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An Update on Revenue Service Tests of Bainitic Steel Rail Crossing Diamonds

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Summary

After up to two years in revenue service trials, bainitic steel rail crossing diamonds continue to show promising results. Three crossing diamonds are in service at locations maintained by Canadian National/Illinois Central and Union Pacific railroads. Tests performed by these railroads and the Transportation Technology Center, Inc (TTCI) are designed to monitor the performance of three, three-rail crossing diamonds in revenue service. The diamonds have required less maintenance and have less deformation than conventional components in the first two years of the test.

Significant findings to date include:

- Running surface height-loss rates ("wear" rates) have been low on the bainitic rail diamonds. At 100 MGT of traffic, the average height loss at the common corners (i.e., frog corners common to both routes) is 0.12 inch. Bainitic running rails are outperforming the previously used pearlitic running rails at the Gilman, Illinois, crossing. Running surface height-loss rate at the flangeway corners is less than half the height-loss rate with the previous two pearlitic rail diamonds.
- Less maintenance has been required on the bainitic rail diamonds. Also, less running surface grinding and track surfacing have been required on the bainitic diamonds than on their predecessor conventional material diamonds. However, one bainitic running rail was replaced due to a bolthole crack.
- Running surface height-loss rates at the three revenue service sites are similar. Although the traffic patterns are different, the common corner height-loss rates are similar. The revenue-service height-loss rates are higher than those seen at the Facility for Accelerated Service Testing (FAST). Yet, the average wheel load is lower. This suggests that cross traffic and wheel profile play significant roles in running surface height-loss rates.
- Frog corners common to both routes are showing more height loss than corners that are part of the main line only. The height-loss rates are lowest for mainline corners and higher for both common corners and branch-line corners. The better running surface profile (i.e., no transverse rails at the frogs) on mainline corners results in less height loss.
- Rolling contact fatigue (RCF) is appearing on the bainitic rails. The running surfaces of all three diamonds show signs of cracking and spalling. The onset of the running surface damage is associated with an increase in average surface hardness above 500 Brinell, due to cold working. RCF tends to occur sooner on pearlitic rails because of their lower strength and toughness.
- No significant differences in performance of RE section rail versus thick web (TW) section rail have been noted. Two diamonds have RE rail and one has TW rail.
- Based on the first 100 MGT of service, the predicted wear life for the bainitic rail diamonds is 2 to 4 times better than pearlitic rail diamonds.

Suggested Distribution:
- ☐ Safety
- ☐ Maintenance-of-Way
- ☐ Track Maintenance
- ☐ Planning & Analysis

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INTRODUCTION AND CONCLUSIONS

Three bainitic running rail, high-angle crossing diamonds have been installed in revenue service tests. These diamonds were built based on results of TTCI testing of bainitic running rails in crossing diamonds under 39,000-pound wheel-load traffic on the High Tonnage Loop at FAST. In those tests, bainitic rail had a service life that was three times the service life of premium pearlitic rails.[1]

Revenue Service Operating Environment

Each test site has a significant amount of heavy axle load (HAL) traffic. HAL traffic is defined as cars with loaded gross rail weights more than 263,000 pounds. Each site is located on level open ground. Test sites at Gilman and Zeigler, Illinois, have good drainage conditions. Hoxie, Arkansas, has a road crossing and a second diamond nearby which limits the effectiveness of the track drainage.

The three diamonds vary in construction details. Two of the diamonds have RE section running rails, of which one has bainitic guard and easer rails. The other diamond has conventional pearlitic guard and easer rails. And the third has all bainitic rails rolled to a thick web section.

The test sites are described in Table 1. They are located on main lines in the Midwest.

Table 1. Revenue Service Bainitic Rail Crossing Diamond Test Sites

Test Location	Crossing Angle (Degrees)	Rail Section	Owning Railroad	Crossing Railroad	Annual Tonnage Rate (MGT/Yr)	Speed Limit (mph)	Installation Date
Gilman, IL	78	136RE	CN-IC	TP&W	37	40	July 2000
Zeigler, IL	76	136RE	UP	BNSF	60	40	May 2001
Hoxie, AR	84	136TW	UP	BNSF	110	40	Nov 2001

All three diamonds, having high crossing angles, were selected for testing due to their severe service environments. Crossings with an angle above about 60 degrees have frogs that cannot support the wheel across the flangeway gaps. These crossings generate some of the highest vertical loads on the railroad. Dynamic loads 3 to 4 times static wheel load are typically measured for conventional high angle frogs at FAST.[2]

Performance Results

Figure 1 shows the average running surface height loss versus tonnage for each test diamond at each site. Running surface height-loss measurement—an indication of combined metal flow and wear—was made 1 inch from the flangeway of each common corner. The height-loss rates are declining with tonnage as the running surfaces become harder due to deformation. For comparison purposes, the measured height-loss values from the two previous diamonds at Gilman are shown. These were conventional head hardened pearlitic TW rails.

As of November 2002, each crossing diamond has accumulated about 100 MGT of traffic. The common corners show the most deformation due to having both tracks' traffic. The three crossing diamonds are performing very similarly with average deformations of about 0.12 inch on the common corners.

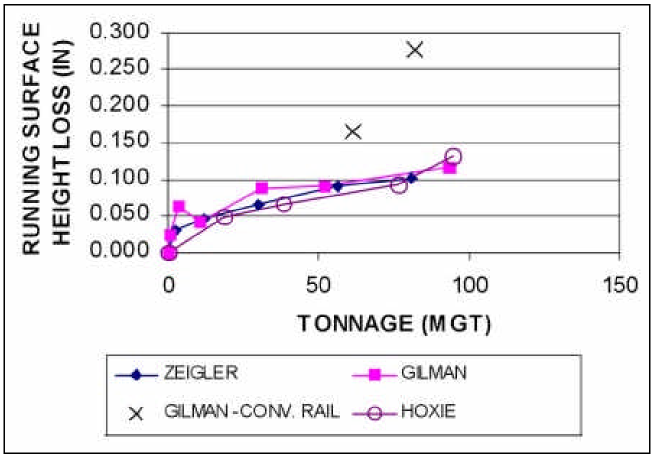

Figure 1. Running Surface Height Loss vs. Tonnage for Bainitic Rail Crossing Diamonds

Figure 2 shows typical worn profiles for mainline and common corners. Common corners show the most deformation because they receive impacts from two directions. The effect of branch-line traffic is most significant due to the running surface discontinuities created by the mainline guard, running, and easer rails. The height loss on the easer rail is from the impact of the wheel on the branch-line side. The typical worn profile of the corner that only has mainline traffic has less height loss. The wear from hollow tread profile wheels is seen on the easer rail. Common corners have the most height loss due to the impact from both mainline and branch-line traffic.

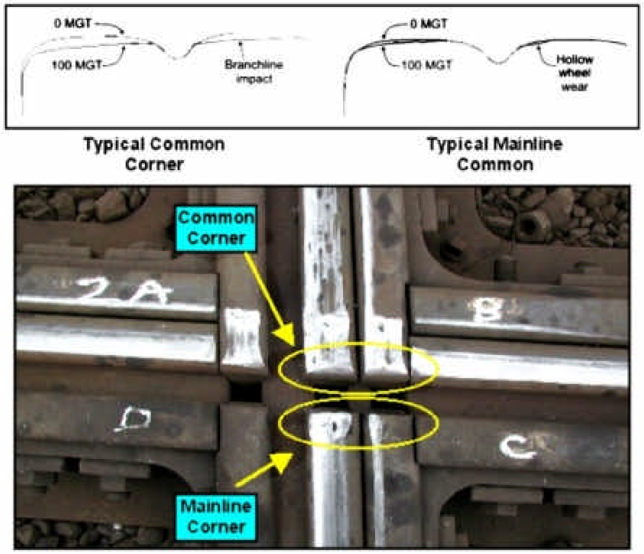

Figure 2. Typical Worn 3-Rail Frog Corner Running Surface Profiles

A corresponding increase in surface hardness has been measured with running surface height loss. Figure 3 shows average running surface hardness with tonnage for the test sites. The significant increase in average hardness at Gilman during the last measurement came with an increase in surface cracks and spalls. .

The running surface hardness values will be watched closely because they may be a predictor of surface cracking and rolling contact fatigue. It is not known how hard the bainitic rail running surface can get with dynamic loading. However, pearlitic rail and AMS both reach a characteristic hardness level beyond which they are likely to crack rather than flow. This "ductility exhaustion" value is around 500 Bhn for pearlitic rail and 600 Bhn for AMS castings. To date, the bainitic rails are still work hardening under traffic.

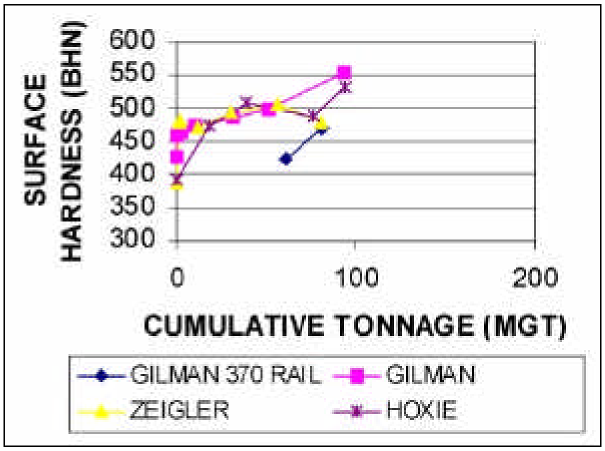

Figure 3 . Running Surface Hardness vs. Tonnage for Bainitic Rail Crossing Diamonds

In addition to the comparison of conventional rail and bainitic rail, additional test variables included:

- Running rail section: RE vs. TW
- Traffic distribution: main vs. crossing line
- Traffic rate: 40 to 110 MGT/yr

The TW rail section is assumed to be more durable for crossing applications as it strengthens the head-web connection in the rail. Many crossing-diamond rail failures result from head-web area defects. TW rail also requires thinner filler bars. These bars connect the frog rails across flangeways and provide bending strength. To date there has been no significant difference in deformation between RE and TW sections. One TW section running rail was replaced due to a bolthole crack. No RE section running rails have been replaced to date.

The effect of traffic distribution would appear to be small over the three test sites. Running surface height-loss rates are similar for Gilman (3-percent crossing traffic), Zeigler (about 33-percent crossing traffic) and Hoxie (about 45-percent crossing traffic). However, the height-loss rates for all three diamonds are higher than the rates seen for two bainitic diamonds tested at FAST. Tests at FAST are conducted under higher wheel loads and similar speeds. Diamonds at FAST had no crossing traffic. Previous analysis has shown that a small amount of cross traffic contributes to a large increase in wear rate for the common corners.[3] Further analysis with the latest data also shows that the common corners have a significantly higher height-loss rate than the other running surfaces. Figure 4 shows these rates for each crossing.

The effect of traffic rate has not been significant in this test. Running surface height-loss rates (per MGT) at all three sites are similar. Load application rate can affect height-loss rates if there is insufficient track time allowed for inspection and timely maintenance.

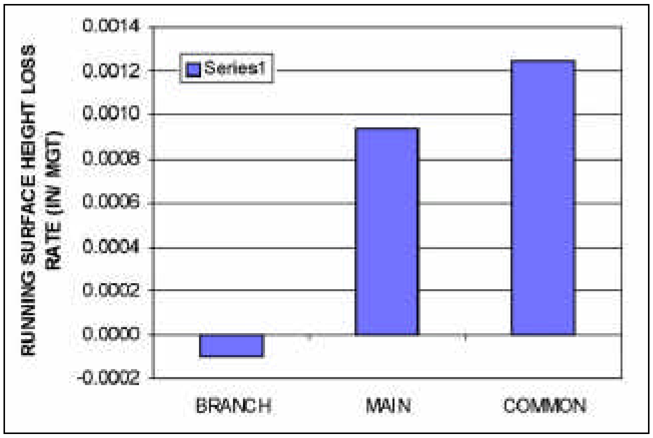

Figure 4. Comparison of Running Surface Height Loss by Frog Corner Location

Maintenance Records

The bainitic rail crossing diamonds have required much less initial maintenance than the conventional three-rail and AMS casting diamonds previously in place at these locations. Having less running surface deformation appears to be benefiting the rest of the diamond resulting in lower dynamic loads, fewer loose fasteners, thus requiring less surfacing. This is not to say that the diamonds are not deteriorating under traffic. Figure 5 shows a deformed common corner on one of the test diamonds. Hollow worn wheels are deteriorating the running rails and easer rails.

Figure 5. Bainitic Rail Crossing Diamond Common Corner

Crossing Performance Measurements

TTCI is measuring the performance of the crossing diamonds through frequent inspections. Measurements made include running surface elevations, profiles, and hardness. Maintenance and component replacement records are also being monitored. Figure 6 shows a TTCI engineer measuring the running surface elevation of the mainline rails. With this device, the running surface height loss from wear and metal flow can be determined.

Figure 6. TTCI Measurements of Running Surface Elevation

Running surface wear and deformation are calculated from the change in elevations with tonnage. Non-running surface points are also measured to serve as reference marks. Comparison to the previous two pearlitic rail crossing diamonds can be made since similar measurements were taken when these diamonds were removed from track.

FUTURE WORK

Bainitic rail has proven itself effective in high-dynamic load environments. It retains its shape and has relatively low deformation rates. It is superior to pearlitic head hardened rails with hardnesses of 380 Brinell, as previously tested in crossing diamond applications.

Being an experimental steel, there is room for improvement in the performance characteristics of medium carbon bainitic steels. Additional efforts should be devoted to the development of welding (joining), repair methods, and materials. The lack of a good thermite weld limits the ready acceptance of this steel for frog applications.

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References

1. Davis, D. and Guillen, D., "Evaluation of Bainitic Rail for Crossing Diamond Applications," *Technology Digest* TD00-016, Transportation Technology Center, Inc., Pueblo, Colorado, August 2000.
2. Singh, S. and Davis D., "Reducing Impact Forces on High-Angle Crossing Diamonds," *Technology Digest* TD98-021, Transportation Technology Center, Inc., Pueblo, Colorado, August 1998.
3. Davis, D., Guillen, D., Robeda, J., and Sasaoka; C. "Field Performance of Bainitic Steel Rail Crossing Diamonds," *Technology Digest* TD01-025, Transportation Technology Center, Inc., Pueblo, Colorado, November 2001.