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Effects of Elastic Rail-Seat Pads on Crossing Diamond Performance

Xinggao Shu, David Davis, and Rafael Jimenez

Summary

As part of the Associations of American Railroads' Strategic Research Initiatives Program to evaluate solutions for the foundation and frog material degradation problems associated with special trackwork, Transportation Technology Center, Inc. conducted experiments using a crossing diamond on the High Tonnage Loop at the Facility for Accelerated Service Testing, Pueblo, Colorado. Initial results indicate that the use of rail-seat pads to optimize track damping is effective at reducing maximum dynamic loads under heavy axle load traffic.

The following conclusions can be drawn from the test results:

- At 30 mph running speeds, two types of rail-seat rubber pads reduce the vertical dynamic loads on the four corners of the crossing diamond by 9.6 percent compared to the baseline. The softer of the two pads reduced maximum forces for up to 23 percent.
  - The impact reduction increases with the wheel static load. The heavier the wheel load, the more benefit can be obtained by using a rail-seat pad
  - Softer rubber pads (Rubber Pad B) reduce more impacts than harder rubber pads (Rubber Pad A)
  - The impact reduction increases with the running speed over the range tested (10 to 30 mph)
- To be effective, the rail-seats must be in contact with both the plate and the frog. Any gap between the rail base and pad diminishes the pad's capability to reduce impact forces.
  - The effectiveness of the rail-seat is greatest with full contact and diminishes to near zero at gaps of 1/4 inch or more.

Durability testing of the rail-seats is ongoing.

INTRODUCTION AND BACKGROUND

As part of the Association of American Railroads' (AAR) Strategic Research Initiatives (SRI) Program to evaluate solutions for the foundation and frog material degradation problems associated with special trackwork, TTCI conducted experiments using a crossing diamond on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST).

Previous theoretical analysis suggested that maximum vertical loads could be reduced by up to 10 percent by optimizing damping in the track structure.[1] The AAR-sponsored SRI for special trackwork has developed several methods for reducing dynamic loads in switches, frogs, and diamond crossings. The most effective method is to eliminate running surface discontinuities, such as unsupported flangeway gaps. Flange bearing frogs are an example of this approach.[2] The next most effective method is to optimize running surface profiles for dynamic performance. Longitudinally ramped running surface profile frogs are an example.[3] Optimizing track properties for dynamic performance is the next most effective method. This method, using a rail-seat to modify the damping properties of the track, was evaluated for a high-angle diamond in heavy axle load service. This third method is appealing in that it is relatively low cost and can be retrofit to existing frogs.

A high-angle (86^0 41' 00") crossing diamond was donated by the BNSF for testing at FAST. The diamond was removed from revenue service as a panel. The panelized diamond was installed at FAST as it was removed from revenue service with all its original components, including crossties and insulated joints.

HTL Section 40, a section of tangent track on the bypass, was selected as the location for installing the diamond. This section of track was selected in order to reuse the existing design foundation that had been used in earlier studies. The diamond, therefore, was installed on a foundation consisting of an 8-inch layer of hot mix asphalt topped with a ballast mat and 13-inches of existing ballast. The initial installation was completed on September 7, 2007.

The diamond was monitored for settlement and required maintenance in its as-received condition during 31.46 MGT until September 5, 2008, when the diamond was rebuilt. The rebuilding of the diamond involved:

- 1 1/4-inch-thick milled seat plate
- New cross tie

The recess milled on the plate work is to provide:

- space for installing elastic or rigid pads between rail base and the plate work
- restraint on diamond longitudinal and lateral movements instead of using welded stops

Before the crossing diamond was rebuilt, the failures modes were broken plate fasteners and welded stops; after the installation of milled seat plates on September 2008, the failures modes were broken angle bars and leg rails.

Instrumented wheelset (IWS) measurements for the crossing diamond baseline without rubber pads were conducted on April 29 2009. Two types of rubber pads were installed under the crossing diamond on May 1 2009. Instrumented wheelset measurements for rubber pad cases were conducted immediately after the pads installation. Results are presented here.

Test Equipment and Instrumentation

Wheel rail forces were measured using two load measuring wheelsets. The two 38-inch load measuring wheelsets (IWS 35 and IWS 36) were installed on the B-end of an aluminum coal gondola at FAST. Each axle load is about 80,000 pounds. Measurement runs were made in both clockwise and counterclockwise directions. The consist was turned at each switch so that IWS 35 was always in the leading axle position. The sampling frequency of the IWS measurement system is 1000 Hz, filter frequency is 100 Hz.

Figure 1 shows the tested crossing diamond at FAST and the layouts of IWS and the two rubber pads under the crossing diamond. Basic characteristics of these two pads are as follows:

- Pad A: natural rubber, hardness 70 A, thickness about 0.31 inch as measured, manufactured in 2006, installed under Frogs 1 and 2
- Pad B: damping enhanced natural rubber, hardness 50A, thickness about 0.24 inch as measured, manufactured in 2008, installed under Frogs 3 & 4. Pad B is softer than Pad A

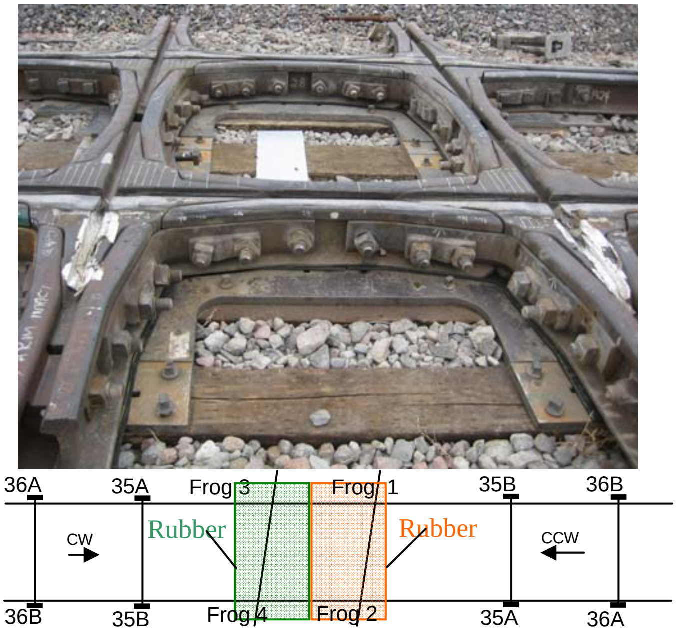

Figure 1. FAST Crossing Diamond and Layouts of IWS and Rail-seats

Test Results

Figures 2 to 5 show the IWS dynamic vertical loads on the diamond at speeds from 10 mph to 40 mph. Two IWS amplifiers broke due to severe impacts during the last run (about 40 mph) for baseline test cases. To protect the amplifier, the maximum running speed for the rubber pad test cases was limited to about 30 mph.

Figures 2, 3, and 4 show that the impact force on Frogs 2, 4 and 1 linearly increased with speed at speeds lower than 35 mph, but became saturated when speed was above 35 mph. However, the impact force on Frog 3 linearly increased with speed at speeds up to 40 mph, as Figure 6 shows. The reason for this phenomenon is still under investigation. It may be related to the capacity of the instrumentation.

In general, the impact reduction increases with the running speed at speeds lower than 35 mph (no higher speed data is available for rubber pad cases). The faster the vehicle runs the more reduction in impact force the rail-seats can provide. This is seen in comparing the base case and rubber pads runs for each frog. See Figure 5 or Figure 6, for example.

Table 1 lists the four frog impact force reduction percentages at 30 mph speed.

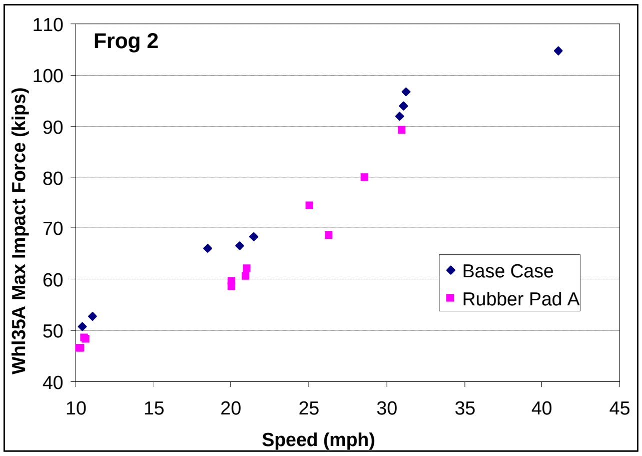

Figure 2. Frog 2: IWS Vertical Dynamic Load (Impact Force)

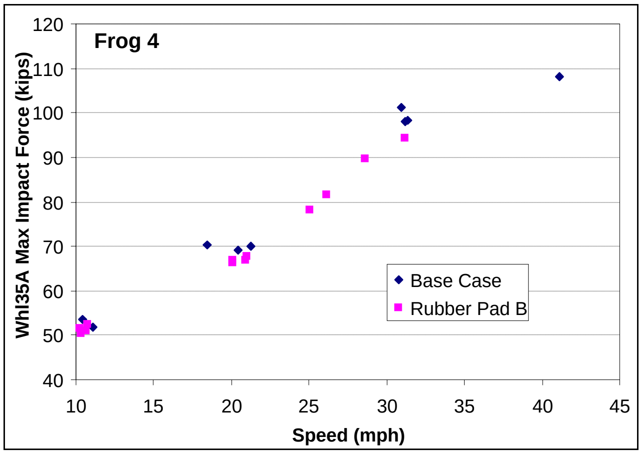

Figure 3. Frog 4: IWS Vertical Dynamic Load (Impact Force)

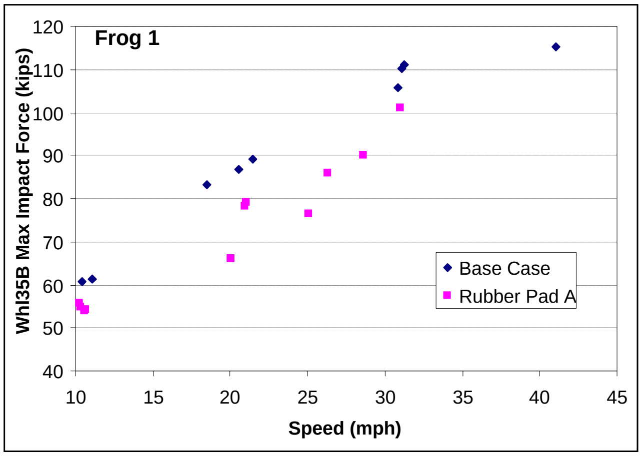

Figure 4. Frog 1: IWS Vertical Dynamic Load (Impact Force)

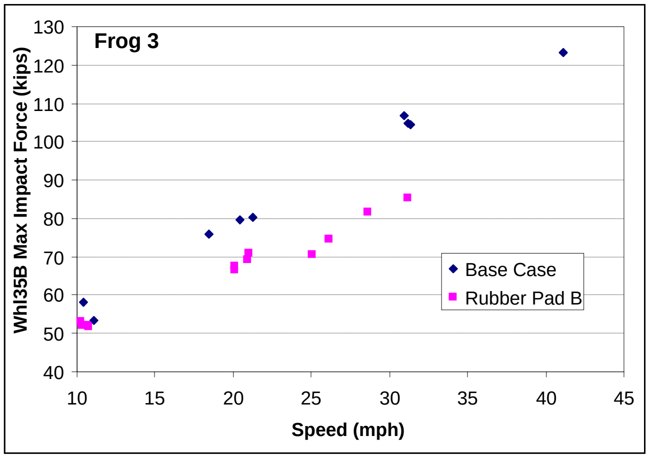

Figure 5. Frog 3: IWS Vertical Dynamic Load (Impact Force)

Table 1. Vertical Dynamic Load Reduction Percentages (30 mph)

IWS No.	Frog 1 (Pad A)	Frog 2 (Pad A)	Frog 3 (Pad B)	Frog 4 (Pad B)	Avg.	Wheel Load* (kips)
35A	6.30	11.19	13.60	6.72	9.45	37.42
36A	7.10	5.79	6.20	-0.47	4.66	36.08
35B	13.71	12.10	19.75	2.40	11.99	43.99
36B	10.53	10.90	23.33	3.80	12.14	43.18
Avg.	9.41	9.99	15.72	3.11	9.56	40.17

*Quasi static load, measured at 9 mph on tangent track

A relationship (formula) between the impact force and running speed was obtained through linear regression of IWS measured data at speed lower than 35 mph, as Figure 6 shows.

The impact forces at 30 mph were then calculated by using the linear fitted formula, and the impact force reduction percentage was calculated by taking the difference in dynamic vertical load between the base case and rubber pad cases divided by the base case dynamic vertical load.

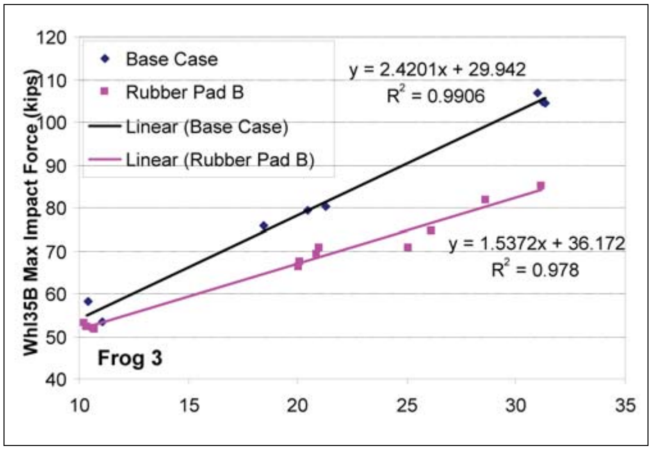

Figure 6. Regression Analysis Results

In general, at 30 mph running speed, the two types of rail-seat rubber pads reduce the vertical dynamic loads on the four corners of the crossing diamond by 9.56 percent compared to the baseline; Rubber Pad B on Frog 3 reduces the vertical dynamic load by maximum 23.33 percent, as Table 1 shows.

However, the impact reduction on Frog 4 was the lowest one for the four frogs for all four wheel load cases. The vertical dynamic load with rubber pads even increased for IWS 36A, because there was about a ¼-inch gap between the rail base and rubber pad after installation. The rubber pad was installed between the crossing rail base and plate work by jacking up the diamond panel. When the diamond panel was lowered back to the plate work, it did not fit into the recess of the plate work due to structural deformation. After the material was ground off from the edge of the recess in the plate work, the rail corners of Frogs 1 and 3 sat on top of the rubber pad, but there was still about a 1/4-inch gap between the rail base and rubber pad on the corner of Frog 4, and about a 1/8-inch gap on the corner of Frog 2. The impact reduction percentage in Table 1 shows that the restoring quality of the crossing diamond retrofitted with rubber pads has a significant effect on the impact reduction. Any gap between the rail base and pad degrades the pad's ability to reduce impact forces and even increases the impact if the gap exceeds 1/4 inch.

Table 1 also shows that the impact reduction increases with the wheel static load. The heavier the wheel load, the more benefit can be obtained by using rail-seats.

As expected, softer rubber pads (Rubber Pad B) reduced impacts more than harder rubber pads (Rubber Pad A).

Future Work

Additional testing of rail-seat bearing pads will be conducted to determine the optimal dynamic properties required. In addition, the expected service life of each component will be estimated.

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