation of a Conventional IJ, and an IJ with Improved Surface Treatment and Durable Adhesive**

## FUTURE WORK

TTCI will continue to monitor the performance of IJs in revenue service. Based on the performance, IJ designs may be revised. Thick web rail is currently used for making keyed IJ plug. The next iteration of this design using standard rail is in progress and is expected to reduce cost of material and machining significantly. A Cost Benefit Analysis is planned based on projected service life of IJs.

## REFERENCES

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