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Improving Joint Bar Service Life – Maintenance Practices

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Summary

Under the Association of American Railroads' Strategic Research Initiatives Program, Transportation Technology Center, Inc. is leading an industry-wide effort to improve the performance of standard joint bars (noninsulated) in a heavy axle load environment. The multifaceted approach to achieve this goal includes: improving maintenance practices, refining manufacturing processes, increasing material properties, and designing a new joint bar profile. This *Technology Digest* provides an update on the research conducted to improve maintenance practices of rail joints in service. Observations, test results, and classical analysis suggest the following improvements to maintenance practices:

- Maintain the rail joint deflections similar to those under the rest of the track. Current methods of maintaining rail joint surface include spot tamping, changing ties under and adjacent to joints, and peaking joints. These methods do not always result in durable repairs. Additional methods such as injecting elastic materials could be investigated to improve the performance of rail joint foundations.
    - Maintain the track such that maximum load deflections do not exceed 0.35 inch at the rail joint, because deflections greater than 0.35 inch are likely to cause bending stresses that are higher than the fatigue threshold of current joint bar material.
- Minimize torque loss in the bolts by improving the joint bar profile, which may reduce the wear between rail and the joint bar surface. In tests of prototype rail joints, standard bolts lost more than 50 percent of applied torque during the first 25 MGT of traffic. Torque loss in the center bolts was even higher. No nut rotation was measured, suggesting that vibration effects on bolt loosening were minimal. Instead, most torque loss was due to wear and metal flow between rail and joint bar surfaces.
- Use rail anchors at the rail joints to restrict rail end gap width when joint bars break. Temperature-thermal force relationship of joint bars tested by anchoring every other tie was similar to anchoring every single tie.
- Reduce rail gaps at the joints in continuously welded rail to mitigate rail joint related problems such as rail end battering, railhead metal flow, and foundation degradation. Reducing the gap may also increase overall joint stiffness. A standard rail joint installed at FAST with reduced gap has not required surfacing over 300 MGT of traffic.

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INTRODUCTION AND CONCLUSIONS

Mainly because of the gap between the rails and resulting stiffness changes, rail joints require more maintenance compared to the rest of the rail. Maintenance is also affected by self loosening of threaded fasteners, rail end batter, and ballast degradation. This *Technology Digest* recommends techniques likely to mitigate some of these rail joint maintenance issues.

Foundations are perhaps the single most important factor responsible for variations in rail joint performance. Degraded foundations cause higher deflections, which increase the bending stresses in joint bars. Currently, various practices are used to reduce foundation degradation under rail joints, such as spot tamping, newer ties under joints, or track surface crowning. These practices have good short-term benefits, but are not durable enough under heavy axle load traffic. This suggests that innovative materials and techniques should be investigated to increase the rail joint performance over the long-term basis. Injection or spraying of elastic composite materials are techniques that can be investigated to maintain the deflections under rail joints at levels similar to those under the rest of the track.

Torque loss in threaded fasteners of rail joints is more likely caused by wear and metal flow between the joint bar and the rail surfaces than by the train-induced vibrations in rail joints.

The gap at the rail ends in joints was useful in jointed rail track, but in continuous welded rail (CWR) the gap tends to increase maintenance in terms of metal flow caused by wider rail gaps in winter.

RAIL JOINT FOUNDATIONS

Figure 1 shows average bending stress and vertical loaded deflections of five rail joints, which were tested on track with wood ties under 315,000-pound cars at the Facility for Accelerated Service Testing (FAST). As expected, the increase in bending stress was proportional to the increase in rail joint deflections. Average degradation was 0.0016 inch per MGT. Considering the current joint bar material properties, maximum bending stresses in joint bars of 20,000 pounds per square inch (psi) is desirable. To keep bending stresses within this range, maximum deflections would be 0.35 inch. The tests joint at FAST accumulated about 100 MGT traffic to achieve these deflections.

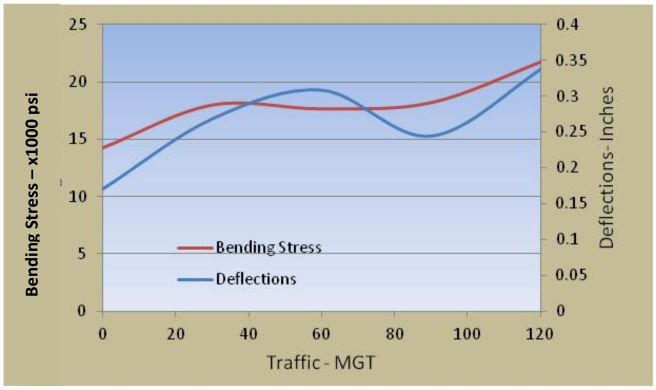

Figure 1. Average Rail Joint Deflection and Bending Stress

This can also be confirmed on the stress-deflection relationship for most common rail joints on moderate to poor foundations that was developed under a Federal Railroad Administration funded study.[1] Figure 2 shows bending stresses were very close to 20,000 psi when the deflections were about 0.35 inch. After the track was disturbed to simulate poor foundation conditions, stresses increased up to 60,000 psi. At this level, fatigue-induced cracking may occur, even yield can be expected if other loads are present in addition to vertical live load. Other track parameters such as, track geometry, track type, and fastener type did not show similar increases in stresses. That means, maintaining the foundations under rail joints is key to achieving better service life.

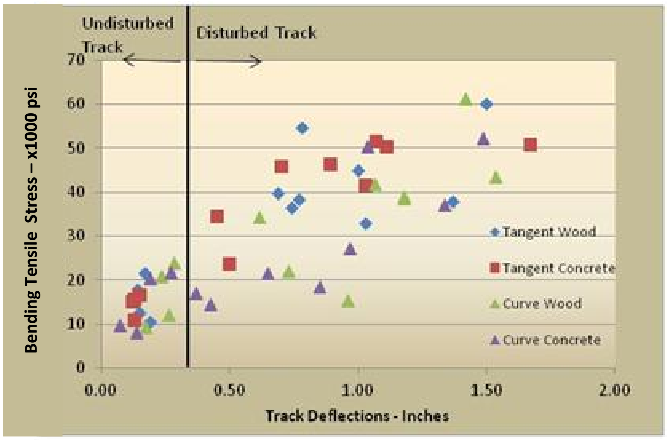

Figure 2. Bending Stress-Track Deflection Relationship of 16 Rail Joints[1]

Railroads provide special attention to rail joint foundations. The techniques used to maintain rail joints include, but are not limited to, spot tamping/surfacing, installing newer ties under rail joints and track surface crowning. However, more research could find sustained foundation maintenance solutions for rail joints to increase efficiency of current maintenance practices.

Spot Tamping/Surfacing. A certain level of material degradation occurs whenever ballast is tamped/surfaced. Tamping breaks ballast particles and re-orients the tie bottom to ballast contacts into higher stress configurations.[2] As a result, the spot being tamped improves track surface, but then experiences more rapid degradation rates than the rest of the track. As the ballast breaks down, the effectiveness of surfacing decreases until the cycle of tamping-degradation-tamping further stresses the joint bars.

An extreme example of the combined effects of ballast degradation and high track deflection on joint bar performance occurred at FAST. A 20-foot-long track section was replaced with new ballast for a rail joint test. This section of track was spot tamped six times in 50 MGT, resulting in five cracked or broken joint bars. The joints in the adjacent track, which was not tamped, did not fail during this period. This case is not typical of revenue service performance for several reasons. The entire ballast section was replaced over a short distance, creating a soft spot in the track. All the traffic was loaded 315,000-pound cars. The initial track surface degradation was high enough that surfacing was required before the track stabilized after each tamping.

Installing Newer Ties under Rail Joints. Railroads tend to install good ties directly under the rail joints. However, ballast degrades not only under the joint, but also within a certain distance beyond the rail joint ends, i.e., the affected zone. The larger benefit of newer ties appears to be achieved if all ties in the affected zone are replaced.

Track Surface Crowning or Peaking (Over Lifting of Rail Joints). On level track a certain percentage of wheel load is carried by a single tie. However, if the joint is at a higher level than the rest of the track around it, the percentage of load carried by a single tie is likely to increase, thereby further increasing the ballast degradation underneath it.

Using unconventional methods such as composite materials could be investigated to improve rail joint locations so that the deflections under the rail joints are similar to those under the rest of the track.

Joint Bar Response to Thermal Changes

By design, the bolt holes in joint bars and the rail are slightly larger (typically 1/8-inch) than the diameter of track bolts to accommodate longitudinal movement of the rail in response to temperature changes. The design works well for 39-foot jointed rail, but the bolt hole clearance is insufficient for the amount of rail movement that is typical of CWR. The thermal stress in the joint bar will be the same as the stress in the rail once the clearances are taken up and the rail is bearing against the bolt.

Two joint bars already installed in revenue service were strain gaged to measure relative stress change caused by thermal changes. Strain gages were also installed on both rails close to the joint bar ends. Because the rail joint was already installed, neutral temperature was not known. Figure 3 shows a similar thermal response of joint bars and rail to temperature change.

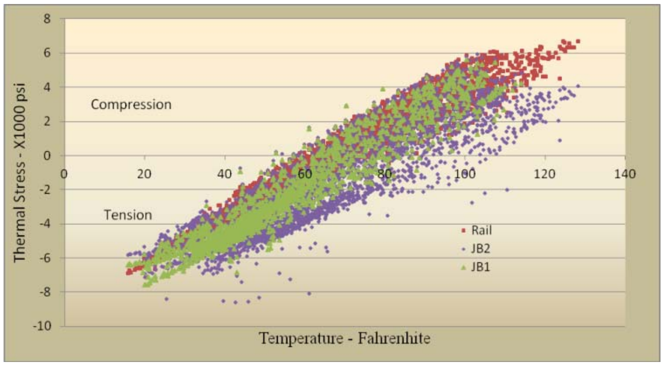

Figure 3. Thermal Stress – Temperature Relationship of Joint Bars and Rail

One of the joint bars broke, effectively reducing its tensile stress to zero. Figure 4 shows the stresses of Joint Bar 2 before and after it broke. Joint Bar 2 was subjected to 20,000 to 25,000 psi thermal tensile stresses at the time of failure. Gages on Joint Bar 1 did not record stress data at this time; however, it is likely that the stresses on Joint Bar 1 increased after Joint Bar 2 broke. No change in stress was observed in the rail before and after the joint bar broke.

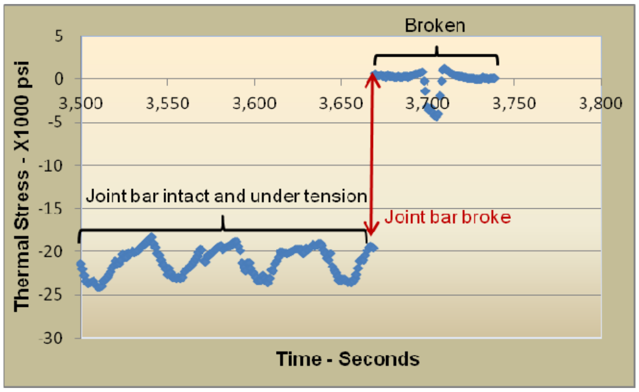

Figure 4. Stress Levels before and after Joint Bar 2 Broke

Effects of Rail Anchors on Thermal Stresses

Rail is anchored to control longitudinal movement or rail creep. In addition, in CWR, rail anchors may be required at every tie up to 195 feet around a rail joint as a safety precaution.[3] After a joint bar breaks in CWR, rail anchors are supposed to resist the rail movement and restrict the gap width.

In order to quantify the effect of anchors on thermal force, data was collected from the same joint with every tie anchored and then compared to data collected with every third tie anchored, as Figure 5 shows. The slopes are similar; thus, for this case, the track was sufficiently strong to develop the same longitudinal resistance with fewer anchors. For many locations, the additional anchors are needed to develop the same longitudinal resistance. Other possible beneficial effects of anchoring every tie, such as controlling the size of the joint gap and minimizing track movement, were not evaluated in this revenue service test. In the current case, joint bars were strain gaged when the joint bars were already in track; i.e., the force shown on the plot is not absolute. Instead, the plot shows only change in force with change in temperature.

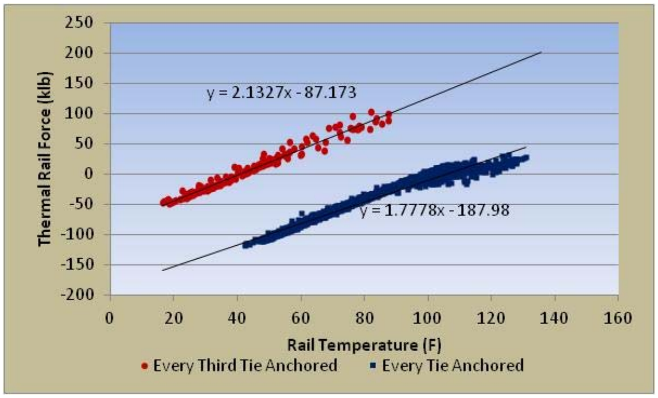

Figure 5. Effect of Rail Anchor Patterns

Vibration Resistant Bolts & Washers

Self loosening of threaded nuts and bolts in track is a continuing problem. Railroads use a significant amount of resources in retorquing the bolts, especially in jointed rail track. Tightened nuts rotate loose as soon as relative motion between the nut and bolt threads occurs. This motion opposes the friction grip and creates an off torque. The off torque rotates the nut loose if the friction under the nut or bolt head bearing surface is overcome.

Two products which have shown promise to reduce vibration-related torque loss in other industries are being tested at FAST. Both products provide higher thread pitch than the normal pitch of the nut/washer threads. Each product was installed on one rail joint along with standard nut washers and bolts, as shown in Figure 6.

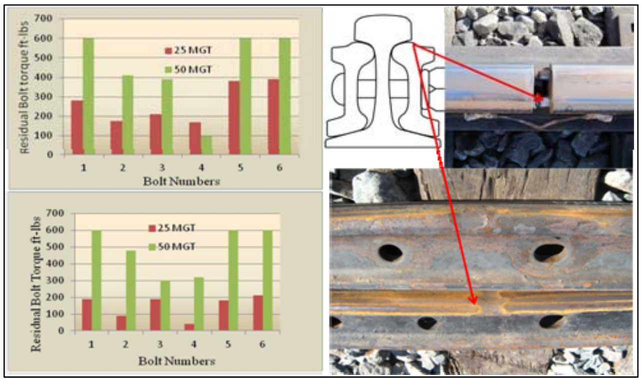

Figure 6. (Top Left)1,2,3 Vibration Resistant Bolts- 4,5,6 Std. bolts, (Bottom Left) 1,2,3 Vibration Resistant Washer- 4,5,6 Std. bolts, (Bottom Right) Metal Flow and Wear on the Joint Bars

All the bolts were tightened to 600 foot-pounds (ft-lb), which is the design torque for 1-inch diameter grade 5 track bolts. After 25 MGT and 50 MGT, residual torque, i.e., the remaining torque in the bolts after all losses, was measured. Residual torque is the torque at which the nut just starts to rotate when being tightened. After each set of measurements, the bolts were again torqued to 600 ft-lb.

No nut rotation in any bolt was recorded. That means, torque loss was caused by wear between joint bar and rail surfaces. In general, joint bars experience excessive wear where they make contact with the rail. There is more rail joint bar wear at the joint bar center, which results in higher torque loss on the bolts close to the center.

Rail Joint Gap

The rail end gap in the rail joint releases some of the compressive forces during warm weather, and in jointed rail track it helps reduce the possibility of track buckling. In CWR track, this feature has no benefit because compressive stresses are controlled by neutral temperature management. The gaps create impacts, which cause rail end batter and degrade the ballast. In colder weather, when rail gets cooler and contracts, the gaps increase significantly, further accelerating ballast degradation. The study of various gap widths (from 0.06 to 0.25 inch) has shown that the shortest gap creates the least impact.[4] Besides reducing rail end batter and ballast degradation, reducing the gap may also increase overall joint stiffness.

Figure 7 shows a standard rail joint that was assembled with only a 0.03-inch gap between the rails. This gap was necessary for tolerances in bolts and holes. The joint has accumulated 300 MGT of 315,000-pound cars at FAST and has not required ballast surfacing, implying that ballast degradation under the joint was similar to the track around it. Metal flow was ground twice during this time. No significant rail end batter was observed during the service life of the rail joint.

Figure 7. A Standard Rail Joint in Track

FUTURE WORK

The ballast degradation zone under and around rail joint bars will be determined in future studies. The effects of reducing or eliminating rail gaps at joints will be quantified in terms of reduction in wheel impacts and rail end batter.

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