

"EFFECT OF FLANGE BEARING FROGS ON TRAIN FORCES"

by David D. Davis, Richard P. Reiff,
Joy Cooke, and Semih Kalay
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Summary

The Association of American Railroads (AAR) is conducting an evaluation of the Flange Bearing Frog (FBF), an alternative low-impact crossing diamond concept, through the Advanced Crossing Diamond Research Program at the Transportation Technology Center, Pueblo, Colorado. 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 revenue service. Industry experts on track, freight car wheels, locomotives, and train operations provided input on potential areas of concern. These potential problems are being evaluated by analytical and experimental methods. Information is presented from the AAR's evaluation of the potential effects of train action in causing wheel unloading of empty cars while moving over an FBF. The effects of side-to-side, uneven wheel pickup on lateral forces in the frog were also investigated.

Test results show that empty cars traversing the FBF while the train was in buff (i.e., compressive force) did not experience excessive wheel unloading.

Using load measuring wheel sets and a load measuring coupler, a series of runs were made with a lightweight empty hopper car in the consist of a train to measure the effects of buff force and speed on wheel loads across a test FBF. Buff forces of 50 kips to 225 kips were generated on 10 mph to 30 mph runs. Wheel unloading was not materially affected by the amount of buff force applied.

The effect of uneven flange heights on the same wheel set was simulated by the configuration of one set of FBF ramps with mismatched ramp rates. The effect of the offset transitions from tread-to-flange bearing on wheel loading is a brief lateral load spike. The value of the lateral load spike is a function of flange height mismatch and running surface conditions.

The use of an effective guarding device for the inside of each running surface is considered to be essential for heavy haul freight operations. The lateral forces and axle steering moments generated by an uneven tread-to-flange transition could cause high lateral to vertical force ratios.

The ability to maintain the running surfaces will play a key role in FBF maintenance; the high contact stresses of flange bearing may cause high rates of running surface wear and flow. Running surfaces must be maintained to close tolerances for longitudinal profile. The two flangeway surfaces must also match each other acceptably.



Suggested Distribution:

- Train Handling
- Maintenance of Way
- Track Maintenance
- Research & Development

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INTRODUCTION

The Association of American Railroads (AAR) is evaluating an alternative low-impact crossing diamond concept called the Flange Bearing Frog (FBF) for use in heavy haul freight railway applications. While the potential savings of FBFs in track maintenance costs and train operations delays are quite large, possible negative effects from FBF operations need investigation before FBFs are placed in revenue service. The AAR's concept evaluation, conducted at the Transportation Technology Center (TTC), Pueblo, Colorado, is focusing on the effects of FBFs on vehicle wheels. This concept can be viable only if the negative effect of FBFs on wheel performance is negligible. Information from these tests will be used by the AAR Special Track Work and Track Component Task Force to guide the Advanced Crossing Diamond Research Program.

In this test, the potential for train forces to cause empty cars to unload while traversing a FBF was evaluated. Operations personnel raised the concern that a light car may tend to be "squeezed" up by the FBF ramp and longitudinal buff forces occurring simultaneously. It was speculated that this combined action may cause the light car to unload vertically and increase the risk of derailment over the frog.

Approximately 4,700 crossing diamonds are in service on North American railroads; the AAR estimates \$240 million is spent annually on their replacement and maintenance. The initial cost of a crossing diamond is in excess of \$100,000 and average maintenance costs are \$700 per million gross tons (MGT). Crossing diamonds also affect service reliability and line capacity. High angle crossing diamonds have very short lives (e.g., 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. Approximately \$421 million in train delays due to

slow orders and track outages can be attributed to crossing diamonds each year. These slow orders generally result from impact loading related damage caused by the unsupported flangeway gaps in the diamonds.

The life expectancy of conventional crossing diamonds is dramatically shortened when operated under heavy axle load (HAL) traffic (315-kip car) as compared to 100-ton (263-kip car) or mixed freight operations. Testing at TTC's Facility for Accelerated Service Testing (FAST) has shown that high angle conventional diamonds have very short lives (i.e., 5-15 MGT). 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 conventional diamonds, the limits of technology may have been reached.

TEST CONFIGURATION

Test were conducted by running an instrumented 6-kip wheel load hopper car across the FBF at various speeds and with various amounts of buff force. The speeds ranged from 5 to 30 mph; while the buff forces ranged from 5 to 225 kips. Wheel loads were measured on the wheel sets of one truck with strain-gaged wheel sets. Buff forces were measured with a strain-gaged drawbar at one end of the car.

A FBF was simulated with filler blocks machined to create an up and down ramp, along with a 14-foot level running surface. Each ramp was configured to lift wheels clear of the top of rail by at least .25 inch. The lead-in ramp for buff force testing was 10 feet long, while the trailing ramp was 20 feet long. A cross section of the path is shown in Exhibit 1. The 14-foot level running surface provided a flat area simulating a crossing of about 45 degrees.

Although ramp rates of left and right rails were intended to be machined in matched pairs, fabrication errors created an offset of about 5 feet on the 20-foot section. This anomaly created a left-to-right lag in transition from tread to flange contact. The offset effectively simulated a worst



case skewed truck condition, where one wheel on an axle would transition from tread to flange before the other, potentially causing high lateral loading. The skewed truck condition causes one wheel to wear faster than the other. It is this wheel wear/flange height differential that was simulated by the mismatched ramps. This situation was used to the advantage of the test team by allowing data to be collected that simulated skewed truck operation over a flange bearing frog.

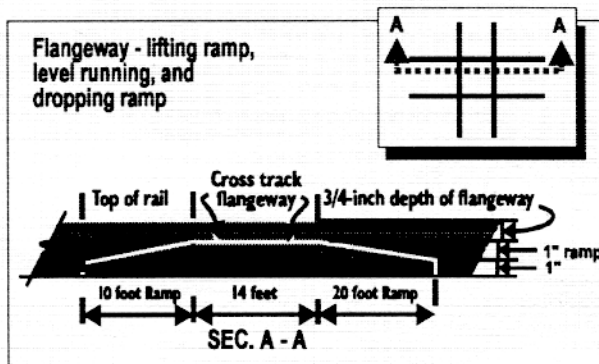


Exhibit 1. Flange Bearing Frog Cross Section

TEST RESULTS - BUFF FORCES

The test train was configured to limit tonnage operated over the FBF. In some cases, when large buff forces at higher speeds were required, it was often necessary to operate the full test consist over the FBF. This included the four locomotives and seven loaded HAL cars. A deep groove wearing into one side of the flangeway resulted, which forced the wheel flanges into the wedge of the groove and into severe loading of the back of the wheel plate. This was seen as a high vertical load on some runs. There was also a tendency for the other wheel on an axle to be forced against the gage face of the rail and lift off flange contact, even though overall wheel loading indicated little unloading.

Exhibit 2 shows instrumented wheel set data for the leading axle traveling over the FBF at 5 mph under 225,000 lbs. of buff force. Exhibit 3 shows the same wheel set and speed but at a much lower buff force of 5,000 lbs. Little

difference is seen in minimum wheel load for either run. The lightest wheel load was about 4,200 lbs. The maximum wheel load is also in the area of deepest grooving, and back-of-flange loading may have influenced what the instrumented wheel set gages were reading.

A number of passes were made over the FBF at different buff forces. Minimum wheel loads are for each run are shown in Exhibit 4 at speeds of 5 mph to 25 mph.

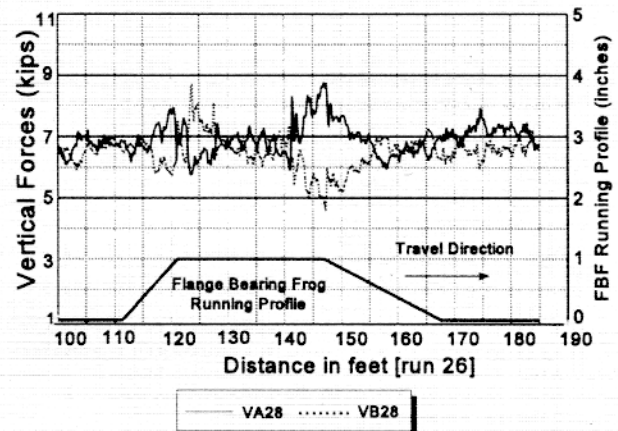


Exhibit 2. Vertical Wheel Load at 5 mph/225,000 lbs. Buff—Leading Right and Left Wheels

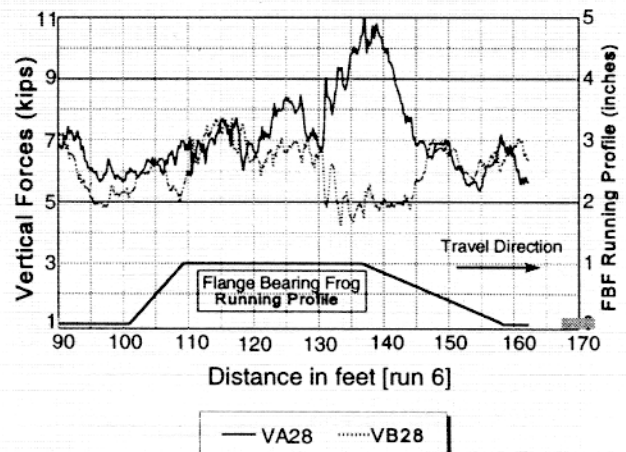


Exhibit 3. Vertical Wheel Load at 5 mph/5,000 lbs. Buff—Leading Right and Left Wheels

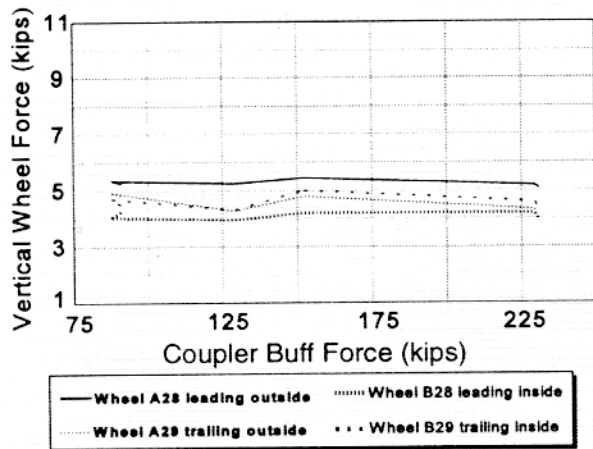


Exhibit 4. Minimum Wheel Load for Various Buff Forces

No significant change in wheel load was seen in the range of buff forces operated. Thus, the operation of light cars over FBFs does not appear to be a safety issue as it relates to wheel unloading or car lift.

TEST RESULTS-OFFSET FLANGE BEARING

The mismatched 20-foot ramps allowed the effect on lateral loading of non-simultaneous, left to right tread-to-flange transition on an individual axle to be measured. During the period when one wheel is still in tread contact and the other is already in flange contact, a large (up to 1 inch) difference in rolling radius on a single axle can occur.

A peak lateral load of about 4,600 lbs. was generated during the run (Exhibit 5). This equates to an L/V ratio of 0.76, which is reduced to 3,000 lbs. (L/V of 0.5) or less after the unbalanced transition. These high lateral loads, should they occur in service, can be protected from flange climb by incorporating a high guard rail surface throughout the FBF.

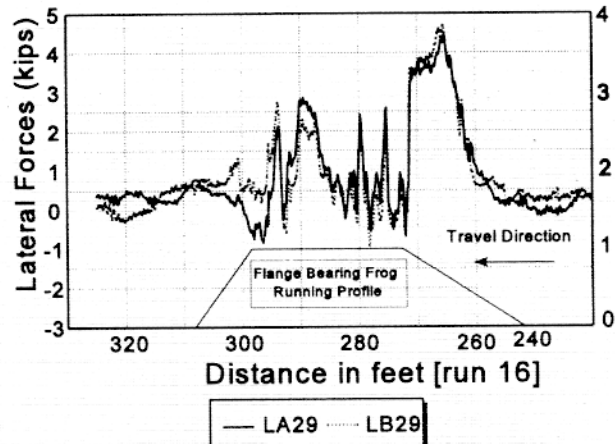


Exhibit 5. Lateral Load at 5 mph up 20-foot ramp with Mismatch

COOPERATIVE RESEARCH EFFORTS

A multidisciplinary team of railroad experts has been assembled to evaluate and develop new crossing diamond concepts under the Advanced Crossing Diamond research program. The first concept to be evaluated is the Flange Bearing Frog. The evaluation team consists of the following:

- AAR Railway Technology Department Staff
- Railroad Track Experts from the Special Track Work & Track Components Task Force
- AAR Operations and Maintenance Department Staff
- Railroad Mechanical Experts from the Wheel and Car Engineering Committees
- Railroad Operations Experts from the Derailment Prevention Committee

Note: Call Dave Davis at (719) 584-0754 with questions or comments regarding this document.
E-mail: david_davis@aar.com

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