

### THE EFFECTS OF CROSS GROOVES IN FLANGE-BEARING FROGS

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#### Summary

An advanced crossing-diamond concept known as the wheel flange-bearing frog (FBF) caused no damage to wheels in recent evaluations by the Association of American Railroads (AAR). The frog was monitored for potential in-service impact loading on the wheel flange that may occur if the running surface of the frog wears unevenly due to differences in traffic between crossing lines. In some uneven traffic situations, a set of two cross grooves will be created for the lighter traffic line.

Observation of the locomotive and loaded test-car wheels operating over three sets of cross grooves at speeds up to 60 mph showed that no mechanical damage was done to the wheels. There were no visible marks or detectable cracks created.

Wheel loads measured under a 263-kip car operating over the FBF with cross grooves were as high as 80 kips. This occurred at 60 mph speeds over 2-inch-wide and 0.25-inch-deep grooves. This situation is more severe than any likely to be encountered in actual practice. The flange was not conformal to this groove, leaving an unsupported gap in the running surface.

Theoretical analysis of groove impacts on wheel flanges in flange bearing show that forces of 80 kips can be generated at speeds of 40 mph over sharp-cornered, 2-inch wear grooves. Measured forces were around 60 kips at 40 mph. Both force levels are less than the 120 kips at 40 mph measured with wheel-tread impacts at a 2-inch conventional diamond gap.

Deformation rates of grooves under cross traffic were determined for the running-surface material of the test frog. The initial deformation (height loss) rate of the 240 Brinell Hardness (HB) surface was about 1 inch per million gross ton (MGT) for the first 0.2 MGT. Cross traffic quickly rounded the groove corners to a more conformal depression in the running surface.

Three groove dimensions were tested under a range of operating conditions over the FBF. The simulated conditions ranged from an infrequently used branch line crossing a heavily used main line, to a secondary main line crossing a heavily used main line. Both were tested at speeds of 10 and 25 mph. The later also was tested at speeds of 40 and 60 mph.

#### Suggested Distribution:

- Train Handling
- Maintenance of Way
- Planning and Analysis
- Track Maintenance



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## INTRODUCTION AND CONCLUSIONS

The Association of American Railroads (AAR) is evaluating an advanced-concept crossing-diamond, the wheel flange-bearing frog (FBF), for use in heavy-haul, freight-railway applications. Tests thus far have demonstrated no damage to wheels. 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 FBFs 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 Special Track Work and Track Component Task Force to guide the crossing-diamond research program.

In this test, the FBF concept was evaluated for the possibility of impacts on the flange caused by uneven wear of the frog flange-ways. This could occur if the traffic on the two crossing routes is uneven. This is often the case when a branch line crosses a main line. The mainline running surface will deform faster than the branchline running surface. At the intersection of the two surfaces a discontinuity may occur. The branchline traffic may find a cross groove that it must traverse while in the flange-bearing condition. Other situations that may cause impact loading on the flange include spalls and mechanical joints in the running surface.

The tests showed that wheels fully weighted on the flange can cross running-surface discontinuities with no apparent damage. The magnitudes of impacts generated from the grooves will depend on the train speed, and the size of the cross groove. The likelihood of cross grooves developing will be dependent on the running-surface material characteristics, the traffic rates on the two lines and the maintenance policy of the railroad.

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 (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 maintenance costs of the diamond.

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 flange-way gaps in the diamonds.

The life expectancy of conventional crossing diamonds operated under heavy-axle-load (HAL) traffic (286,000-pound or heavier railcars) is dramatically shortened compared to 100-ton or mixed-freight operations. Testing at AAR's Facility for Accelerated Service Testing (FAST) has shown that conventional diamonds have very short lives (5-15 MGT) under HAL traffic. 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. With unsupported-gap diamonds, we may have reached the limits of the technology.

## CROSS-GROOVE TESTING

Exhibit 1 shows the results of the groove impact testing. A loaded hopper car with 33-kip static wheel loads was equipped with two load-measuring wheel sets in the leading truck. Data was collected at 200 and 500 sam-



Exhibit 1. Flange Impact Test Results

Run Number	Speed (mph)	FRA Track Class	Groove Shape	Maximum Vertical Load (kips)		
				0.05"	0.15"	0.25"
1	10	1	Fresh Edges	48	48	51
2	25	2	Fresh Edges	57	63	48
3	10	1	Worn Edges	43	46	47
4	25	2	Worn Edges	51	53	58
5	40	3	Worn Edges	47	49	59
6	60	4	Worn Edges	52	57	82

ples per second, depending on run speed. The maximum vertical load was determined from the eight data points generated (two runs of four wheels running over one groove of each depth).

The consist was run over the freshly ground grooves in runs numbered 1 and 2. Subsequent to the run, 2,180 loaded HAL cars (39-kip wheel loads) were run across the frog to deform the edges of the grooves to a more conformal worn shape. This had the effect of widening all grooves, as well as reducing the maximum depth (by wear). The deepest groove still had unsupported gaps after the HAL cars went across. The groove shapes ground into the frog were circular sections 1.5 to 2.0 inches wide, with three depths: 0.05, 0.15, and 0.25 inch. These were ground using

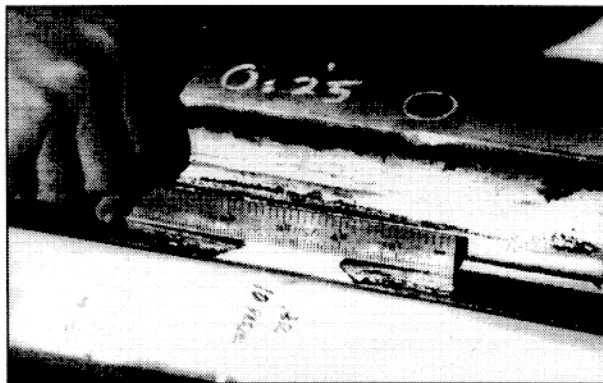


Exhibit 2. Worn 0.25-Inch-Depth Groove

an 8-inch-diameter wheel. Exhibit 2 shows one of the 0.25-inch-deep grooves in the worn-edge condition.

Wheels were inspected visually after the initial runs and after the conclusion of testing. No flange gouges or marks from the impacts were found. The impact loads, while higher than desired for revenue service, were recorded over a groove that is likely to be beyond a worst case for maintenance limits. The grooves, when ground fresh, were non-conformal to the wheels; producing a situation similar to the unsupported flangeway gap seen in conventional-design high-angle diamonds. A small amount of cross traffic was able to wear down the sharp corners of the relatively soft 1040 steel frog. This had the effect of reducing impacts on the frog, especially for the shallowest grooves. These were worn back to conformal during the course of our testing. This suggests that cross-groove maintenance limits may be desired for lightly used lines.

Impact forces were calculated from finite element modeling of crossing diamonds. The model predicted impact forces of 80 kips for a 2-inch gap at 40 mph. Conformal depressions, likely from wear of traffic in both tracks, will cause dynamic forces similar to those seen at the FBF ramps (40 kips at 60



Exhibit 3. FBF Test Frog Running Surface Cross-Section Profile

mph). This is a significant dynamic force reduction from the 80- to 120-kip loads generated over conventional diamonds at 40 mph.

### RUNNING-SURFACE DEFORMATION RATES

Flange Bearing Testing at FAST under locomotives and HAL cars has shown that a fairly wide groove will develop from a limited number of cars (See Exhibit 3). The shape and depth of grooves worn in service will depend on the characteristics of the running-surface material, the wheel-flange shapes and the relative amount of traffic on the two crossing

lines. Based on the back-to-back tolerances for wheels allowed in North American freight cars, we expect to see a wear band of at least 1.25 inches in revenue service. Also, the initial shape of the running surface will affect where the wheels first wear a groove. Subsequent wheels will tend to follow that groove.

This test provided limited data on the deformation rates of cross grooves under flange-bearing conditions. Rates of groove deformation have been established for the soft running-surface material used. The material is a 1040 steel with an initial hardness of 240 HB. Previous train operations over the frog have hardened the surface to around 290 HB. Exhibit 4 shows the groove-dimension changes with tonnage.

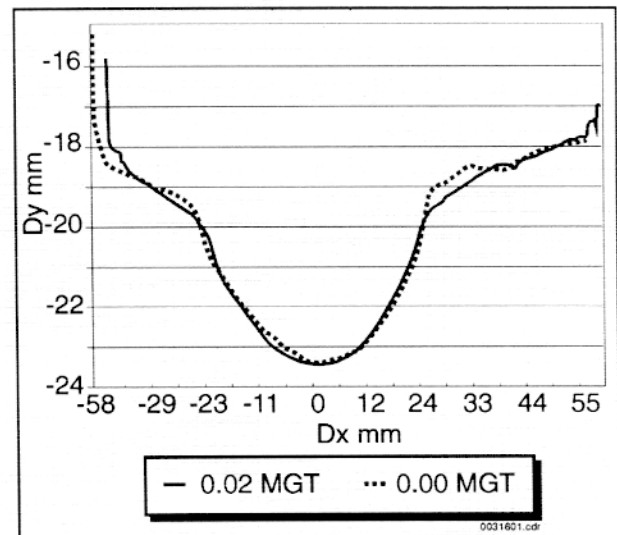


Exhibit 4. FBF Cross-Groove Profiles at 0 and 0.02 MGT

Note: Contact Dave Davis at (719) 584-0754 with questions or comments about this document.

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