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Evaluation of One-Way Low-Speed Flange Bearing Crossing Diamonds at Higher Speeds

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Summary

Transportation Technology Center, Inc. (TTCI), in conjunction with a North American Class 1 railroad, performed instrumented wheelset (IWS) tests across a simulated One-Way Low-Speed (OWLS) crossing diamond at speeds greater than 10 mph. Results indicate that the use of OWLS at speeds higher than 10 mph will exceed the industry's stated goal of limiting dynamic loading to 1.5 times static wheel load at crossing diamonds.

The tests were performed at the Facility for Accelerated Service Testing (FAST) using a specialized track panel designed to test flange bearing crossing diamond materials. OWLS diamonds are typically used where a heavy axle load (HAL), high tonnage rail line crosses a lower tonnage HAL line. The flange bearing movement has been limited to 10 mph by the Federal Railroad Administration's Track Safety Standards. Results of the tests show:

- Higher vertical wheel-rail forces occur for both new and worn OWLS diamonds as compared to full flange bearing diamonds.
- "Worn" OWLS diamonds are predicted to experience vertical dynamic wheel loads in the range of 2 to 2.5 times static wheel loads (i.e., 72 to 90 kips for 286,000-pound cars) at speeds of 30 mph.

The data compiled during the IWS runs was evaluated against several different dynamic load factor cases. These cases included open track; a reversible casting, 89-degree standard diamond; and the specialized, fully flange bearing track panel. The results of this comparison indicate:

- The new OWLS performed better than the 89-degree reversible diamond as speed increased, but still exceeded the recommended dynamic load factor value of 1.5.
- The worn OWLS performed slightly worse than the 89-degree reversible diamond at 10 mph with improved performance as speed increased, but still exceeded the recommended 1.5 dynamic load factor.
- Both OWLS simulated performed worse than the fully flange bearing panel.
- Both OWLS simulated performed worse than the open track condition.

The dynamic loading measured is a function of the train speed, vehicle elevation change, and the length of the unsupported flangeway gap (i.e., effective gap) that is crossed. The only design likely to meet this performance target for speeds above 10 mph is a full flange bearing frog (FBF) crossing diamond. However, a higher speed OWLS FBF crossing diamond may still offer some economic benefits over a tread bearing diamond for locations where a low volume track crosses a mainline by reducing dynamic loading for the mainline traffic.

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INTRODUCTION

Transportation Technology Center, Inc. (TTCI) has investigated the vertical loading on a One-Way Low-Speed (OWLS) crossing diamond as speed increases above 10 mph. Current designs typically have been limited to 10 mph on the low speed route, which poses operational issues depending on traffic and location of the crossing diamond. For a location where traffic has substantially increased after installation of an OWLS, there are disadvantages from an operational standpoint by limiting crossing traffic to 10 mph. Operation at over 10 mph increases the velocity of the crossing route; however, it poses operational concerns that were addressed by this testing. The tests were conducted on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST) using instrumented wheelsets (IWS) on the B end of an open top aluminum hopper in a four-car consist. Also included in the test train were an instrumentation car used to collect real-time data as the runs were made, and a braking car behind the IWS car. Figure 1 illustrates the layout of the test consist.

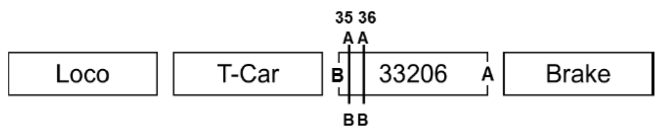

Figure 1. Layout of Test Consist used for OWLS IWS Runs at FAST Test Setup

Figure 2 Simulated "New" OWLS Flangeway Gap Ground into Existing Coupon

A specialized track panel installed on the HTL designed to test flange bearing crossing diamond materials served as the test location. The panel consists of ramp inserts and flange bearing test coupons. The purpose of the flange bearing panel is to test material properties of various flange bearing crossing materials. Since the panel is technically not a crossing diamond, but rather allows material testing of crossing diamond materials, it required modification prior to the testing conducted as part of this experiment. The simulated flangeway gaps were installed at the center of the test coupons, which is approximately where the flangeway gap on a revenue service OWLS would be located. The existing ramp inserts and test coupons had been installed previously, and had accumulated some tonnage during normal FAST operations. Figure 2 shows the simulated flangeway gap in the existing test coupon prior to the start of IWS runs. To simulate OWLS condition in both a new and worn condition, flangeway gaps were ground into the existing fully flange bearing track test panel located in Section 40 of the HTL. Once testing on the new condition was completed, the simulated flangeway gap was enlarged via additional grinding to simulate an OWLS in a worn condition. The same set of IWS runs was performed across the simulated worn OWLS crossing. Figure 3 shows the test panel location and layout as installed.

Figure 3. Flange Bearing Test Panel at FAST

Once the simulated crossing flangeway gaps were installed on both rails, the IWS consist was run across the test location at speeds ranging from 10 mph to 30 mph in 5-mph increments. Upon completion of IWS runs on the "new" OWLS condition, the same set of IWS runs was then repeated at the same speeds with the same consist on the simulated "worn" condition. There is an inherent advantage for tread bearing frogs over OWLS flange bearing frogs for high angle frogs (i.e., ~60 to 90 degrees). The width of the wheel tread helps shorten the effective gap of the flangeway for angles less than 90 degrees. This also spreads potential impact locations over a wider area than the flange tip.

The IWS consists of two instrumented wheelsets in a truck of a freight car capable of recording vertical and lateral forces and accelerations experienced by the car as it runs around the HTL.

RESULTS OF IWS RUNS AT FAST

Data collected from the IWS was compiled for each of the speed runs and flangeway conditions. This data was compared against IWS data across the flange bearing test panel before any modifications were made. This allowed a baseline case for a fully flange bearing crossing diamond to also be simulated as part of the test.

The IWS runs performed on the test track panel prior to modification were not run at all the same speeds. These runs were conducted as part of regularly scheduled IWS runs at FAST performed at speeds of 20, 30, and 40 mph, respectively. An additional run at 10 mph was conducted to provide the full range of speeds for the fully flange bearing case. This is evident in the data plots as there are no data points for the fully flange bearing cases at speeds of 15 and 25 mph. Runs performed on the simulated OWLS flangeway gaps were of special interest; and as such, a wider range of speeds was selected to ensure sufficient data on the vertical wheel/rail forces. For each of the speed intervals, two runs were made. Thus, for each speed shown in the plot contained in Figure 4, there are multiple data points at the same speed.

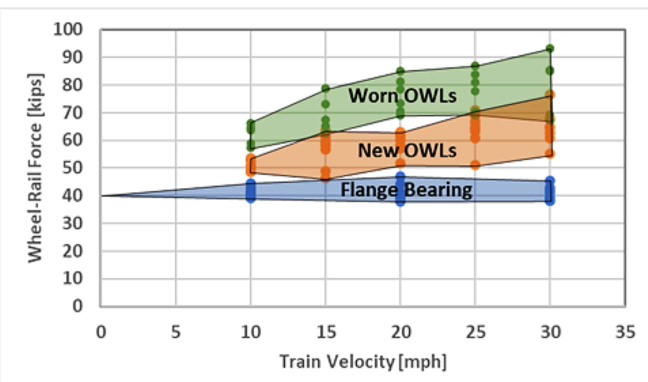

Figure 4 Vertical Impact Forces by Test Section

The IWS data collected shows that for both the new and worn OWLS conditions, vertical wheel rail forces measured are higher in all cases when compared with a fully flange bearing crossing diamond. Likewise, a "worn" OWLS performs worse than a "new" OWLS; except at the higher end of speeds tested where there was some overlap between the two test cases. The vertical wheel load limit for IWS runs at FAST is 90 kips. As the plot indicates, this limit was achieved at 30 mph. No runs were made at a speed greater than 30 mph to prevent damage to the IWS equipment.

CROSSING DIAMOND INFLUENCES ON ROLLING STOCK COMPONENTS

Research on improved ride quality created by flange bearing frogs was studied as part of the Association of American Railroads' (AAR) Strategic Research Initiative (SRI) on special trackwork. During experiments at FAST, the dynamic load factor was calculated for various track conditions including high angle conventional crossing diamonds, fully flange bearing crossing diamonds, and tangent open track.[1]

As part of the IWS data analysis, a dynamic load factor for each of the speed runs conducted on both simulated OWLS conditions was calculated. The dynamic load factor is calculated via the following formula:

$$Dynamic\ Load\ Factor\ = \frac{Dynamic\ Vertical\ Wheel\ Load}{Static\ Vertical\ Wheel\ Load}$$

This data was then combined with pre-existing data from previous experiments conducted under the SRI Special Trackwork (9A) program. Based on previous research conducted by the AAR, an acceptable dynamic load factor is any value below 150 percent of the static wheel loading. Keeping dynamic loads under this threshold has been shown to improve the longevity of both car components and special trackwork components — in this case, the crossing diamond castings, bolts, and rail.[2] Figure 5 provides an updated plot containing calculated dynamic load factors for the simulated OWLS.

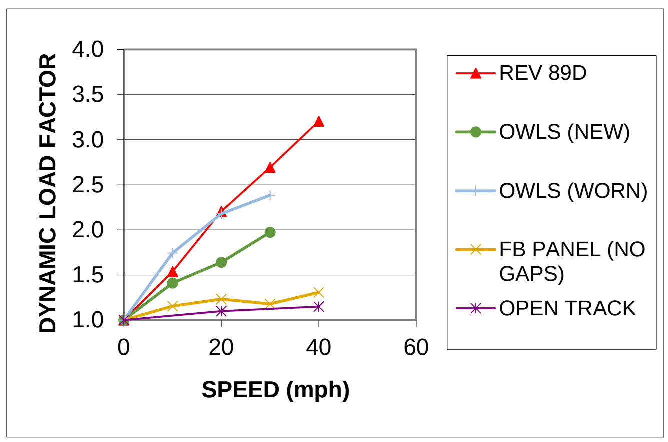

Figure 5. Dynamic Load Factors by Type of Crossing Diamond

In both test scenarios, the OWLS conditions resulted in dynamic load factors that exceeded the recommended value of 1.5 as speed increased. The worn OWLS exceeded this limit at 10 mph. Yet, they still generally perform better than a conventional high angle, reversible casting crossing diamond also previously tested at FAST. A worn OWLS shows performance that is comparable to a reversible casting tread bearing crossing diamond. The fully flange bearing case performs the most similar to an open track condition.

CONCLUSIONS

The results of the IWS testing at FAST indicate that the performance of OWLS crossing diamonds as speed increases results in increased dynamic loads. These increased dynamic loads rapidly exceed the recommended 1.5× static wheel load limit. A brand new OWLS diamond rapidly exceeds this recommended value with speed increase to 20 mph across the diamond. The effects of dynamic vertical loads above this limit are potentially detrimental to both the crossing diamond components and carbody components for any traffic that travels across the location. Neither a new nor worn OWLS minimizes the dynamic load factor as effectively as a fully flange bearing crossing diamond (Figure 6). For areas where speed is an operational concern, using a fully flange bearing crossing diamond provides the best benefit. This benefit, however, comes at an increased cost as fully flange bearing diamonds are generally more expensive than an OWLS crossing diamond. However, depending on annual tonnage, it may not be justifiable to install a fully flange bearing diamond on a crossing subdivision that does not see an appreciable annual tonnage.

Figure 6. Fully Flange Bearing Crossing Diamond in Revenue Service

FUTURE WORK

Optimizing system performance in terms of safety and economic return is the goal of the AAR's SRI Program. While use of an OWLS may greatly reduce dynamic loading for one track, it may limit allowable track speeds for the other track. In addition, the effects of dynamic loading on wheel flange failures should be studied. Currently, there is little documented experience with loading of wheel flanges above the 1.5× dynamic loading factor. There has been a desire in segments of the rail industry to use OWLS crossing diamonds at speeds greater than 10 mph as opposed to installing a fully flange bearing diamond because of potential cost savings in using an OWLS instead of a fully flange bearing setup.

In conjunction with other research efforts under the SRI 9A initiative, such as work on decreasing impact loading using under-tie pads, or by testing material properties for flange bearing material inserts, the possibility of decreasing the dynamic load factor for both new and worn OWLS crossing diamonds exists. If an OWLS could be modified or retrofitted to perform better than the 1.5× threshold, it would have a tremendous upside for railroads that need a crossing diamond that can operate at higher speeds than currently seen. This could save the expense of installing a fully flange bearing crossing diamond when traffic may not merit such an installation.

References

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2. Davis, David, Guillen, D., LoPresti, J., Robeda, J., and Singh, S. February 2002. "Results from Special Trackwork Experiment at FAST." Research Report R-954. AAR/TTCI. Pueblo, Colorado.