TECHNOLOGY DIGEST
TD-09-037
©DECEMBER 2009
TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc.,
a wholly owned subsidiary of the Association of American Railroads.

Performance of Diamond Crossing at Northport, Nebraska

Dingqing Li, Rafael Jimenez, David Davis, and Ed Kohake (UP)

Summary

Since October 2006, engineers of the Transportation Technology Center, Inc. have been monitoring the performance of a diamond crossing at Northport, Nebraska, as part of the revenue service mega site testing program.

Under heavy axle load (HAL) unit coal train operations, this diamond crossing requires extensive maintenance and is slow ordered to 25 mph. Frequent maintenance is required due to problems of component breakage (e.g., broken castings, plates, bolts and rails) and rapid rail running surface degradation. The diamond is replaced approximately every 300 MGT on the track carrying higher tonnage (or 420 MGT of total crossing traffic).

Investigations have shown that the root causes of the problems are high impact forces resulting from running surface discontinuities and degradation, high contact stresses between castings and plates, inadequate resilience and damping to attenuate high impact forces, and nonuniform deformation due to the abrupt change in track stiffness caused by the large castings and multiple plates required to withstand high dynamic forces.

At this location, components of the diamond crossing are subjected to tremendous dynamic impact forces, even under slow ordered train operation because of flangeway gaps and joints that exist on the running surfaces. At 25 mph, test results showed that vibration of the diamond crossing was at least three times as high as that of an adjacent open track.

Several methods have been implemented to improve the performance of the diamond at this location, including installation of expansion joints and ramped-up running surface profiles, rubber pads under tie plates, and placing ties longitudinally in higher tonnage track. However, they have not led to a performance improvement great enough to reduce extensive maintenance requirements. This is because none of the methods has completely addressed flangeway gaps and joints, which are the primary reason for high impact forces at crossing diamonds.

To eliminate these problems completely, a bridge crossing is probably necessary, but costly. Rubber pads could be placed between the castings and tie plates to provide some relief by attenuating the high impact forces. This remedy is presently under test at the Facility for Accelerated Service Testing.

Note: Although the findings presented were from a case study at Northport, Nebraska, they are applicable for similar diamond crossings under HAL operations.

INTRODUCTION

The Union Pacific's (UP) double tracks cross a BNSF Railway's single track at milepost 115.48 near Northport, Nebraska. Two diamond crossings are used at an angle of 73 degrees and 45 minutes. UP track No. 2 carries loaded coal trains going eastbound and has an annual tonnage of 250 MGT. UP track No. 1 mainly carries empty coal cars going westbound and has an annual tonnage of 50 MGT. The BNSF single track is in a curve (4.5 degrees) and has an annual tonnage of 115 MGT.

These crossings, particularly the one on track 2, require frequent maintenance due to problems of component breakage and running surface degradation. Trains are slow ordered to 25 mph at this location.

An investigation has been ongoing since October 2006 to identify the root causes of crossing diamond component degradation and to find possible solutions to address these performance issues as part of the revenue service mega site testing program. This *Technology Digest* (TD) summarizes the findings of the investigation.

PROBLEMS AND ROOT CAUSES

The investigation has focused on the diamond crossing on track 2 because of the higher axle loads and traffic. It is a straight rail reversible diamond and is the latest design for heavy axle load operations. Figure 1 shows the crossing that was in service in October 2006. Performance problems at this crossing include frequent track component breakage (e.g., broken castings, plates, and bolts) and rapid running surface degradation (e.g., battered and spalled rail end corners).

Figure 1. Diamond Crossing in 2006 (looking east)

The diamond was replaced in August 2007 and then again in September 2008 due to broken components and excessive running surface degradation. Figure 2 shows the diamond design installed in 2007 and again in 2008. In comparison, the diamond crossing in Figure 1 had the casting and running rail in one piece on each side, but the diamond crossing in Figure 2 has two castings with a short rail on each side (actually creating two more joints on each side). In addition, there were changes made to improve foundation support to the diamond crossing when it was replaced in August 2007 (see Improvements and Results).

Figure 2. Diamond Crossing Installed in 2007 (looking east)

Even under a slow order speed of 25 mph, broken castings, broken plates, broken rails, broken and missing bolts, and rapid running surface degradation have been an ongoing problem associated with this crossing. Figure 3 shows some examples of these problems. This diamond crossing would require complete replacement after just over one year of operation or after 395 to 425 MGT total diamond traffic or 270 to 300 MGT on the track operating higher tonnage.

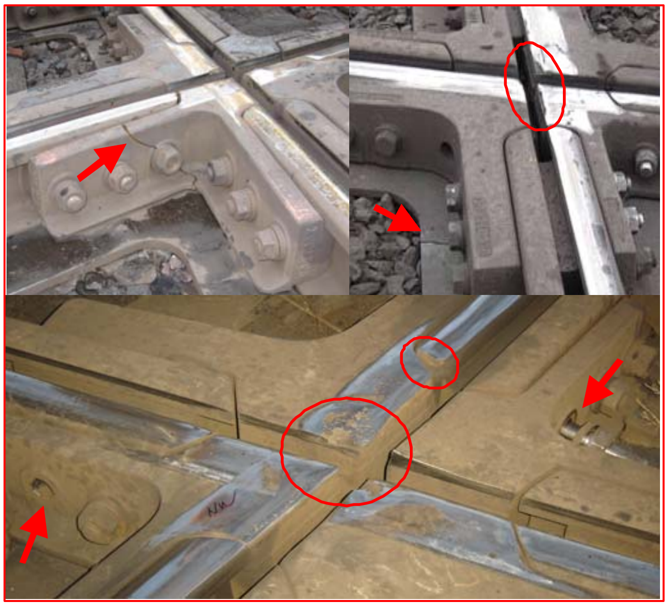

Figure 3. Broken/Missing Components (arrows) and Running Surface Degradation (circles)

The main root causes of problems found during the investigation at this crossing are as follows:

1. High impact wheel forces due to running surface discontinuities and degradation: High impact forces are inevitable because of flangeway gaps and rail to casting joints that exist with this type of crossing. Running surface degradation further increases the magnitude of impact forces. Obviously, higher operating speeds would lead to higher impact forces. According to a previous study, even at 25 mph, impact wheel forces can be 2 times as high as the static wheel load when the crossing is new

and 7 times as high as the static wheel load when the crossing is in a worn condition.[2]

2. Adverse component contact (bearing) conditions leading to high contact stresses between the metal castings and plates: As Figures 1 and 2 show, castings are supported directly on plates, inevitably leading to high impact stresses between them, especially for nonuniform contact conditions. These high stresses can lead to casting or plate cracking, as Figure 3 shows.
3. Inadequate resilience and damping to attenuate high impact forces (e.g., zero resilience and zero damping between casting and plate).
4. Nonuniform deformation due to the abrupt change in track stiffness caused by the large castings and multiple plates required to withstand these high dynamic loads. This also contributes to bolt cracking as a result of high bending and shear stresses generated on the bolts.

The longitudinal forces and track foundation under the ballast layer are not considered root causes of problems at this location because expansion joints have been installed on track 2, which should prevent longitudinal forces from pushing/pulling the diamond crossing causing alignment problems. Further, a hot mixed asphalt underlayment has been installed, creating an adequate foundation under the ballast layer. In addition, observations have shown that there is adequate track drainage at this location.

IMPROVEMENTS AND RESULTS

To address the root causes of problems at the diamond crossing, potential improvements or remedies need to accomplish the following:

Reduce Wheel Impact Forces

To eliminate impact forces associated with this type of diamond crossing permanently, a bridge is needed to replace the at-grade crossing, but will require a large capital investment. However, an alternative remedy may be the use of a flange bearing frog crossing,[1] once this new technology has fully matured.

Other methods of improvement include the use of ramped corners and provision of additional resilience and damping to reduce or attenuate impact forces. Ramped corners have been implemented for the diamonds shown in Figures 1 and 2, but have not led to performance improvements significant enough to prevent frequent maintenance requirements (note that ramps are more effective for speeds higher than 25 mph, e.g., 40 mph). Figure 4 shows the running surface profiles (measured using a digital caliper and a straight edge) for a corner of this diamond when it was new and after eight months of traffic (170 MGT on the UP track). As shown, the new profile had the ramped-up surface towards the gap, but eight months of traffic led to significant profile degradation (0.2-inch dipping or 0.4-inch running surface height loss from its original position).

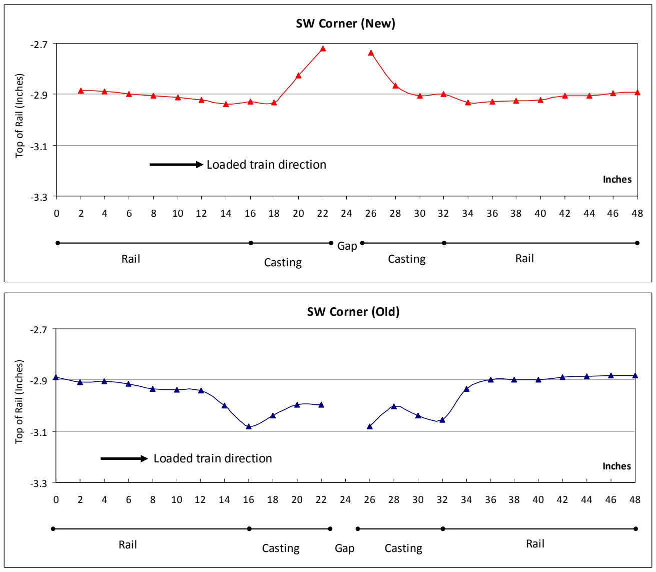

Figure 4. Ramped-up and Degraded Running Surface

Provide Resilience and Damping

When properly designed and installed, rubber pads can reduce track stiffness and increase track damping. Therefore, TTCI suggested that the addition of a rubber pad between each casting and tie plate may help improve the performance of the diamond. In addition to improved track stiffness and damping properties, rubber pads can provide additional benefit in reducing high contact stresses through more uniform contact conditions (bearing) between the casting and plate, which should help address casting and plate cracking problems.

However, because this has never been done before and the pad material may not be capable of surviving the forces at this interface, UP and TTCI decided to test this method first at FAST. (A future TD will summarize performance results of a similar diamond crossing installed at FAST that is fitted with rubber pads between the casting and tie plates.)

As a compromise, UP and TTCI decided to install pads (0.5 inch, 90 durometer) between tie plates and timber ties at this revenue service site. When the crossing was replaced in 2007 and 2008, pads were included under the plates directly below the castings, as well as under the tie plates for the crossing diamond panel.

Subsequent monitoring has shown that the pads have no issue in terms of surviving the load environment. No degradation was observed after 13 months of traffic (275 MGT on the UP track) when the diamond was replaced in September 2008. However, the effect of the pads on track performance was determined to be short term, if any, because the diamond installed in August 2007 only survived for 13 months, although for the first 6 months, the maintenance requirements were lower. After the first six months, problems discussed previously came back and got worse with more traffic accumulation.

When the diamond was replaced in August 2007, another change made was to place longitudinal ties in the UP track, rather than in the BNSF track (see the comparison between Figures 1 and 2), because of higher tonnage for the UP track. The BNSF track is supported on discrete cross ties.

As mentioned earlier, performance improvements to date have not been significant enough for the diamond crossing installed in either 2007 or 2008. Trains are still slow ordered to 25 mph. Figure 5 shows vibration results obtained in October 2007, two months after the crossing replacement in August 2007. Note that for this vibration test, the sample rate was 4,096 samples per second with a low pass filter of 360 Hz.

In Figure 5, the graph on the top shows the results from a spot on open track about 60 feet from the diamond crossing. Acceleration results were measured from the rails to ties (see Figure 6). The graph on the bottom of Figure 5 shows the results at the diamond crossing, again from the rail to tie (see Figure 6). As illustrated, under slow ordered train operation (25 mph), vibration at the diamond crossing was at least three times as high as that measured on the open track.

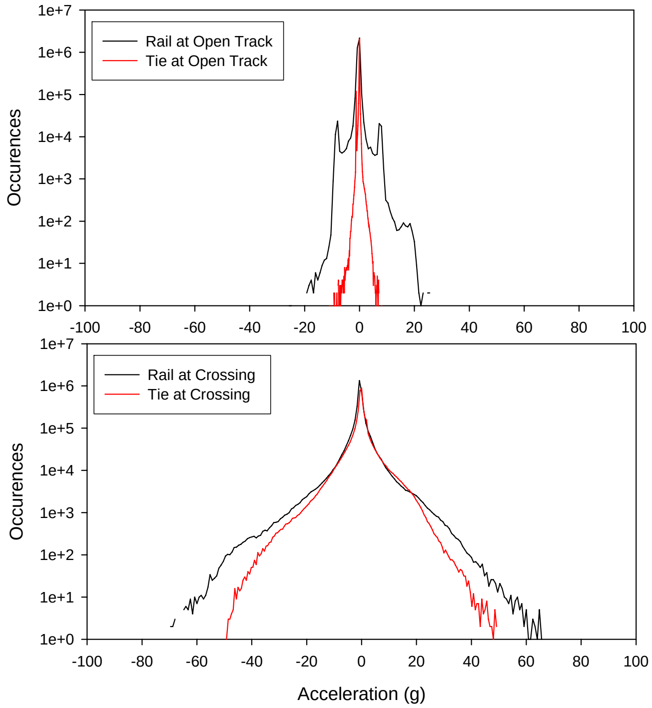

Figure 5. Vibration Results between Diamond Crossing and Adjacent Open Track under 25 mph Coal Train

CONCLUSIONS

The diamond crossing installed near Northport, Nebraska, is not capable of withstanding 365 MGT/year total traffic under normal train operation. Even under slow ordered trains (25 mph), components of the crossing are subjected to tremendous impact forces because of flangeway gaps and rail to casting joints that exist on the running surfaces of the crossing. As running surfaces degrade, impact forces further increase. After only two months of traffic after the installation, the vibration measured on the diamond crossing was at least three times as high as that measured on an adjacent open track.

The following methods have been implemented to improve track performance, including expansion joints, ramped-up running surfaces, pads under tie plates, and placing longitudinal ties in the higher tonnage track. However, they have not led to improvements great enough to satisfy the railroad operating requirements. This is because none of these methods has completely addressed the flangeway gaps and joints that exist with the current design, which is the primary reason for high impact forces. To eliminate the problems completely, a bridge crossing may be necessary. An alternative may be implementation of the new flange bearing crossing technology.[1] To a lesser degree, use of rubber pads between castings and tie plates, which is under testing at FAST, may provide some relief and attenuation of impact wheel forces.

Figure 6. Acceleration Measurements

ACNOWLEDGEMENTS

UP employees Bill GeMeiner and Dwight Clark contributed significantly to the investigation presented in this TD.

REFERENCES

1. Davis, David et al. June 2007. “Revenue Service Implementation of a Flange Bearing Crossing Diamond at Shelby, Ohio.” TD-07-016, AAR/TTCI, Pueblo, CO.
2. Sasaoka, Charity and David Davis. September 2005. “Crossing Diamond Dynamic Performance Study.” TD-05-020, AAR/TTCI, Pueblo, CO.