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Proof Tests of Crossing Diamond Surface Ramps in Heavy-Axle-Load Service

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Summary

Transportation Technology Center, Inc. (TTCI) has developed a running-surface ramp that reduces impact loads to crossing diamonds for heavy-axle-load (HAL) freight service between 40 and 80 mph. The 6-inch-long upward ramps, shaped to the running surface, are located at the flangeway-gap corners of the crossing diamonds. Field tests to verify the NUCARS-predicted reduction of impact loads due to ramping and to monitor the wear and deformation have yielded the following major observations:

- Actual wheel-impact factors and impact-factor reductions were very close to those predicted by NUCARS modeling. Impact factors (i.e., maximum dynamic load / static load) were used to compare test results with a 39-kip wheel-load hopper car to model results with a 33 kip wheel-load hopper car.
- Maximum reduction in impact load occurred at 50 mph, which was predicted by NUCARS modeling. This reduction was calculated to be about 38 percent, equivalent to the reduction of the test wheel-impact load from 127 kips to 78 kips for the 39-kip wheel load car wheel traversing the flangeway-ramped gap at 50 mph.
- In FAST testing with speeds at or below 40 mph, ramps were found to be less effective in imparting enough upward velocity to the wheels for them to leap over the flangeway gaps. Forty miles per hour is at the low end of the range of speeds for which the ramp design tested should be effective in reducing forces.
- In durability testing, ramped corners deformed similarly to conventional flat corners under 39 kip wheel loads. This suggests an initial shaped ramp that is steeper at the corner allowing initial deformation.

These ramps can easily be incorporated into most cast crossing diamond frogs with minor modifications and could substantially increase the duration between maintenance cycles.

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

Work performed by TTCI Transportation Technology Center, Inc.
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INTRODUCTION AND CONCLUSIONS

Using field tests to verify the reduction of impact loads predicted by NUCARS modeling, TTCI has developed a running-surface ramp for application to crossing diamonds for heavy-axle-load (HAL) freight-railroad service between 40 and 80 mph. These tests, which also monitored the wear and deformation of these ramps, have been completed. The main findings of this research and conclusions are as follows:

- Actual wheel-impact factors and impact-factor reductions were very close to those predicted by NUCARS modeling. Impact factors (i.e., maximum dynamic load/static load) were used to compare test results with a 39-kip wheel-load hopper car to model results with a 33 kip wheel-load hopper car.
- Maximum reduction in impact load occurred at 50 mph; which was also predicted by NUCARS modeling. This reduction was calculated to be about 38 percent, equivalent to the reduction of wheel-impact load from 127 kips to 78 kips for the loaded 125-ton car wheel traversing the flangeway-ramped gap at 50 mph.
- At speeds below 40 mph, ramps were found to be less effective in imparting enough upward velocity to allow the wheels to leap over the flangeway gaps.
- The results of durability tests conducted at FAST provide data for developing an "as-built" profile that will deform to the desired 1:64 profile.
- The ramps will also provide additional material for deformation. The interval between weld repairs for build-ups will be increased accordingly.

Overall, the test results show that, in a higher-speed HAL revenue-service environment, the provision of TTCI-designed ramps at flangeway gaps of crossing diamonds will not only reduce the impact loads but will substantially increase the duration between maintenance cycles.

RAMP DESCRIPTION

The 6-inch long upward ramps, formed to the shape of the running surface, are located at the flangeway-gap corners of crossing diamonds. They have a slope of 1-in-64, raising the gap-corner running surface 3/32 inch above the surrounding track's running-surface level.

The ramp concept functions by helping the car wheels over the flangeway gaps. The ramps counteract gravity, keeping the wheels from falling in the gaps by generating upward velocity in the components of traversing cars. It is expected that the reduction in impact loading at landing beyond the flangeway gap corners, due to ramps, will also reduce failures in the running-surface and track structure. With minor modifications, these ramps can easily be incorporated into most cast crossing-diamond frogs.

BACKGROUND

Crossing diamonds suffer mostly from high-impact loads causing damage to the flangeway-gap corners. One of the reasons for high impacts seen on high-angle crossing diamonds is that the vehicle wheels are unsupported while crossing the flangeway gaps. As the wheel rolls across a level running surface and into the gap, it falls and bluntly strikes the gap corner on the opposite side. The resulting impact loads may be as high as two to four times the static wheel load. Consequently, crossing diamonds are a major maintenance problem and operating bottleneck for heavy-haul lines. An estimated $240 million is spent annually on replacement and maintenance of approximately 4,700 crossing diamonds in use on North American railroads. Furthermore, temporary track outages or permanent slow orders due to crossing-diamond replacement and/or maintenance operations result in delay costs estimated to be approximately $421 million annually.

Due to the ill effects of high impact loads, high-angle crossing diamonds have short lives (approximately 100-200 million gross tons [MGT]) under 100-ton or mixed-freight traffic. This relatively short life is dramatically shortened to approximately 5-15 MGT under HAL traffic. Unlike turnouts, the use of premium components in conventional crossing diamond designs for 39-kip wheel loads does not restore their average lives to what they were under 33-kip wheel loading. This data from FAST, under 39-kip wheel loads, suggests that, for unsupported gap diamonds, increases in car capacity beyond 100 tons cannot be economically maintained without improvements in the dynamic performance of the diamonds.

The reduction of maximum dynamic vertical forces is, therefore, the premise to investigate the crossing-diamond running-surface ramps at the flangeway-gap corners. Since the dynamic wheel-load reduction gives the flangeway-gap corner steel a chance to work-harden, mitigates circumstances for contact-stress defects, and retards the rate of development of battered corners, it will prolong the service life under existing operating conditions and will reduce train-delay costs by raising speeds. Additionally, extra material in the ramps at the flangeway gap corners would need to be worn before maintenance is required.

RESULTS AND ANALYSIS

Impact Loading

The primary objective of impact load tests was to assess, by field measurements, the manner and magnitude of reduction of wheel impact forces on the flangeway-gap corners of the simulated 90-degree-angle crossing diamond, with running-surface ramps, at various operating speeds between 30 and 60 mph. About two-thirds of all new crossing diamonds are subjected to track speeds above 40 mph. Speeds used in the tests were therefore adequate, and were within the effective range between 40 and 80 mph for the optimal 1-in-64 ramp slope (TD-98-021).

Since NUCARS predictions were made for loaded 100-ton car wheel loads, while the testing was done using a loaded 125-ton car consist, for uniformity's sake the impact-load data presented in Exhibits 1 and 2 has been normalized with respect to static wheel load of the respective loaded car. Also both the predicted and test results are given in these exhibits for the optimal ramp slope of 1-in-64.

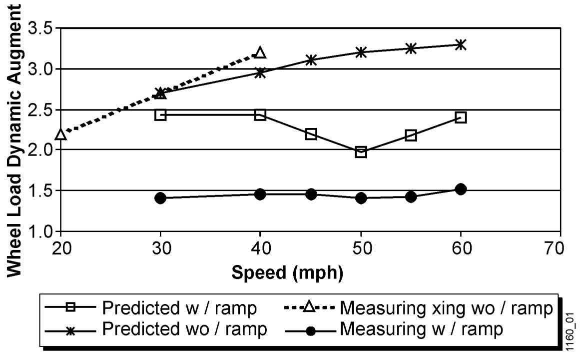

Exhibit 1. Wheel Load Dynamic Magnification Factors as Measured Using Instrumented Wheel Set and from NUCARS Model

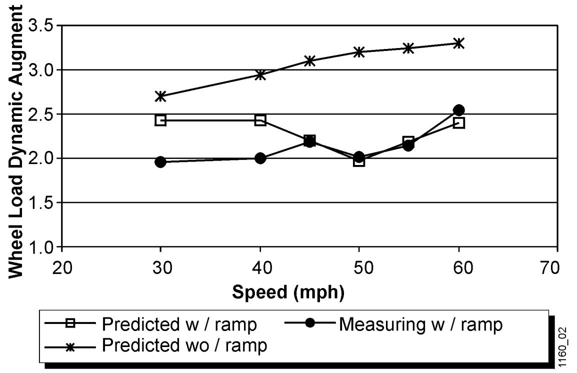

Exhibit 2. Wheel Load Dynamic Magnification Factors as Measured Using Wayside Instrumentation and from NUCARS Model

Impact loads on crossing-diamond flangeway-gap corners are high-frequency phenomena. As such, the data-collection sample rate (Nyquist frequency) of the instrumentation becomes the most important factor in the acquisition process. Strain gages mounted on the test-panel rails were used to measure flangeway-gap impacts at data-collection rate of 10,000 samples per second. Instrumented Wheel Set data (IWS) was also collected to measure wheel loads at 1,000 samples per second. While the IWS measurements are insufficient to capture the peak impact loading, they do capture the loading resulting from wheel rebound; which can be the maximum load with a 1:64 ramped running surface and, thus, is a key parameter to this study. In addition, use of IWS data allows comparisons to be made to measurements of previous diamonds tested at FAST.

The results of the panel tests were very encouraging with both wayside and IWS measurements showing the same trends as the model predictions. The track-measured loads for the ramped gaps agreed well with the predictions; while the vehicle-measured loads were less than the predicted loads. This is most likely due to the inability of the IWS to always capture the peak impact loads. The IWS-measured loads for the conventional flat crossing diamond were higher than predicted. This is likely due to the wear and deformation of the actual running surface; which creates a larger effective gap.

Wear and Deformation

A comparison wear / deformation experiment was conducted with the ramp panel at FAST. An additional pair of flangeway gaps was cut into the panel with (flat) conventional running surfaces. The panel was subjected to 20 MGT of HAL traffic at 40 mph. The wear / deformation test had the following findings:

- For ramps made of premium rail steel, an effective life of 20 to 40 MGT can be expected under HAL traffic based on projections from the FAST test.
- The 1:64 ramps were not completely effective in helping the wheels "jump" the flangeway gaps at 40 mph. The mashed-down flangeway corners are evidence of this. The test-panel ramps were optimized for 50-mph operation.
- Ramped corners were as durable as the conventional flat corners. Neither set had any cracking in 20 MGT of HAL traffic.

The deformation data recorded suggests the use of a two-slope "as-built" profile which will wear to the desired profile in service. The as-built profile will have a steeper slope at the corners to account for the deformation caused by slower traffic.

Exhibit 3 shows the initial and deformed shapes on the test-panel running surfaces at the flat and ramped flangeway gaps. Both sets are deforming in a similar manner, with the ramped corners having more deformation.

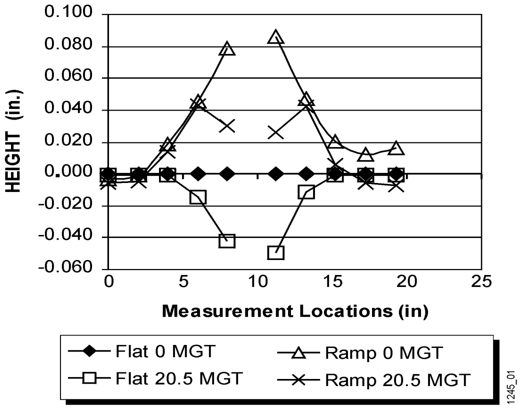

Exhibit 3. Flangeway Gap Ramp Surface on Outside Rail with respect to MGT of HAL Traffic at FAST

REFERENCES

1. Satya P. Singh and David D. Davis, "Reducing Impact Forces on High-Angle Crossing Diamonds," *Technology Digest* 98-021, Transportation Technology Center, Inc., Transportation Test Center, Pueblo, Colorado, 81001, August 1998.

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