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Revenue Service Implementation of a Flange Bearing Crossing Diamond at Shelby, Ohio

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Summary

CSX Transportation installed the first flange bearing frog crossing diamond in revenue service tracks with speeds above 10 mph. The diamond, installed July 31, 2006, is the first one installed under the Association of American Railroads' waiver granted by Federal Railroad Administration (FRA). After 4 months of operation, the diamond is performing well, with approximately 20 MGT of traffic on the mainline side and about 1 MGT of traffic on the crossing railroad (Ashland Railroad).

A waiver of the FRA Track Safety Standards is needed to allow flange bearing frog operations in track above speed Class I. The track safety standards (CFR 49, part 213.137) for minimum flangeway depth in frogs was intended to prevent accidental flange bearing for frogs that are not designed for it. The unintended consequence of this standard has been to delay implementation of a promising innovation.

Although it is very early in the life cycle of the Shelby diamond, the following findings are presented:

- 40 mph operations are quieter and smoother than at similar conventional tread bearing diamonds. Train crew comments have been favorable.
- Based on contact marks on the diamond, all wheels going over the diamond have flange heights between 1.0 and 1.5 inches.
- Cross grooving is occurring for the branchline trains. The dimensions of the cross grooving are approximately 1.25 inches wide with a maximum depth of 1/8 inch (~3 mm). Data from the Shelby diamond will be used to formulate a maintenance policy.
- Metal flow is highest at the flange bearing running surface joints between castings. Joint maintenance will be more difficult than with tread bearing diamonds due to the relative inaccessibility of the running surface.
- A significant amount of rail lubricant is being deposited on the diamond. Wheels make contact with the diamond in locations that do not contact any other track work. Thus, the diamond collects rail lubrication to the extent that occasional cleaning is necessary to keep ballast from fouling.
- The Facility for Accelerated Service Testing (FAST) has proven to be a good simulation of revenue service performance for flange bearing. Revenue service performance has been similar to that at FAST.



INTRODUCTION

The implementation of a full flange bearing frog (FBF) crossing diamond in heavy haul freight service was accomplished by CSX Transportation at Shelby, Ohio, on July 31, 2006. The first 20 MGT of operations has been successful with minimal maintenance required and no operating problems. As expected, degradation and, presumably, dynamic loads for both routes are reduced with this design.

Background

FBFs have been used for many years in specific, non-heavy haul situations. FBFs are used where the railroad requires minimization of impacts, noise, and vibrations due to unsupported wheels crossing flangeway gaps. Street railways and ports have used them for many years. Flange bearing greatly simplifies the design of frogs for double flanged wheels used in port cranes. The Federal Railroad Administration’s (FRA) track safety standards currently do not allow FBFs on freight railroads for track above Class I and speeds above 10 mph for freight and 15 mph for passenger trains. The concern, of course, is for cases where a frog not designed for flange bearing would become flange bearing due to wear. Due to a long history of tread bearing frog usage, the existing rules evolved. After extensive evaluation and testing of the concept under 315,000-pound car traffic, a waiver of FRA *Track Safety Standards* CFR 49 part 213.137 was obtained by the Association of American Railroads to allow limited implementation of FBF crossing diamonds.¹ The Shelby diamond is the first installed under the provisions of the waiver.

Prototype Flange Bearing Frog Crossing Diamonds

Table 1 and Figure 1 show the characteristics of the Shelby FBF diamond. For comparison, other types of diamonds, an OWLS diamond (flange bearing on the branchline track only) and a conventional tread bearing diamond, are also listed. The flange bearing diamonds are expected to have smoother train operations, lower maintenance requirements, and longer service lives than conventional designs.



Figure 1. CSX Shelby, OH FBF Crossing Diamond

Shelby FBF Diamond Performance Train Handling

Train handling and locomotive operations have not been affected by FBF diamonds. At Shelby, the branchline trains can obtain clearance when they enter the signal block. Thus, most trains are traveling at track speed (10 mph) when crossing the diamond. As with other diamonds, the locomotive engineer on either railroad will notch down the throttle when the locomotives cross the diamond. This is traditionally done to “calm” DC traction motors before the impacts of crossing flangeway gaps and reduce the risk of “flash-over.” With the FBF ramps, it helps by reducing the likelihood of wheel slip as the wheels transition from tread bearing to flange bearing. CSX reports no train operating problems with the FBF crossing at Shelby. Additionally, there is no evidence of engine burns on the running surfaces of any of the diamonds.

Wheel Performance

A fleet of 12 covered hoppers was pulled from storage and placed into service to support the FRA wheel/truck inspection requirements for the waiver. Inspections with truck roll-out are conducted on a 90-day cycle. Wheels and axles are examined with non-destructive evaluation methods and all major truck components are inspected visually. Figure 2 shows a truck inspection with ultrasonic inspection of the axle and dye penetrant inspection of the wheel flanges in process. Wheel tread profiles are taken during these inspections. From these profiles, tread and flange height loss (i.e., wear rates) are determined. The inspection cars are cycling between Indianapolis, Indiana, and Albany or Buffalo, New York. They are seeing about 10 FBF diamond passes and 5,000 miles of operation per month.

Figure 3 shows the measured average flange heights versus FBF diamond passes for the 12 cars in the FBF test fleet. The measurements of the Shelby fleet show that flange heights have decreased slightly in the first 25 passes. This is not unexpected as the initial deformation on the flange tips is relatively large. The average flange height changed from 1.23 to 1.22 inches (statistically the same for each measurement).

Table 1. FBF Crossing Diamond Design and Operating Characteristics

Location	Ramp Length	Ramp Design	Allowable speed (mph)	Mainline Traffic	Branch-line Traffic	Dynamic Wheel Loads	Comments
Full FBF Shelby, OH (CSX – ASH)	15 feet	Parallel, AAR vertical profile	CSX – 40 FB ASH – 25 FB	60 MGT Mixed Freight 60 mph	2 MGT Mixed Freight 10- 25 mph	1.5 x Static	Frogs & ramps are AMS castings
OWLS	6 feet (typical)	Parallel	Main – 79 (pass) TB Branch – 10 FB	Mixed Freight 60 mph Passenger 79 mph	Mixed Freight 10-25 mph	1.5 x Static	Frogs are running rails with bolt-on AMS castings
Conventional Tread Bearing Diamond	N/A	N/A	Typical – 40 mph TB Slow ordered to 25 mph	Mixed Freight 60 mph	Mixed Freight 10-60 mph	2 to 4 x Static	Frogs are AMS castings or rails

For comparison, Figure 3 also shows flange height versus FBF passes for other freight operations. The effect of miles to passes can be seen in this plot. The original tests at FAST, with cars going over a diamond every 3 miles, reduced flange heights over time. The rate of flange deformation exceeded the amount of wheel tread wear. For operations more representative of revenue service, such as the OWLS diamond at Chenoa, Illinois, the flange heights have increased with time.

Figure 4 shows a time series of profiles for one wheel being monitored. It is typical of the group. Note that the flange height decreased in this initial interval of flange bearing. From the shape change it is clear that flowed metal on the tip flattened and accounts for much of the height loss. In future intervals, we expect the flange heights to grow, indicating that tread wear is exceeding flange height loss. As was measured at FAST and in OWLS revenue service tests, the flange tip flattens rapidly to become conformal to the diamond running surface.² The gage side corner of the flange tip may also sharpen (i.e. decrease in radius).



Figure 2. Truck and Wheel Inspections at CSX Avon, Indiana, Shop

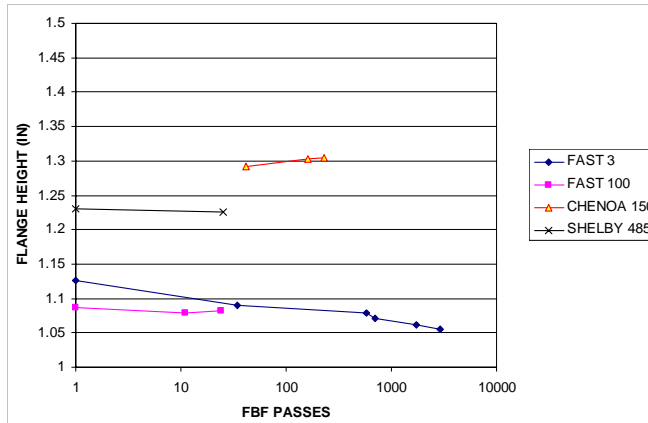


Figure 3. Flange Height vs. Flange Bearing Diamond Passes for Various Operations

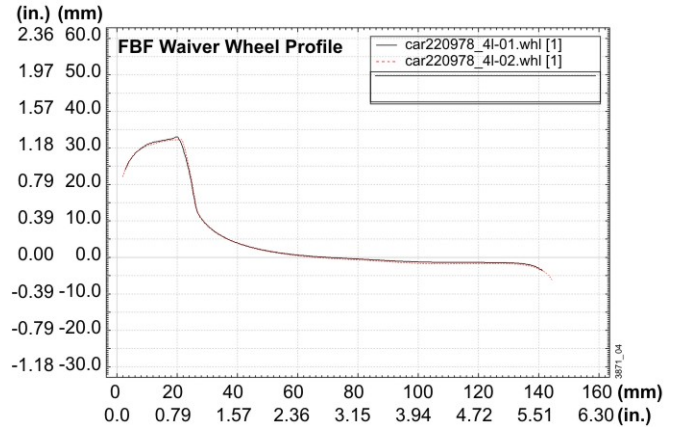


Figure 4. Time Series of Wheel Profiles from Loaded Car Operating Over FBF Diamond

Frog Running Surface Performance

The flange bearing running surfaces of the diamonds have been monitored for deformation and rolling contact fatigue. To date, the running surfaces have performed well. As with tread bearing austenitic manganese steel diamonds, initial deformation was relatively large. The rate of running surface height loss has decreased with tonnage as the running surfaces work harden and become more conformal. Absolute measurements of flange bearing running surface height loss measurements were made using non-wearing portions of the ramp and frog castings as references.

Figure 5 shows average flange bearing running surface height loss versus mainline tonnage. For comparison, running surface height loss measured under 315,000 pound, 40 mph traffic at FAST is also shown. The two tests show similar trends, with the higher wheel load test at FAST having higher wear rates. In both tests, the running surface hardness increased from under 400 BHN when installed to about 600 BHN (582 at Shelby and 610 at FAST) after about 20 MGT of traffic.

A significant issue for flange bearing frogs is how well the running surface at the flangeway intersections will perform. This area is analogous to the common corner on a tread bearing diamond in that it is where the traffic from both tracks runs on a common running surface. Concerns revolve around the potential for the heavier trafficked line to wear a cross groove into the lighter trafficked running surface. If this wear is severe enough, the dynamic equivalent of flangeway gaps will begin to reappear as cross grooves. The maximum depth of the cross groove was measured at each frog using a profilometer.

Wear on the flange bearing surfaces of the crossing track have been minimal compared to the CSX track due to lower speeds and tonnage rates. Thus, the cross groove depth is nearly equal to the running surface height loss on the CSX track. Figure 6 shows the cross groove developing in a time series of cross section profiles on the CSX route during 20 MGT of service.

The depth of the groove is relatively unimportant, compared to the width. The width is the length a crossing route flange must “jump.” To provide good ride quality in the crossing track, the cross groove edges must be blended into the rest of the running surface. Measurements at the Shelby diamond will be used to formulate cross groove maintenance policy.

Another measure of the running surface wear performance is the length of flange bearing measured for each track of the diamond. Taller flanged wheels (i.e. worn wheels) will begin flange bearing sooner than will short flanged (i.e. new wheels). The range of flange bearing lengths, as measured from the wear marks on the diamond range from 27 to 44 feet. This corresponds to wheel flange heights of about 1.0 inches to 1.4 inches. As expected, the location where the first wheel becomes flange bearing has remained stable at about 7 feet into the 1:180 ramps. The location where the last (shortest flange) wheel becomes flange bearing has moved towards the center of the diamond as the flange bearing surface has worn. This location moved from about 13 feet to about 15 feet during the first 5 MGT. It remained at 15 feet for the 20 MGT measurements.

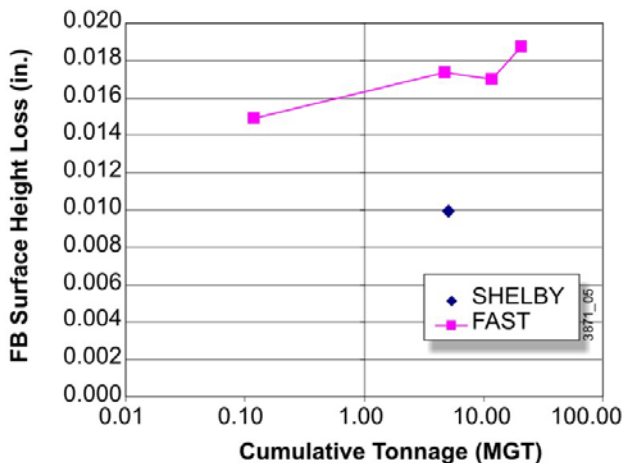


Figure 5. Flange Bearing Running Surface Height Loss vs. Tonnage

FBF Diamond Maintenance

Maintenance on the diamond has been typical with the following exceptions:

- No bolts have failed. Bolts have been tightened and periodically retightened with a torque wrench.
- Track surface has also been good for the CSX side. There is little, if any, visible pumping of the diamond. CSX has done timely work in welding all mainline leg rails on the diamond into track.
- Rail Lubricant build up. The diamond flangeways and treadways collect rail lubricant to the point that it fouls the ballast and obscures the flange bearing running surfaces.

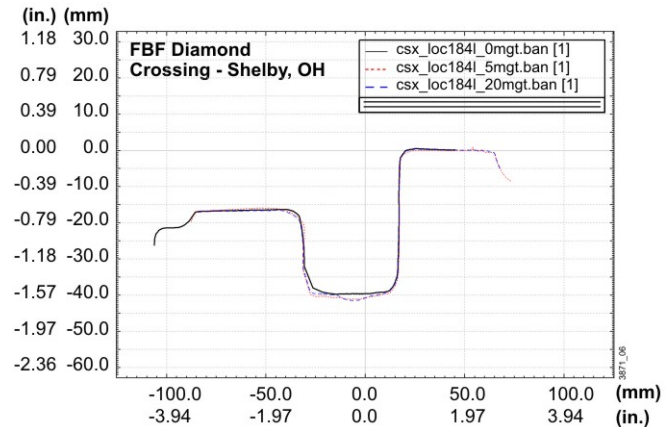


Figure 6. Frog Cross Section Profile Time Series Showing Cross Groove Development

Lessons Learned From Prototype Design

Despite being the first of its kind for mainline HAL revenue service operations, the Shelby diamond has had relatively few problems. Some lessons have been learned for future installations. Among these are:

- Profiled flange bearing running surfaces may be useful for reducing initial running surface deformation of flanges and diamond. A concave cross section profile would be more conformal to flange tips.
- Additional flaring of treadways is needed at frog points. The Shelby prototype had tight tolerances on treadways to keep wheelsets aligned and minimize angle of attack. The treadway width proved to be inadequate for the first few (slow-ordered trains). At the frog intersections, the wheel tread field side edges did come in contact with the raised guards.
- As with all diamonds, joint maintenance is critical. Further development is needed for a better joint design. Additionally, tools, such as slot grinders, are needed to facilitate successful maintenance.

FUTURE WORK

TTCI continues to support implementation of FBF diamonds under the AAR waiver. Monitoring continues for the Shelby diamond and the wheel/truck inspection fleet.

REFERENCES

1. Davis, David D., et al. November 2004. “Field Implementation of Flange Bearing in Crossing Diamonds.” *Technology Digest* TD-04-019. AAR, Transportation Technology Center, Inc., Pueblo, CO.
2. U.S. Department of Transportation, Federal Railroad Administration. January 1999. Office of Safety; Track Safety Standards Part 213, Subpart A to F Class of Track 1-5.