TECHNOLOGY DIGEST

Timely Technology Transfer — 99-012

Initial Performance Evaluation of Flange-Bearing Frog Crossing Diamonds at FAST

by D.D. Davis, D. Guillen, R. Reiff, and S.F. Kalay

Summary

Transportation Technology Center, Inc., researchers have obtained wheel-performance measurements during 31 million gross tons (MGT) of testing over the first prototype flange-bearing Frog (FBF) diamond designed for heavy-haul applications. Significant findings after 2,693 train passes at the Facility for Accelerated Service Testing (FAST) include:

- Wheel performance has been satisfactory in terms of fatigue/durability and deformation.
- Wheels have sufficient capacity to withstand flange bearing in heavy-haul service.
- The flange tip flattens and contact area increases rapidly until it is about 15 mm wide (roughly the diameter of a dime).
- Flange-face wear and wheel-tread wear are unaffected by FBF crossings.
- In FAST tests, with a FBF diamond every 2.7 miles, the average flange initially loses about 1.5 millimeter (1/16 inch) in height.
- Comparison of wheel flange and tread vertical wear rates were made during the FAST test. The long-term wear rates show that one FBF pass is equivalent to about 5 miles of tread operation.
- There were no significant flange fatigue failures. One wheel in 592 was removed for flange shelling due to a large inclusion. Such shelling had also occurred before the FBF was installed. The shell was not considered to pose a safety risk to the train.

A sample of 32 wheels on 16 wheel sets was selected for wear measurements during the FBF prototype tests. This sample consisted of 20 wheels with FAST worn profiles and 12 newly reprofiled Association of American Railroads (AAR) 1-B wheels. In addition to the sample wheels, the remaining wheels in the FAST train (typically 70 to 78 cars) were monitored for cracks and dimensions according to AAR Rule 41.

These tests were sponsored by the AAR, and were conducted at the Federal Railroad Administration's Transportation Technology Center near Pueblo, Colorado.

Suggested Distribution:

- ❑ Maintenance of Way
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ Safety

Work performed by Transportation Technology Center, Inc.

a subsidiary of the Association of American Railroads

April 1999©

INTRODUCTION AND CONCLUSIONS

A test of the flange-bearing frog (FBF) concept for high-angle diamonds under Heavy Axle Load (HAL) traffic — and its effect on 38-inch wheels — is being conducted by Transportation Technology Center, Inc. (TTCI), at the Facility for Accelerated Service Testing (FAST). Under 39-kip-wheel-load train at 40 mph operations, wheel performance has been satisfactory in terms of fatigue / durability and deformation. These conclusions were drawn after approximately 31 million gross tons (MGT) and 2,700 train passes over a 90-degree FBF diamond on the FAST High Tonnage Loop (HTL). The wheel-flange tip deforms to a flat shape, conformal to the frog running surface, in a relatively few passes over a FBF diamond. The normal wheel running surfaces (the bulk of the flange and the tread) are unaffected by flange bearing.

Train operation has been normal during this testing of flange-bearing frogs, which traditionally have been used in less-demanding service applications — either high-speed / light-gage, or low-speed / heavy-tonnage situations. Successful operation has been conducted by following the long-standing industry practice for crossing-diamond operating rules of reducing throttle setting when the locomotives are on the crossing diamond. Some downloading and wheel slip has occurred when operating outside of these guidelines (such as at low speeds and under full tractive effort).

The Nortrak FBF diamond design has performed well with the lone exception of pumping at one set of joints. This pumping is related to the abrupt stiffness change resulting from the particular joint design used in this diamond. The large stiffness change is the result of TTCI's desire to have more easily replaceable ramp rails. This detail can easily be remedied on future crossing diamonds; the FAST diamond has been retrofitted with an improved joint. Replaceable ramp rails were provided out of concern about high wear rates, but so far it has not been necessary to replace ramps. The wear rates on the heat-treated rail (ramps) and austenitic manganese steel (AMS) castings have been very low. The projected wear life of each component is about 1,000 MGT.

The objectives of these tests are:

- Determine the performance of wheels subject to flange bearing on actual diamonds. This information is necessary to obtain a waiver of the Federal Railroad Administration (FRA) track-safety standards for minimum flangeway depth (213.137).
- Determine the performance of prototype diamond designs under HAL service (i.e. does this diamond perform better than conventional high-angle diamonds under HAL?).
- Suggest improvements to prototype designs.

BACKGROUND

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 estimated to be in excess of $100,000. In addition, average maintenance costs are $700 per MGT of traffic. 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 costs of diamond maintenance.

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 HAL traffic is dramatically shortened compared to 100-ton or mixed-freight operations. Testing at FAST, under 39-kip wheel loads, has shown that conventional diamonds have very short lives (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. This data suggests that for unsupported-gap diamonds, the limits of the technology may have been reached.

FAST OPERATION RESULTS

As of the end of 1998, the diamond had accumulated 30.9 MGT of traffic in 2,693 passes of the HAL train. The FAST train cars weigh 315,000 pounds and are supported on four 38-inch wheel sets. This produces a 39-kip static wheel load. The two 125-ton-capacity trucks in each car have one of three improved suspensions. The premium suspensions are aimed mostly at improving vehicle steering and reducing lateral forces.

The diamond has been noisier and has caused a rougher ride than was expected. The flange-bearing ramp to casting joints and the flangeway intersections are believed to be the sources. One flangeway intersection was finished poorly with the cross flangeway ground about 0.04 inch deeper than the mainline flangeway. The joints are pumping under load due to the stiffness change. The casting ends are beginning to batter. The ramps appear to be performing well.

WHEELS

One wheel has been removed from the train after 423 laps because of spalling on the flange. This defect was found during an inspection of the train at servicing. The wheel was a class C forged wheel. Initial examination of this wheel by TTCI wheel experts found the cause likely to be an inclusion in the steel. The defect was not considered to be an immediate safety hazard. Four wheels with similar flange spalls were removed from the FAST train prior to the installation of the FBF diamond.

Profiles have been taken on a group of 32 wheels. In general, the sample wheels have flattened on the flange tip, losing height and gaining width in the contact area. The flow of metal can be seen in the widened tip and sharpened corners. As was seen at the Track Lab tests, the rate of height loss is rapidly approaching a steady state with load cycles.

The average test wheel has lost 1.63 mm (about 1/16 inch) in flange height since the beginning of the test. Exhibit 1 shows the average flange-height loss vs. passes. Flange height loss rate continues to decline with additional tonnage. Currently, one FBF pass is equivalent to about 5 miles of operation at FAST (in tread wear). Thus, at FAST, average wheel flange height can be kept constant by operating over the FBF diamond at the one per 5 miles "break-even"frequency. Exhibit 2 shows a time series of wheel-flange profiles taken on one of the test wheels. The height loss and shape change is greatest on the new 1B wheels. This is expected as they are not work-hardened. And, they are wearing to a FAST worn profile on the tread.

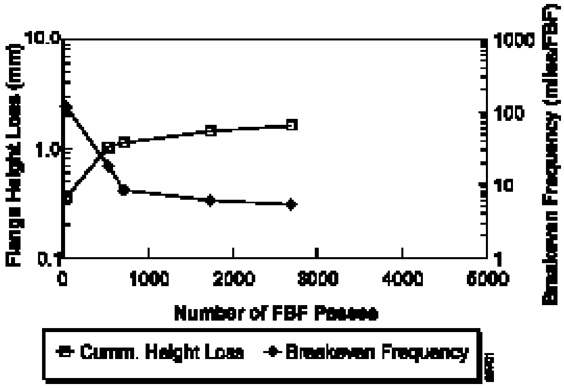

Exhibit 1. Average Wheel Flange Height Loss vs. Cycles

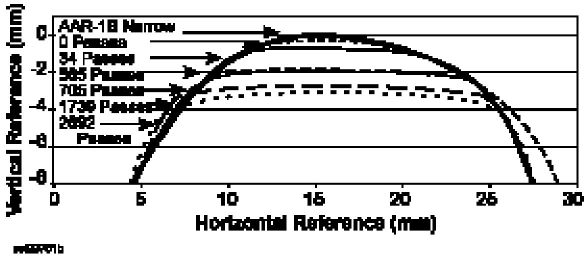

Exhibit 2. Close-Up View of Flange-Tip Profiles

In summary, wheel performance has been very good. The particular FAST test operation (of one FBF diamond per 2.7 miles of running), is causing wheels to lose flange height. Initially, the rate of flange deformation greatly exceeded the rate of tread wear. This situation was causing concern about setting minimum flange-height limits. FAST instituted a minimum flange-height removal criterion at 13/16 inch. However, this is not expected to happen in revenue service, even if FBF diamonds replace all conventional diamonds in the North American freight system since the rate of diamond occurrence is much less than the one per 2.7 miles at FAST. The rate of flange-height loss has decreased with loading cycles of more than 31 MGT. The rate appears to be reaching a steady-state value. Currently, one FBF pass is roughly equivalent (in flange height loss) to 5 miles of running (in tread height loss). This is shown in Exhibit 1.

This test data supplements the previous long-term flange-bearing wheel-fatigue studies done in the Track Lab. Under a 100-ton car, 10 wheels were tested for up to 80,000 passes of a flange-bearing frog at low speed. Eight of the wheels were purposely damaged (thermally) with skid flats, forming an area of untempered martensite. The long-term durability of skid-damaged wheels was then evaluated. One of the wheels developed a crack on its skid flat at between 70,000 and 80,000 passes. The undamaged areas of the wheels performed well.

DIAMOND DESIGN

The diamond is a flange-bearing version of the Nortrak Lapped Beam design. The minimum flangeway height is 0.75 inch for 23 feet. The flange-bearing ramps have a 1:240 slope from conventional flangeway depth to 0.75 inch. The ramps are made from fully heat-treated rail. The castings are AMS that has been explosion hardened in the flangeway. Exhibit 3 shows the Nortrak diamond after 20 MGT of traffic. The wear marks on the tread-bearing rail and flangeway bottom show the extent of flange bearing for the range of wheels in the FAST train.

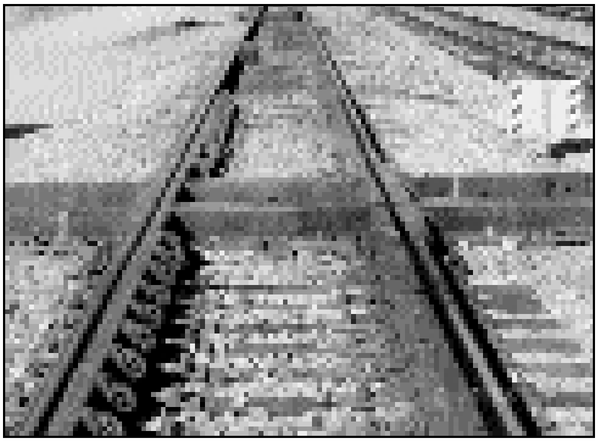

Exhibit 3. Nortrak FBF Diamond in FAST Service

FUTURE WORK

Continued long-term monitoring of wheel performance under flange bearing is planned for 1999. Tests with the Nortrak diamond will employ castings made with J9 bainitic steel. A second design diamond, made by ABC Rail Products, will be added to the FAST HTL as a 75-degree crossing. TTCI also hopes to begin revenue-service evaluations when AAR has obtained a waiver of the Track Safety Standards for minimum flangeway depth from the FRA.

ACKNOWLEDGMENTS

Successful conduct of this test would not be possible without the commitment and support of TTCI's FAST experiment management, operations and track maintenance forces. Joe LoPresti, Manuel Perez, Mark Woodworth, Rick Montoya, and Ira Kalb have been essential to this effort. The sponsorship of the Association of American Railroads, from concept evaluation to prototype testing, and of the FRA, through its sponsorship of FAST, is greatly appreciated. Ned Parker of The ARC Group, Incorporated, expertly provided the wheel-profile data analysis.

Note: Contact Dave Davis at (719) 584-0754, with questions or comments about this document.
E-mail: david_davis@ttci.aar.com
Web site: www.ttci.aar.com

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.