TECHNOLOGY DIGEST
Timely Technology Transfer

LOAD AND RIDE-QUALITY ASSESSMENT OF CROSSING DIAMONDS

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Summary

Continuing evaluations of flange-bearing frog (FBF) designs by the Association of American Railroads (AAR) indicate that this advanced crossing-diamond concept provides a loaded auto-rack car with a much improved wheel-impact load when compared to a conventional high-angle, unsupported-gap crossing diamond. In this Technology Digest, the fourth on FBFs, two frogs with ramp rates of 1:120 and 1:240 were evaluated for wheel impacts and ride-quality issues, using a loaded auto-rack car at mainline track speeds.

Peak dynamic wheel loads over FBFs measured in full-scale tests under an 89-foot auto-rack car with 20-kip static wheel loads were 22 kips at 20 mph, and 28 kips at 60 mph. The maximum dynamic load usually occurred on the flat portion of the frog. By comparison, the impact forces measured in a previous test on a conventional 89-degree crossing diamond under a loaded hopper were 72 kips at 20 mph and 106 kips at 40 mph.

One of the two frog configurations tested, the 1:240 ramp frog, met the Minimum Ride Quality Performance Requirements for Motor Vehicle Shipments specification (RP-803-96) for maximum vertical accelerations of 0.5 g. The other frog configuration barely exceeded the specification at 60 mph. At speeds ranging from 20 to 80 mph, the maximum vertical acceleration did not exceed 0.32 g for the 1-in-240 slope downramp frog and 0.52 g for the 1-in-120 slope downramp frog. The maximum accelerations occurred on the downramp or beyond the frog itself. RMS accelerations did not exceed 0.25 g on either frog at any speed. Dynamic impact loads did not exceed 1.5 times static wheel load. This is a remarkable improvement over conventional frogs, where car-body accelerations routinely exceed 1 g at 40 mph and dynamic impact loads of two to four times static have been measured.

Suggested Distribution:
- ☐ Train Handling
- ☐ Maintenance of Way
- ☐ Planning and Analysis
- ☐ Track Maintenance

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INTRODUCTION AND CONCLUSIONS

Tests conducted by the Association of American Railroads (AAR) show that the advanced crossing-diamond concept known as the flange-bearing frog (FBF) provides a loaded auto-rack car with a much improved ride compared to conventional high-angle, unsupported-gap crossing diamonds. AAR is evaluating this concept for use in heavy-haul, freight-railway applications.

While FBFs offer a potential for large savings in track-maintenance costs and train-operations delays, the possible negative effects from FBF operations need investigation before these designs are placed in service. The concept evaluation is focusing on the effects of FBFs on vehicle wheel performance. Information from these tests will be used by the AAR's Engineering Research Committee to guide the Crossing Diamond Research Program.

In this Technology Digest, the fourth in the FBF test series, the concept was evaluated for the ride quality that an FBF would provide to higher-speed freight operations. Comparison of FBF ride quality to conventional crossing diamonds and open track were made.

At speeds of 20 to 80 mph, the FBF with the 1-in-240 slope downramp did not cause accelerations above the 0.5 g desired maximum limit to a loaded trilevel auto-rack car equipped with an advanced-design, leaf-spring bolster truck. The 0.5 g goal was imposed by the automobile ride quality specification (RP-803-96). It should be noted that the trilevel auto-rack car with this truck met the ride-quality specification on perturbed track tests conducted at TTC. Comparative data with a different car type shows the conventional diamond produces accelerations of 1 g or more under a loaded coal car at speeds of 40 mph. Maximum impact forces were also greatly reduced with dynamic loads remaining below 1.6 times static loads at speeds up to 80 mph. Conventional high-angle diamonds generate dynamic forces of two to four times static loads at 40 mph.

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 initial cost of a crossing diamond is in excess of $100,000. And, average maintenance costs are $700 per million gross ton (MGT). Crossing diamonds also affect service reliability and line capacity. High-angle crossing diamonds have very short lives (typically 100-200 MGT) relative to conventional track or even mainline turnout frogs. In addition, frequent crossing-diamond maintenance operations require permanent or temporary slow orders causing disruptions to train service. Crossing diamonds frequently cause traffic bottlenecks on high-tonnage lines. These delay costs can easily exceed the actual diamond-maintenance costs.

An estimated additional $421 million annually in train delay due to slow orders and track outages can be attributed to crossing diamonds. These slow orders are often imposed due to the impact loading and related damage caused by the unsupported flangeway gaps in the diamonds.

The life expectancy of conventional crossing diamonds operated under heavy-axle-load traffic is dramatically shortened compared to 100-ton or mixed-freight operations. Testing at AAR's Facility for Accelerated Service Testing has shown that conventional diamonds under 39-kip wheel loads have very short lives (5-15 MGT). Unlike the case of turnouts, the use of premium components in conventional frog designs does not restore the average life to what it was under 33-kip wheel loading. This data suggests that for unsupported-gap diamonds, the limits of technology may have been reached.

IMPACT-LOAD AND RIDE-QUALITY TESTING

Exhibit 1 shows the configuration of the test frog and the test vehicle. Wheel loads were measured on all four wheels of one truck and accelerations were measured at four locations on the car body. The frog was divided into five

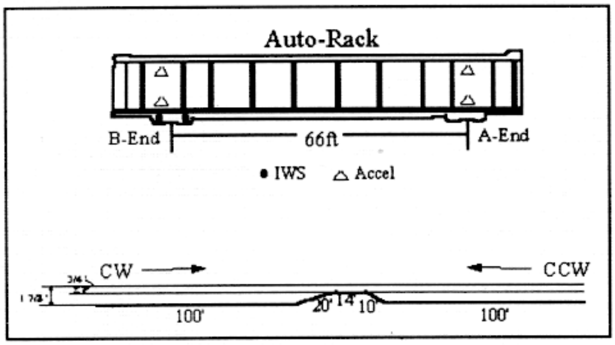

Exhibit 1. FBF Ride-Quality Test Configuration

segments, each denoted by a location marker. Summary statistics for each of the five segments, including maximum, minimum and average (or RMS) values, were calculated.

Exhibit 2 shows how the maximum vertical force is affected by speed and crossing-diamond type. The 89-degree diamond is nearly the widest flangeway-gap that one can encounter. Here, the wheel has to jump a full flangeway width of 1⅞ inches. Dynamic wheel loads of 106 kips under 33-kip static wheel load cars (3.2 times static) are measured at 40 mph over this diamond.[1] The 62-degree diamond represents the angle at which the wheel becomes unsupported over part of the flangeway gap. The wheel has to jump a very small gap of ¼ to ½ inch. Dynamic wheel loads of 79 kips under 33-kip static wheel loads (2.4 times static) are measured at 40 mph over this diamond.[2]

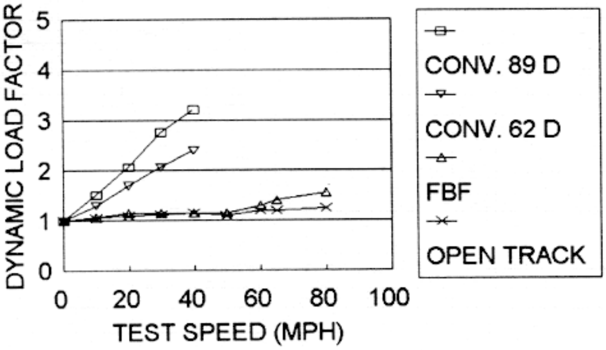

Exhibit 2. Comparison of Dynamic Loading vs. Speed by Crossing-Diamond Type

The FBF with the 1-in-120 ramp produced dynamic forces that were much lower than the conventional diamonds at all comparable test speeds. The FBF does effectively reduce the impact forces in the crossing diamond to levels which approach those found in conventional (open) track. Whereas the conventional diamonds had dynamic-load factors (dynamic load/static load) of 2.5 to 3.3 at 40 mph, the FBF had a dynamic-load factor of 1.35. Conventional track had a factor of 1.15 at 40 mph.

Vertical accelerations were also measured on the auto-rack car at four locations: two on the top deck and two on the bottom deck. The auto-rack car was equipped with an advanced design, leaf-spring bolster truck. This truck provides improved lateral and vertical ride quality compared to a conventional three-piece freight truck. The maximum accelerations always occurred on the upper deck of the car.

The section of track where the maximum acceleration occurred varied with downramp length and speed. With the 1-in-120 upramp, the maximum acceleration occurred on the flat section, the 1-in-240 downramp, or the conventional track beyond the frog. The maximums that occurred on the flat segment were up (positive) accelerations. The maximums that occurred on the downramp and conventional track beyond the frog were down (negative) accelerations. With the 1-in-240 upramp (and corresponding 1-in-120 downramp, the maximum acceleration always occurred on the conventional track beyond the frog.

Exhibit 3 shows the maximum acceleration vs. speed relationship for both FBF configurations and for open track. The configuration of 1-in-240 upramp, 14-foot flat segment and 1-in-120 downramp (1:120 downramp) caused much larger accelerations than the 1-in-120 upramp and 1-in-240 downramp (1:240 downramp) configuration. The first ramp combination caused the 89-foot auto-rack car to experience accelerations of up to 0.52 g at 60 mph. Maximum accelerations were above 0.4 g for this ramp-and-car combination at speeds above 60 mph. The second ramp configuration, with

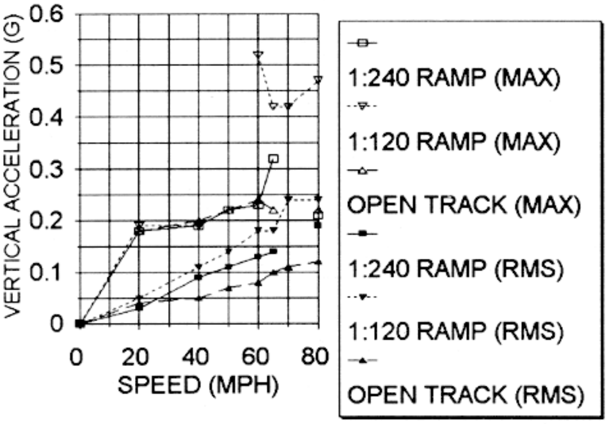

Exhibit 3. Comparison of Vertical Accelerations vs. Speed by Down Ramp Rate

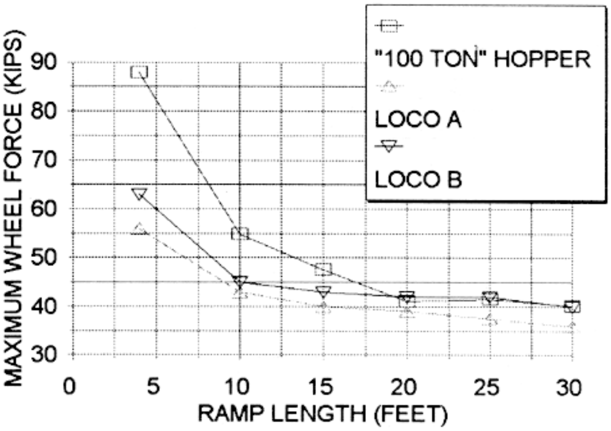

Exhibit 4. NUCARS Study of Ramp Length

its longer, gentler sloped downramp, had much lower maximum accelerations. TTX reported that the critical ride-quality speed for this type of car is in the 60 to 65 mph range. The RMS accelerations do not exceed 0.25 g at any speed.

RAMP DESIGN

Unlike the conventional, unsupported flangeway-gap diamonds, FBFs can be designed to attain desired dynamic performance. By changing the slope and shape of the ramps that transition the wheels from tread to flange bearing, one is able to affect the maximum loading and accelerations produced by a given vehicle.

NUCARS analysis of forces produced by locomotives and loaded hopper cars suggests that ramps no steeper than 1-in-120 slope (i.e. ramps that are at least 10 feet in length) are needed for mainline freight service. Exhibit 4 shows the maximum force vs. ramp length relationship for vehicles traveling at 60 mph. The hopper car, with its simpler suspension, is the critical vehicle in this analysis. Locomotives are better able to cope with the ramps. Obviously, there is a trade-off between the better performance provided, and the additional cost incurred, by a longer ramp. Little benefit is gained for ramps longer than 20 feet.

ACKNOWLEDGMENT

The car and wheel-set performance data for the FBF evaluation was collected and provided to the AAR by TTX. TTX representatives coordinated the company's test program to provide an instrumented 89-foot trilevel auto-rack car, a data-collection test car, and personnel to monitor and collect data based on the AAR test plan. Special thanks are due to Mr. Kerry Hopkins of TTX who collected and supplied data during these test runs.

REFERENCES

1. LoPresti, J., Otter, D., and Davis, D., "Testing an 89-Degree Crossing Rebuilt with Premium Components under Heavy Axle Loads," TD 96-015, June 1996.
2. LoPresti, J., and Otter, D., "Impact Forces Measured over a 62-Degree Crossing," TD 94-018, October 1994.

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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON D.C., 20001