Installation of Flange Bearing Crossing Diamond

Shelby Flange Bearing Diamond

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On July 31, 2006, CSX Transportation installed the first mainline full flange bearing diamond in the United States. This installation was the pinnacle of more than a decade of research in the flange bearing diamond concept by many in the industry. Prior to installation of the diamond at Shelby, TTCI conducted numerous tests on concept flange bearing diamonds in the Facility for Accelerated Service Testing (FAST) High Tonnage Loop track. These tests involved not only monitoring the performance of the track components, but also detailed inspection of the wheelsets, and particularly the flanges of the cars that traversed the diamond.

The FRA created a waiver to its flangeway depth requirements to allow installation of the Shelby diamond in revenue service. Accordingly, the FRA has mandated frequent follow up inspection and testing of the performance of the diamond. In addition, a representative sample of cars that normally traverse the diamond in revenue service must undergo a battery of examinations to determine if there is a detrimental effect on the wheels.

After monitoring the diamond’s initial success, CSX and other Class I railroads intend to install additional diamonds across the country. In general, full flange bearing diamonds significantly reduce the impact loading on the trackwork and the mechanical assets that traverse the diamond. This reduced impact leads to lower maintenance costs and higher speeds for trains traversing the diamond. Once this technology is proven successful, flange bearing diamonds are expected to become more prevalent across the national railroad system.
INSTALLATION OF FLANGE BEARING CROSSING DIAMOND

CSX Transportation installed the first full flange bearing frog (FBF) crossing diamond in revenue service tracks with speeds above 10 MPH. The diamond, installed on July 31, 2006, is the first one installed under the Association of American Railroads’ (AAR) waiver granted by the Federal Railroad Administration (FRA). A waiver of the FRA Track Safety Standards is needed to allow FBF operations in track above speed Class 1.

The first year of operation of the Shelby flange bearing diamond has been successful with minimal maintenance required and no notable operating problems. As expected, degradation of the diamond components and, presumably, dynamic loads for both routes are reduced with this design. Accordingly, the operating and maintenance costs have decreased for the FBF location compared to conventional diamond designs. Providing the Shelby FBF continues to perform well, additional flange bearing diamonds may be installed in other locations throughout the country leading to a diamond design with reduced maintenance and longer life cycles compared to conventional diamond designs.

DEVELOPMENT OF FLANGE BEARING CROSSING DIAMONDS

High-angle crossing diamonds present significant challenges to track maintenance engineers, often causing bottlenecks in train operations. Due to the high dynamic loads generated by heavy axle load (HAL) service, diamonds also are associated with train delays for slow orders and component maintenance. The service lives of crossing diamonds are greatly affected by train speeds and wheel loads for trains that operate over the diamond. Thus, HAL operations can be greatly affected by high angle crossing diamonds.

For many years, track engineers have searched for alternatives to conventional crossing diamonds. The FBF offers a simple design that can provide benefits by reducing vertical
dynamic loads. This is accomplished by eliminating the unsupported flangeway gap from the running surface of the frog. As the name implies, FBFs function by supporting the wheel on its flange through the frog. Conventional tread bearing frog crossing diamonds have unsupported flangeway gaps that wheels must cross. These gaps generate high dynamic loads that adversely affect ride quality, track speeds, and component life.

Under the sponsorship of the AAR Engineering Research Committee, Transportation Technology Center, Inc. (TTCI) evaluated the flange bearing concept for HAL operations. The concept was found to be technically sound and the economics are compelling for implementation of FBF crossing diamonds. TTCI conducted a thorough review of potential operations, and mechanical and track issues. The review included input from railroad mechanical and operating officers, wheel and locomotive suppliers, and AAR mechanical committees. This subject was also discussed at the AREA Symposium on Turnouts and Special Trackwork in 1996. Additional research and testing has continued since that time.

While FBFs are used for many railroad applications, their use in North American freight applications have been limited due to regulatory issues. While concerns about the effect of heavy axle loads have been addressed by AAR research and testing, the requirement for a change or waiver to the FRA Track Safety Standards (Code of Federal Regulations 49, Part 213.137) has thus far limited the use of full FBFs. The standard was written to prevent wheel flange impacts on excessively worn tread bearing frogs. Inadvertently, this rule prevents application of flange bearing designs to track above Class 1 speeds (10 MPH freight and 15 MPH passenger). The AAR has been working to change this standard to allow FBFs in track. The efforts have been partially successful, with a 1998 change in wording of the Track Standards that specifically
allowed flange bearing for Class 1 track and a limited waiver to allow testing in Class 2 and above tracks.

**FBF PERFORMANCE AT SHELBY, OHIO**

**Site Selection**

CSX Transportation committed to installing the flange bearing diamond in revenue service during the early 2000’s. A location for the flange bearing diamond was carefully selected in order to satisfy the requirements of the FRA waiver discussed above. The most sensitive part of the waiver criteria was the first FBF diamond was limited to 40 MPH speed and could not be installed on a passenger route. In addition, the location had to be a single track crossing a single track. After scouring the CSX system, a few suitable candidate locations were identified in 2002, but for a variety of reasons, the Shelby, Ohio, location was selected for installation. The 24°50’ angle at Shelby is lower than optimal; a near 90° crossing would have been preferred, but no higher angle locations met the criteria. The selected site carries enough tonnage to exercise the components but is off CSX’s premium Chicago to east coast route.

Shelby is located on CSX’s Western Division Greenwich Subdivision and is part of the former Conrail/NYC route between Cleveland and Indianapolis. This portion of the line hosts approximately 60 MGT/year in a mix of intermodal, mixed freight, and coal traffic. CSX crosses the Ashland Railway, a shortline that operates on an ex-B&O route between Newark and Willard. Ashland’s traffic in this location primarily consists of interchange traffic destined for Willard yard and traffic for an industrial park in Shelby. There is no interchange between the railroads at Shelby.
Installation

CSX received its flange bearing diamond from its special trackwork supplier VAE Nortrak. The diamond was assembled in Seattle, Washington, with some specialized welding being completed in their Birmingham, Alabama, trackwork plant. Upon receipt, CSX track forces assembled the diamond adjacent to the old railbound manganese diamond in preparation for installation. Nortrak’s design was based on experience gained from two previous prototypes FBFs installed at FAST.

A twelve hour curfew was granted on the line to install the diamond panel on July 31, 2006. CSX employed the services of two sidewinders and a front-end loader from Hulcher Professional Services to remove the failing diamond and to place the new FBF diamond panel. Once the old diamond was removed from the trackbed, fouled ballast was removed down to the level of asphalt underlayment that had been installed in years past.

After grading was completed, the diamond location was preballasted with granite ballast that had been trucked to the site earlier. Once the diamond was dropped into place with the sidewinders, additional ballast was delivered to the diamond by front-end loader. Figure 1 shows the installation crew preparing for the final placement of the diamond. Also upon installation, the diamond was bolted to connect all four approaching tracks. A small tamper was used on both approaching routes to ensure proper surface. Approximately ten hours from receiving the track, the first train operated over the diamond at walking speed.

The first train was carefully observed crossing the diamond to ensure there were no issues with the wheel paths. Once it was determined that there would be no problems, speed over the diamond was increased to 10 MPH. Construction activity during the week following installation included additional surfacing, welding of bolted joints, and additional bolt tightening.
with a hydraulic torque wrench. By the end of the first week of operation, the speed over the diamond had been increased to the maximum speed of 40 MPH. Figure 2 shows the completed diamond several months after installation.

Early reports from train service personnel indicated that the diamond rode very smooth. Unlike conventional diamonds, the sound generated by the flange bearing diamond did not include the normal banging or clicking of its predecessor leaving a sound not unlike a train passing over a short bridge on open track. The noticeable reduction in sound energy alone witnesses to the reduced impact energy dissipated on the diamond components compared to the flange bearing diamond’s predecessor.

**Train Handling and Hirail Transition**

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, this notching down helps by reducing the likelihood of wheel slip as the wheels transition from tread bearing to flange bearing. Overall, there have been no detectable 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.

Hirail and other on track equipment (OTE) have not had any issue crossing the Shelby FBF. With hirail trucks, the guide wheels become slightly flange bearing as the vehicle traverses the diamond. The hirail truck’s rubber wheels simply ride up and over the high guards on either
side of the flangeway. Other OTE simply operates over the diamond in flange bearing and has not created an issue with crossing the diamond. Speeds for these types of vehicles transiting Shelby (or any CSX diamond) are limited to 5 MPH.

**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 rollout are conducted on a quarterly cycle. Wheels and axles are examined with nondestructive evaluation methods, and all major truck components are inspected visually. Figure 3 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 4 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).

For comparison, Figure 4 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 performed at the TTCI, with cars going over a diamond every three 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 flange bearing diamond at Chenoa, Illinois, the flange heights have increased with time.

Figure 5 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 TTCI and in revenue service tests, the flange tip flattens rapidly to become conformal to the diamond running surface\textsuperscript{3}. The gage side corner of the flange tip may also sharpen (i.e., decrease in radius).

**Frog Running Surface Performance**

The flange bearing running surfaces of the diamonds have been monitored for deformation and rolling contact fatigue. In general, the diamond is performing as intended. Flange bearing has eliminated frog corner impacts and associated frog deterioration. The diamond has been inspected/measured four times by TTCI, including a 0 MGT baseline. Measurements include:

- Running surface cross section profile
- Running surface height loss
- Running surface hardness
- Flange bearing length and transition zone
- Flange bearing surface wear band width

**Wear Rates of FBF**

Figure 6 shows the average height loss of the flange bearing running surfaces of the diamond. Height loss has accumulated at a steady rate for the last 35 MGT. By comparison, the height loss rate for flange bearing frog diamonds at FAST decreased significantly over time. The
differences in operation relate to the fleet of wheels traveling across the diamonds. Being the only FBF diamond in service, the Shelby diamond is seeing wheels with flanges of various shapes and hardnesses. At FAST, the single train that operates developed wheel flange shapes that quickly became conformal to the frog running surfaces.

About half of the tread clearance has been consumed on the Shelby diamond to date, suggesting short flange wheels will become tread bearing in another 40 MGT. This will not be the end of the diamond’s life as it was designed to function as a tread bearing diamond. Another course of action would be to remove the tread bearing surfaces by an amount equal to or greater than the flange bearing wear. This will restore tread clearances and assure flange bearing for all wheels for an additional amount of traffic. The castings are essentially solid from running surfaces down to the plate work, so removal of even an inch of material will not significantly affect their strength.

The branchline surface height loss rate has been higher than the mainline side. Due to the low tonnage rate, the total height loss is still about 10 percent of the mainline height loss.

Figure 7 shows the average hardness of the flange bearing running surfaces over time. Note that the flange bearing surfaces are hardening at a rate similar to the previous FAST tests. This indicates that the frog material is behaving similarly, by work hardening under deformation. What is different from FAST is the wheel performance. FAST wheel flange tips became conformal to the running surface. Whereas, revenue service is continuously providing “new” wheels to the frog.

Movement of Flange Bearing Area

The locations where the first wheels (i.e. tall flange wheels) become flange bearing and where the last wheels (i.e. short flange wheels) become flange bearing have been monitored. The
difference between the two locations is the transfer zone of the frog, where wheels transition from tread bearing to flange bearing. These measurements show quantitatively what is happening to the running surfaces. Figure 8 shows the plot of mainline first and last flange bearing locations.

Note that the largest changes in locations happened during the first inspection interval. The location of first flange bearing moved forward on the ramps. This is due to the tread bearing surfaces on the ramps deforming from loading. The tread bearing surfaces were typical flat surfaces. Thus, the gage corners deformed rapidly, resulting in height loss on the tread bearing surfaces. Note also that the location of last tread bearing (also the location where the last wheels become flange bearing) shifted back during the first traffic interval. This is due to wear/deformation of the flange bearing surfaces. Thus, the transfer zone increased during the first interval from 6 feet to 9-1/2 feet.

Since the first interval, the location of first flange bearing has continued to move forward while the location of last tread bearing has stabilized around 16 feet. Thus, the transfer zone has increased to about 10-1/2 feet at the latest inspection.

On the branchline side, the locations of first flange bearing and last tread bearing have been fairly stable. Keep in mind that the branchline traffic rates are very low as compared to the mainline. Total branchline tonnage to date is 1.3 MGT, or about 30% of the first mainline inspection interval.

*Excessive Lubrication Deposits*

One difference in performance noted between tests at TTCI and in revenue service is the amount of rail lubricant being deposited on the frogs. Since the FBF frogs contact the wheels where no other track work is intended, they collect built up lubricant. This extra lubricant may explain the
differences in running surface performance noted. The diamonds tested at TTCI had no visible rolling contact fatigue (RCF) during testing. The diamond at Shelby shows some RCF in the form of small surface shells in the flangeway. These are similar to the “orange peel” surface seen on the high rails of some curves.

The excessive lubrication appears to have been deposited by hydraulic curve greasers located about 12 miles either side of the diamond. The track in this area is mostly tangent with one 1 degree curve located east of the diamond. Insofar as hydraulic greasers are not directional, trains leaving curves and heading toward the diamond became fully greased. With no curve to consume the grease and with the grease migrating to the flangetips due to centrifugal force, the grease was deposited on the diamond as the wheelsets entered the flange bearing mode. This problem has been generally corrected by the installation of electric greasers with directional control.

Flangeway Intersection

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 9 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.”

Another measure of the running surface 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 short flanged wheels (i.e., new wheels). The range of flange bearing lengths, as measured from the wear marks on the diamond range from 27 feet 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.

**FBF Diamond Maintenance**

Maintenance on the diamond has been typical of other diamonds with the following exceptions:

- No bolts have failed. Bolts were tightened and periodically retightened with a hydraulic torque wrench.

- Track surface has also been good for the CSX side. There is little, if any, visible pumping of the diamond. The diamond was resurfaced one time after about 10 months of service. CSX has done timely work in welding all mainline leg rails on the diamond into track.
• Rail lubricant build-up. The diamond flange- and tread-ways collected rail lubricant to the point that it fouled the ballast and obscures the flange bearing running surfaces. This has been corrected by replacing the curve greasers in the area.

CONCLUSION

FBFs have been used for many years in specific, non-heavy haul situations, where the railroad requires minimization of impacts, noise, and vibrations due to unsupported wheels crossing flangeway gaps. Although monitoring will continue at the Shelby diamond and for the wheel and truck inspection fleet, early indications are that flange bearing diamond leads to decrease maintenance and increased life cycle when compared to conventional diamond designs. Accordingly, FBF design diamonds appear to be a viable alternative to other diamond designs for heavy tonnage high speed routes. Long term testing of FBFs will reveal the exact amount of decreased maintenance and increased life that this type of diamond will expect to see.
REFERENCES


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FIGURES

Figure 1. Shelby FBF During Installation (photo)

Figure 2. Shelby FBF Following Installation (photo)

Figure 3. Truck and Wheel Inspections at CSX Avon, IN shops (graph)

Figure 4. Flange Height vs. Flange Bearing Diamond Passes for Various FBFs (graph)

Figure 5. Time Series of Wheel Profiles from Loaded Car Operating Over FBF (graph)

Figure 6. Flange Bearing Surface Height Loss vs. Tonnage (graph)

Figure 7. Flange Bearing Running Surface Hardness vs. Tonnage (graph)

Figure 8. Locations of First and Last Flange Bearing on Mainline Ramps (graph)

Figure 9. Frog Cross Section Profiles (0 – 40 MGT) Showing Mainline Wear Groove in Flange Bearing Running Surface (graph)
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