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Bainitic Steel Test Results: Diamond Crossings in Revenue Service and at FAST

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Summary

As part of its special track work research program, the Transportation Technology Center, Inc. (TTCI) and members of the Association of American Railroads (AAR) have compiled test results of diamond crossings fabricated with bainitic steel. Rolled J6 bainitic rails have performed better than 370 BHN pearlitic rails for high angle crossing diamond applications. J9 bainitic frog castings have performed similarly to explosively hardened austenitic manganese steel (AMS) castings.

Summary of Findings:

- Results show that bainitic steel running surface height loss (i.e., wear and deformation) is half that of premium (370 BHN) rail steel in high angle crossings:
  - J6 bainitic rail steel's running surface height-loss is half of premium pearlitic rail steel at approximately 200 million gross ton (MGT) of traffic.
  - The worn running surface profiles of four J6 rail diamond crossings are similar. The amount of crossing route traffic on these four diamonds ranges from 3 percent to 50 percent.
  - Rolling contact fatigue (RCF) at the flangeway gaps appears to be the dominant failure mode of J6 rail. RCF starts at approximately 100 MGT and corresponds with surface hardness of 560-600 BHN. RCF can be seen on the running surface's gage corners, but in this area it appears to be slowly grinding away with traffic.
  - Long-term running surface height loss of J9 castings has been higher than AMS castings. Initially, J9 had lower height loss.
- To allow wide-scale implementation of bainitic steel-crossing diamonds, welding repair materials and procedures must be developed.
- There are potential production issues with rolling larger section, high hardness rails, such a J6.

Field Observations:

- Site conditions have significant effects on the life of the diamond
  - Adjacent road crossings, tracks, clogged drainage shortened diamond life
- Upward sloping (towards the) flangeway ramps extend diamond crossing life
- Diamond crossings with lower longitudinal stress have fewer broken components and better wear rates at flangeway corners

The diamond crossings were compared for wear, deformation, hardness, maintenance, replacement of components, and overall performance. The project's goal was to increase the life of a high angle diamond crossing along with reducing the overall required field maintenance.

TTCI Transportation Technology Center, Inc.

BACKGROUND

Bainitic steels produced to AAR purchase specifications are designed for heavy axle load (HAL) applications and offer significant benefits over the existing rail steels for special track work. Benefits include improved wear and deformation resistance. Commercial foundries and shops that produce special track work can make bainitic steel to AAR's composition and hardness, which averages 450 BHN, and to meet AREMA specifications.

For castings, the J9 bainitic steel alloy was designed as an improved replacement for the commonly used, lower strength, more ductile austenitic manganese steel (AMS). The J9 bainitic steel composition developed is designed to provide improvements in hardness, strength, casting quality, and ultrasonic inspections. The AMS casting has the disadvantages of being difficult to cast and having a softer base material under the work hardened surface material. Under HAL traffic, AMS casting deformation may reach maintenance limits before the material deformation rates stabilize (i.e., before it work hardens). Visual inspection is mostly used to check for casting defects in AMS. Due to its cast, austenitic structure, and the intricacy of the frog shape, railroads do not inspect frogs ultrasonically. For rolled rail, an advantage of J6 rail is that its shape and structure more closely match rail steel. It can be inspected without major adjustment to existing methods.

Laboratory tests of bainitic steels have shown them to be good candidates for the severe load environment of the railroad. Under pure rolling, and rolling and sliding conditions, medium carbon bainitic steels, such as J6 and J9, show better wear resistance and better rolling contact fatigue (RCF) resistance than pearlitic rail steels of similar hardness. However, in actual practice, the best available pearlitic rail steels have superior wear resistance to J6 and J9. The bainitic steels appear to be better in resisting RCF and gross deformations from wheel impacts. For high angle frogs, where impact resistance is the prime concern, bainitic steels may have an economic application.

Some manufacturers of special track work have noted that the J6 bainitic rail material, which has consistent hardness throughout the cross-section, may be too hard to machine with current machining technology. However, if the demand and economics for bainitic steels prove to be better than existing special track work materials, manufacturers may pursue improved practices and machining technology.

Introduction

Five high angle diamond crossings have accumulated between 60 and 250 MGT of traffic. The five diamond crossings were installed in locations with various foundations, traffic mix, and speeds. Four of the diamond crossings are three-rail design diamond crossings, and one is a reversible casting diamond crossing.

Figure 1 shows the locations of the test sites in revenue service.

Figure 1. Locations of Crossing Diamond Tests in Revenue Service

Diamond Crossing and Site Conditions

The diamond crossing located in Salem, Illinois, has two corners with J9 bainitic steel and two corners with AMS. The J9 castings are setting cater-corner from each other with the AMS casting corners in the other two slots. Each corner bears similar traffic conditions from both the branch and main lines. The initial average deformation rates of the J9 castings are similar to the AMS castings. But, after 200 MGT, the AMS casting corners height-loss is performing better than the J9 casting corners.

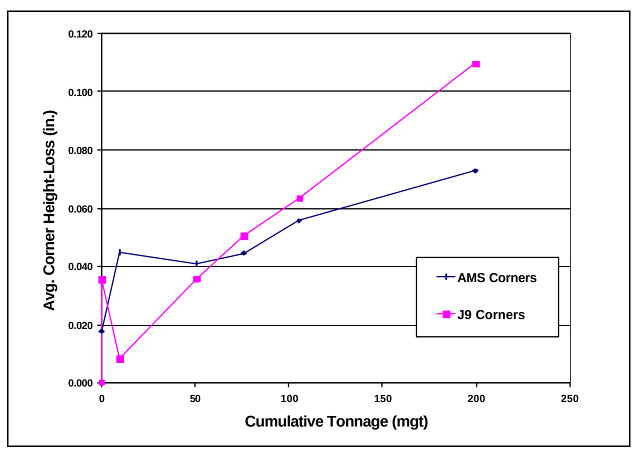

Figure 2. Diamond Crossing Height-Loss, Salem, IL

The advanced design crossing diamond located in Ontario, California, was developed for improved dynamic performance and durability (Figure 3). Improved dynamic performance was measured on the diamond, using load-measuring wheelsets. After 60 MGT of operation, the diamond had no major component failures and low running surface height loss rates. The features intended to improve performance include:

- Running surface ramps: the first one designed for a 3-rail design diamond crossing
- Herringbone corner design: eliminates one rail joint from the crossing track running surface
- Modified flangeway corner radii: smaller flangeway radii on inside corners
- Milled base plates for rail base seats
- Self-centering washer and bolts

Surface ramps were milled into the top of the railhead of the J6 material for 40-mph traffic. The surface ramps have been successful with little deformation at 81 MGT (Figure 4).

Figure 3. AAR Advanced Diamond Crossing, Ontario, CA

Corner 4 Ramp at 5 MGT **Corner 4 ramp at 81 MGT**

Figure 4: Ramping System —Diamond Crossing Minimal Deformation after 81 MGT at the Ontario Site

The diamond crossing located at Hoxie, Arkansas, is a standard 3-rail design crossing, but has an extreme dynamic load environment due to its location. The crossing sits between another high angle diamond crossing and a paved four-lane road crossing. With high speed HAL traffic in both directions, previous pearlitic crossings survived less than a year and experienced numerous component breakages (Table 1).

The diamond crossings at Zeigler and Gilman, Illinois, are also at high-tonnage and high-speed traffic crossings, and are of a standard 3-rail crossing design.

Running surface profiles are similar for all of the diamond crossings in test. Common corners show the most deformation because they receive impacts in two directions. The effect of branch-line traffic is most significant due to the running surface discontinuities created by the main-line guard, running, and easer rails. The height loss on the easer rail is from wheel impacts on the branch-line side. The typical worn profile of the corner that only has main-line 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 mail-line and branch-line traffic (Figure 5).

Table 1: Bainitic Diamond Crossing Test Status

Location	Description	Steel	RR / Tonnage (year)	Total MGT Time of Testing	Status
Gilman, IL	3-Rail Design 77° 00'	J6 Bainitic Rail RE Section	CN-IC Main Line – 40 mgt TP&W Branch* Line – 2 mgt	141	In service, running rails showing RCF. Replacement rails on order
Salem, IL	Str. Rail Reversible 86° 22'	J9 Castings AMS Castings	UPRR Main Line – 40 mgt CSXT Branch Line – 30 mgt	265	In service
Hoxie, AR	3-Rail Design 87° 57'	J6 Bainitic Rail Thick Web	BNSF Main Line – 50 mgt UPRR Branch Line – 50 mgt	197	In service, 1-side of mainline running rails replaced
Zeigler, IL	3-Rail Design 76° 31'	J6 Bainitic Rail RE Section	UPRR Main Line – 45 mgt BNSF Branch Line – 20 mgt	170	In service, running rails showing RCF
Ontario, CA	3-Rail Design 90° 00' Ramped	J6 Bainitic Rail Thick Web	UPRR Main Line – 50 mgt UPRR Branch Line – 1 mgt	93	In service

*Designation as "main" or "branch" refers to orientation of crossing diamond frog corner rails – not the relative importance of the line to the owning

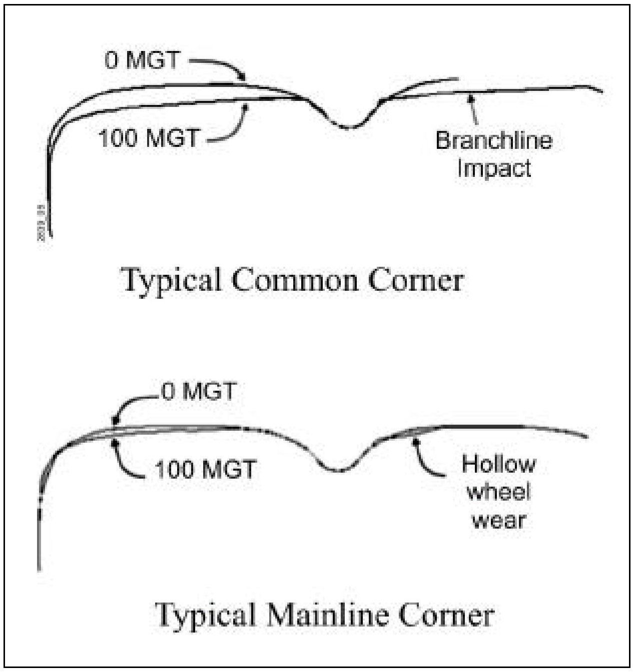

Figure 5. Typical Worn Profiles

Field Observations

Crossing diamond flangeway gaps, component breakage, track gage, and alignment were monitored during the performance evaluation period. Some commonalities were discovered between longitudinal rail stress and performance. Diamond crossings with observed tensile rail stresses showed more distress. For example:

- Larger flangeway gaps
- Pulled apart joints
- Gage variations
- More broken fasteners

These conditions lead to higher dynamic loads that cause more rapid degradations.

The local MOW personnel had added rail to these diamond crossings and the result was fewer components breaking and better surface and alignment. Flangeway gap width measurements were taken to determine if rail movement was occurring (Table 2).

A diamond crossing is considered a fixed point in track; it stops longitudinal rail movement in four directions.

Table 2. Measured Diamond Crossing Flangeway Gap Width

Diamond Crossing	Gilman, IL	Salem, IL	Hoxie, AR	Zeigler, IL	Ontario, CA
Maximum Gap Width*	2 1/8”	2 ¼”	2 ¼”	2 ½”	2 1/8”

* Measurements taken over 4-years at different temperature ranges.

Conclusions

The five crossing diamonds are still in service. Failure modes have been typical of crossing diamond failures under HAL traffic. Common deterioration such as crushed heads at the flangeway gaps, broken bolts and holdowns, and cracked plates and fasteners have been typical. But, rails and crossing diamond component replacement have been prolonged with the use of J6 bainitic rails. The five tests show that using J6 bainitic rails in high angle diamond crossings extends their life or prolongs the maintenance of its replacement parts. Premium pearlitic rails have two-times the height-loss than J6 bainitic rail in high angle diamond crossings (Figure 7). However, wide-scale application of J6 will require development of suitable repair methods and a reliable supply of rail.

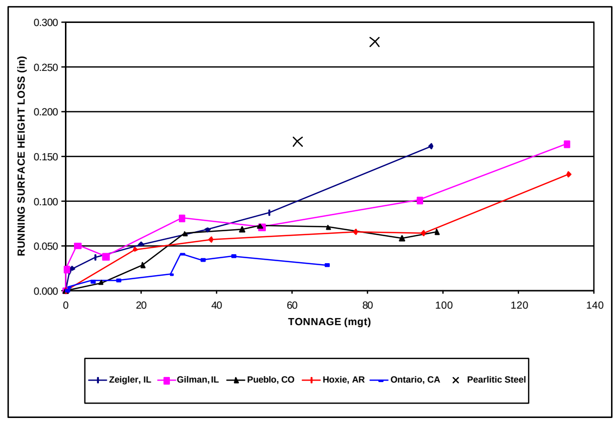

Figure 6: Five Diamond Crossing Tests

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