TECHNOLOGY DIGEST

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Evaluation of Bainitic Rail for Crossing Diamond Applications

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Summary

Transportation Technology Center, Inc. has developed and evaluated a high-strength steel for railroad frog applications. A high-angle crossing diamond outfitted with running rails made with J6 bainitic steel has outperformed all other diamonds evaluated under 39-kip wheel loads. The running rail survived 96 million gross tons (MGT) before the first failure. The diamond was removed from track at 98 MGT due to thermite weld failures. In comparison, head-hardened pearlitic rail survived 29 MGT before its first failure in the same diamond. Testing was performed at the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST).

What makes this accomplishment even more significant is the severe testing conditions under which the J6 steel has outperformed other materials. While premium rail steels were evaluated in a diamond configured with 62-degree gaps, the bainitic rail was evaluated under the more severe conditions of 90-degree gaps. Thus, with dynamic loads that were up to 50 percent larger, the J6 steel outlived the best premium rail by more than 3 to 1. It outlived a softer premium rail by more than 10 to 1.

This bainitic microstructure steel, code named J6, is the lower alloy content version of the bainitic steels developed by TTCI under a project funded by the AAR. This chemistry was developed for curved rail applications. However, because it is a wrought (rolled) product, its performance has been as good or better than the first castings made of J9, the higher alloy frog steel.

Significant findings to date include:

- The J6 rail has shown little deformation over 96 MGT. Average deformation of the eight main track flangeway corners was 0.06 inch.
- The reduced corner deformation has kept the flangeway gaps closer to the original 1 7/8-inch minimum design gap. With AREMA practice 3/8-inch radius corners, the effective running surface gap is 2 5/8 inch. This has resulted in lower than expected dynamic loads at the flangeway corners.
- One corner failed with a horizontal crack that began at the flowed metal lip on the flangeway gap face. The corner that failed had the widest flangeway gap at about 2 1/8 inch (2 7/8-inch running surface gap).
- Use of standard pearlitic rail thermite weld kits to weld bainitic rail to pearlitic rail produces a weld that has an average life of 98 MGT (Weibull statistical analysis).
- Use of high strength (grade 8) bolts and higher torque values (2200 ft-lbs) has kept the diamond joints in compression. Bolt breakage has been minimal compared to previous diamond tests.

Suggested Distribution:

- ❏ Maintenance of Way
- ❏ Planning & Analysis
- ❏ Track Maintenance
- ❏ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

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INTRODUCTION AND CONCLUSIONS

The life expectancy of conventional crossing diamonds operated under heavy axle load (HAL) traffic is dramatically shortened compared to 100-ton or mixed-freight operations. Testing at FAST, under 39-kip wheel loads, has shown that conventional diamonds have very short lives (i.e., 5-15 MGT). Unlike turnouts, the use of premium components in conventional designs does not restore the average life to what it was under 33-kip wheel loading. This data suggests that, in unsupported gap diamonds, the limits of the technology may have been reached.

A test of the bainitic microstructure steels developed by Oregon Graduate Institute for AAR is being conducted for high-angle diamonds under HAL traffic at FAST using the 39-kip wheel load train under 40 mph operations. Both cast frogs and frogs constructed from rail steel are in test. This digest describes the performance of the three-rail crossing diamond.

Testing at FAST has shown that bainitic rail gives significantly improved performance over conventional rail in high-angle crossing diamond frogs. Using a crossing diamond removed from revenue service, TTCI has been able to test various running rails under similar conditions. The bainitic rail survived three times longer than the best available pearlitic rail.

FAST OPERATION RESULTS

In 1998 and 1999, 98.4 MGT and 9,489 train passes were accumulated over a 62-degree three-rail diamond with bainitic running rail cut to 90-degree gaps. The diamond was removed from test after 98 MGT of traffic due to failure of non-test components. Two thermite welds, one base plate, one angle bar and one filler block had failed in the last 8 MGT of operation. One of the eight main track flangeway gap corners failed at 97 MGT.

Comparison of the service life of the three sets of running rails tested in the crossing diamond is given in Exhibits 1 and 2. The bainitic steel performed very well, as its superior strength and toughness provided a more durable and stable flangeway corner.

One of the reasons for the good performance of the bainitic rail is the relatively small amount of deformation seen on the running surface at the flangeway gaps. As Exhibit 3 shows, the bainitic rail has accumulated about 0.06 inch of deformation at one inch from the flangeway gap. One would expect about 0.15 and 0.25 inch of deformation on the corner of a pearlitic rail diamond or an AMS casting diamond, respectively. This lack of deformation has kept the flangeway gaps smaller with the bainitic rail, thus minimizing vertical dynamic loads.

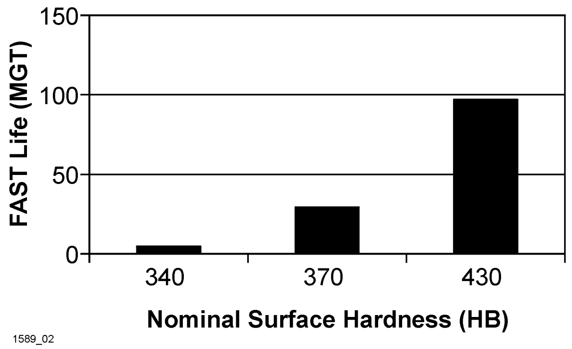

Exhibit 2. Running Surface Life vs. Rail Hardness in FAST Crossing Diamond

Running Rail	Initial Surface Hardness (BHN)	Frog Angle (Degrees)	Tonnage to First Failure (MGT)	Failure Mode	Predicted Average Life (MGT)
Bainitic J6	410	90	97.0	Horizontal head crack	188
Pearlitic HH	370	62	29.4	Head-web separation	56
Pearlitic FHT	340	62	4.6	Head crack	9

Exhibit 1. FAST Crossing Diamond Running Rail Test Summary

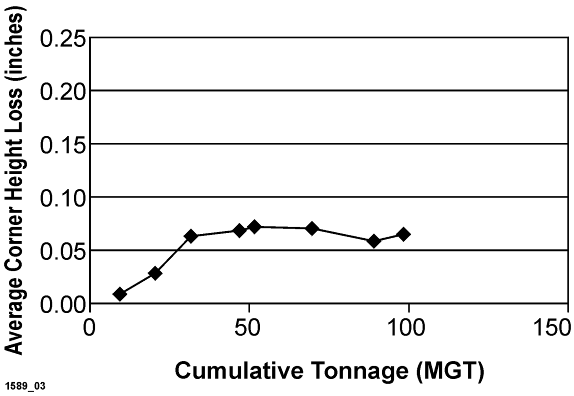

Exhibit 3. Average Flange Corner Running Surface Height Loss

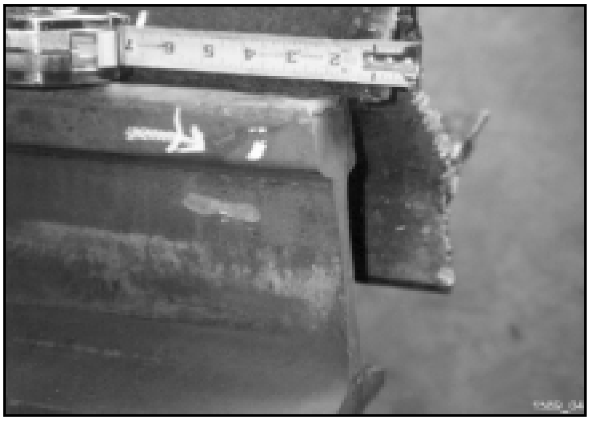

Exhibit 4. Bainitic Rail Crossing Diamond Horizontal Head Crack

RUNNING SURFACE FAILURE

The first running rail failure occurred at 96 MGT at an interior flangeway corner. The rail developed a running surface spall about 0.5 inch from the flangeway. The surface sheared in the direction of the flangeway turning into a horizontal crack. The crack was about 7 inches long when discovered. It was found by visual inspection when the crack appeared at the surface of the rail at the flangeway corner. Exhibit 4 shows the crack after the rail was removed from the diamond. The crack extended the full railhead width for about 2 inches, tapering back to less than 2 inches wide at 4 inches from the gap. The growth of the crack to this length before detection can be interpreted in two ways: (1) J6 is tough, or (2) the crack grew very rapidly. The former is more likely, as the crack was oriented ideally for detection with a vertical probe. Also, the diamond received only about 2 MGT of traffic in the previous two weeks. It is highly unlikely that the defect initiated and grew to that size prior to the last two inspections.

BOLT PERFORMANCE

The use of high strength Grade 8 bolts and bolt tightening practices that assure tensioning of the bolt have allowed the joints in this diamond to remain in compression and solid. Bolt breakage has been limited to a few locations where there are fit problems between the various diamond pieces or when an angle bar was broken. Use of a hydraulic wrench allows us to torque bolts to 2200 ft-lbs. (lubricated).

DIAMOND ALIGNMENT PROBLEMS

The special configuration of the test diamond, with no cross track and 90-degree gaps cut in the running rail of a 63-degree diamond, created chronic alignment problems. The offset 90-degree gaps caused the diamond to rotate clockwise; whereas, the previous 63-degree gaps were less of a problem. The first gap encountered in either direction tended to "kick out" to the field side, rotating the diamond clockwise out of Class 4 alignment in as little as 2 MGT. The lack of a cross track and connecting rails resulted in the ties and ballast providing little rotation resistance. Slack in the diamond angle bars, filler iron, and plate stops allowed the diamond to twist without engaging the cross track members.

Welding stiffener plates to the existing plate work solved the problem. This fixed the angle of the plate work supporting the diamond. It also allowed the entire diamond structure to resist the turning forces. The diamond did not require re-alignment during the last 50 MGT of testing.

TEST CONFIGURATION

The running rails in the crossing diamond were tested with 90-degree flangeway gaps. This was done to provide as severe a test as possible. This severe proof test was used to determine if it would be worth the expense of building a state-of-the-art crossing diamond with J6 rail. Exhibit 5 shows the bainitic running rail in the diamond as tested with 90-degree gaps in a 62-degree diamond. The outside support rails were ramped down at the corners so that they could not provide any support to wheels with hollow worn tread profiles. As the photograph shows, there are no wear marks from hollow tread wheels near the gaps. Thus, each wheel was jumping a full 1 7/8-inch flangeway.

Exhibit 5. FAST Crossing Diamond Running Rail Test Configuration

FUTURE WORK

Based on what was learned in this test, bainitic rail was able to greatly improve the performance of a less than state-of-the-art crossing diamond for heavy haul conditions. The bainitic rail looks promising enough to build modern diamonds for test in revenue service and at FAST. For this purpose, TTCI has made bainitic rail in 136RE and 136 Thick Web section available to AAR member railroads. We anticipate having at least four high-angle three-rail diamonds in revenue service test in 2000. TTCI will also acquire a high-angle bainitic diamond with thick web running rails for testing at FAST.

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