TECHNOLOGY DIGEST

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Reducing Impact Forces on High-Angle Crossing Diamonds

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Summary

The Transportation Technology Center, Inc. (TTCI) has developed two new methods of reducing maximum dynamic vertical forces on conventional high-angle crossing diamonds by using computer models to depict behavior of loaded, passing freight cars. These methods are the addition of running-surface ramping near the flangeway gaps, and optimization of support characteristics, especially damping, of track under the diamond. Modeling of high-angle diamonds using NUCARS (version 3.0), the Association of American Railroad's (AAR) vehicle dynamics model with new track features, offers these preliminary findings:

- Ramping of the running surface at flangeway gaps can significantly reduce maximum vertical loading, by as much as 41 percent at 60 mph. Alternatively, ramping could be used to increase operating speeds over crossing diamonds under the same load environment.
- The optimal ramping rate is dependent on the operating speed and suspension characteristics of the type of cars being evaluated.
- For a loaded 100-ton hopper car at speeds of 40 to 80 mph, the optimal ramp has a positive 1-in-64 slope and a 6-inch length.
- Running-surface ramps can easily be added to new crossing diamonds by modifying casting patterns, and to existing crossing diamonds by adding material during weld build-up / repairs.
- The effect of crossing-diamond foundation stiffness on maximum vertical loading is very small (less than 10 percent) over a wide range of stiffness.
- The effect of foundation damping can be quite significant (10 to 40 percent) over the expected range of damping values.
- The optimal damping value is about 300 pounds / inch / second / tie (for 20-inch tie spacing)
- Since the actual damping values of crossing diamonds and open track are not well known, the understanding of how to design and construct diamonds to a particular damping value is poor. It is estimated that diamonds at the Facility for Accelerated Service Testing have damping values of about 1,000 pounds / inch / second / tie.

Field tests to verify modeling findings are scheduled for 1998. If successful, these tests will be used to establish a database of track-damping values. This research project is funded by the AAR.

Suggested Distribution:

o Maintenance of Way
o Planning & Analysis
o Track Maintenance
o Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

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INTRODUCTION AND CONCLUSIONS

The Transportation Technology Center, Inc. (TTCI), with funding from the Association of American Railroads (AAR), has developed two methods of reducing the maximum dynamic vertical forces on crossing diamonds. These methods, developed by modeling the behavior of loaded freight cars over high-angle crossing diamonds, include running-surface ramping near the flangeway gaps, and optimizing the support characteristics, especially damping, of the diamond foundation.

Approximately 4,700 crossing diamonds are in use on North American railroads. An estimated $240 million is spent annually on replacement and maintenance of these diamonds. The life expectancy of conventional crossing diamonds under heavy-axle-load traffic is dramatically shortened compared to 100-ton or mixed-freight operations. Unlike turnouts, the use of premium components in conventional designs does not restore the average life to what it was under 33-kip wheel loading. This data from the Facility for Accelerated Service Testing suggests that, for unsupported-gap diamonds, further increases in car capacity cannot be tolerated without improvements in dynamic performance of the diamonds.

The reduction of dynamic vertical forces on crossing diamonds is therefore the objective. Also it is enticing because it gives the flangeway gap corner steel a chance to work-harden, mitigates circumstances for contact-stress defects, and retards the development of battered corners. The ramp concept functions by helping the car wheels over the flangeway gaps. One of the reasons for high impacts seen on high-angle 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 ramps counteract gravity, keeping the wheels from falling in the gaps. This is achieved by creating ramps with upward running surfaces on both sides of a flangeway gap to generate upward velocity components in the car while traversing the gap.

Furthermore, track acts as a load-distributing structure and also as an energy-dissipating structure. Load distribution is a function of stiffness and flexibility. Energy dissipation is a function of damping. Track stiffness and damping are thus very important factors to be considered in seeking ways for reducing the impact loads in track. The present study also looked into the effects of track stiffness and damping with and without the provision of running-surface-upward ramps in reducing impact loads on crossing diamonds.

The study does not examine surface failures and structural failures. The only thrust of the study was to find methods that would reduce impact loading of the flangeway gap corners, and in turn reduce surface and structural failures. It was found that the effect of increased foundation stiffness under the crossing diamond was not significant. Crossing-diamond (track) damping, on the other hand, was found to significantly influence wheel impact loading of the flangeway gap corners. Lowering the damping from where we think it is today decreases the impact load. Since actual damping values of track work are not well known, the realization of certain reductions in impact loads due to lowered damping cannot be relied upon at the present time. Because ramps decrease impact loads over a wide range of damping, ramps can be used without regard to determining the amount of damping present in the track. Ideally, a combination of surface ramps and optimal damping should be the route to take, but “gap-ramps” alone could reduce wheel impact loads on crossing diamonds, and remove slow orders, cutting down train delays.

RESULTS AND ANALYSIS

Effect of Track Damping

Track damping is an important parameter of foundation characterization, and probably the least studied. What values of track damping should be used in the NUCARS model at the present time are, at best, estimates. A comparison of peak dynamic wheel loads on a crossing diamond (90-degree crossing angle) was made between field test results and the results from NUCARS modeling for various track-damping values. It was found that a track-damping value of 1,000 pounds/inch/second/tie (ties assumed spaced at 20 inches on centers) resulted in the closest match between test and model wheel loads at 40 mph. These dynamic wheel loads from the test and model, respectively, are about 105 and 98 kips. Although it is difficult to estimate the corresponding percentage of critical damping, the value of 1,000 pounds/inch/second/tie appears to be a reasonable magnitude to be used in the NUCARS study of dynamic wheel loads over the crossing diamonds.

A study of the effect of track damping on dynamic wheel loads over crossing diamonds was made. Damping was varied from 100 pounds/inch/second/tie to 2,500 pounds/inch/second/tie. Flexural rigidity, mass and roll mass-moment of inertia of diamond rails was also varied. Results, shown in Exhibit 1, suggest that implementation and maintenance of running-surface ramps will provide performance benefits to all high-angle crossing diamonds. In any case, a reduction in track damping, in general, decreases the impact loading on wheels traversing conventional (no ramp) diamonds. It also appears that about 300 pounds/inch/second/tie gives the largest reduction in wheel loads for such diamonds. Methods to successfully design, build, and maintain crossing diamonds to the optimal damping value should be developed.

Effect of Track Stiffness

Rails, fastenings, ties, ballast, subballast, and subgrade are components that enter into the stiffness of track, and determine the value of track modulus *u*. Since only one value is used for *u*, it means that the track modulus is taken as a lumped parameter. A *u* value of 2,000-2,500 pounds/inch/inch represents good conventional track. The value can rise to 7,000-8,000 pounds/inch/inch for track on concrete ties with direct fixation fasteners. Dynamic moduli may be in the 10,000-20,000 pounds/inch/inch range.

A track modulus of 5,200 pounds/inch/inch was used to represent a good open track with elastic fasteners. With 20-inch tie spacing, it gave discrete track spring stiffness of 104 kips/inch/tie for use in the NUCARS study. To account for the dynamic aspect of simulation and the special tie layout under a crossing diamond, the crossing diamond track modulus was varied from 5,200 to 100,000 pounds/inch/inch for studying the effect of stiffness. The results at 50 mph are given in Exhibit 2. As seen in the exhibit, the reductions in maximum wheel load are insignificant up to a track modulus of 30,000 pounds/inch/inch. Further increase in track modulus increases the dynamic wheel load. Given that low damping may accompany stiffer track, the stiffness option in reducing impact loads on crossing diamonds is not viable because creating and maintaining very high stiffness in the track under diamonds will be very costly.

Running-Surface Ramping at Flangeway Gaps

The effect of upward ramps was investigated for the case where both wheels of an axle jump the flangeway gap at the same time (i.e., 90-degree crossing), and where the wheels jump flangeway gaps independently (i.e., 71-degree crossing). A parametric study of the effect of ramping rate on dynamic wheel loads with respect to speed was conducted. Track damping and modulus values of 1,000 pounds/inch/second/tie and 10,000 pounds/inch/inch (20-inch tie spacing) were used in this study. Results show that comparable reduction in wheel-impact loads occur for both the 90-degree and 71-degree diamonds. Exhibit 3 summarizes all of the results, with and without the provision of ramps, for a 90-degree diamond.

As seen in Exhibit 3, ramps alone can reduce impact loads by as much as 41 percent (from 110,617 pounds to 65,246 pounds for 6-inch-long 1:80 worn-slope ramp) at 60 mph. Actually, substantial reductions in wheel loads are realized for all speeds from 40 mph and above. Also, as seen in Exhibit 1, damping is less important for diamonds with ramps. Implementation of running-surface ramping will provide benefit for any high-angle crossing diamond. Since train delays are a large cost compo-

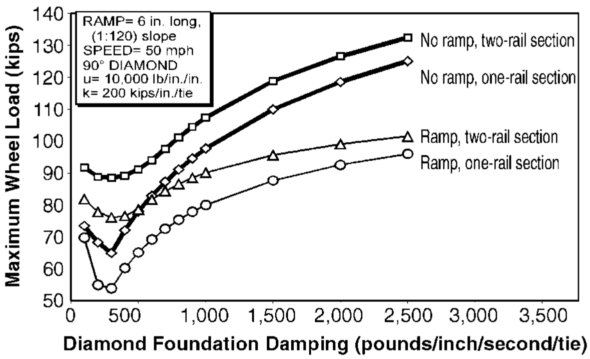

Exhibit 1. Effect of Track Damping and Ramps at Flangeway Gaps, Loaded 100-Ton Hopper Car

Diamond Foundation Stiffness kips/inch/tie	Diamond Track Modulus lb./inch/inch	Maximum Wheel Load (pounds)	Difference Relative to 104 kips/inch Foundation	% Change from 104 kips/inch Foundation
104	5,200	107,552	0	0
200	10,000	107,403	-149	-0.14
300	15,000	107,255	-297	-0.28
400	20,000	107,217	-335	-0.31
500	25,000	107,308	-244	-0.23
600	30,000	107,531	-21	-0.02
800	40,000	108,254	702	0.65
1,000	50,000	109,270	1,718	1.6
2,000	100,000	116,225	8,673	8.1

Exhibit 2. Predicted Maximum Vertical Wheel Force @ 50 mph for 100-Ton Loaded Hopper Car at 90-Degree Crossing Diamond

nent, the provision of ramps alone can provide good economic return in revenue service.

RAMP DESIGN

The running-surface ramping was optimized for typical 33-kip wheel load hopper cars for speeds between 40 and 80 mph. The initial ramp has dimensions of 1:64 slope and 6 inches in length. The initial slope is above the optimal, allowing for some initial wear and deformation. Ramp "death" is defined as a degeneration of slope to 1:300 (ramp height decreasing from 3/32 inch to 1/48 inch) when the reduction in maximum wheel load is below 5 percent at 50 mph. Ramp life (between initial and "death" slopes of 1:64 and 1:300) in terms of million gross tons (MGT) of 100-ton freight car traffic is

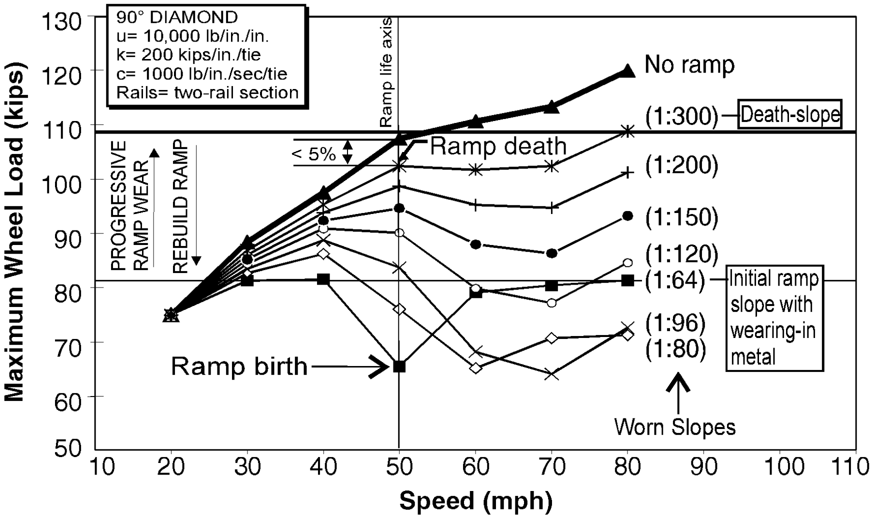

Exhibit 3. Effect of Running-Surface Damping at Flangeway Gaps, 6-Inch-Long Ramps, Loaded 100-Ton Hopper Cars

a matter for field tests.

Rail-surface perturbations of the order of proposed ramp height might exist in the track. To remove the hindrance due to existing rail-surface perturbations from the beneficial effects of running-surface ramping at the flangeway gap, it is necessary to achieve steady-state conditions before wheels start up the ramp. NUCARS modeling suggests that approximately one foot of car travel is needed to achieve this. It is therefore imperative to include about a foot-long approach, level and free of surface perturbations, in the overall design of the ramp. Ramp-rail profile is assumed to be the original rail profile.

The ramps should provide similar benefits to both the AAR-1B and hollow-tread wheel profiles. A conflict however occurs in the placement of ramps at inside corners of the unsupported flangeway gaps in a crossing diamond. Running surfaces at these corners see traffic from both directions requiring ramping in each direction. How this will be achieved is still a matter of further investigation. In any case, the leap-distance over the gaps will be affected, especially for hollow-tread wheels, and will be measured in field tests scheduled at TTC in 1998.

In-service differential wear of ramps, on a flangeway gap's corners, is a concern. Since a slight disparity in ramp wear has only minimal effect on wheel impact loads, it should not be a significant problem.

Ramps can easily be incorporated into new frog castings with a pattern change. In the field, ramps can be built with weld deposits and grinding. Templates can assist welders in achieving the required slope.

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