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Evaluation of Wheel Performance over Flange Bearing Frog Crossing Diamonds in Revenue Service

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Summary

The effects of flange bearing frogs (FBF) on wheel performance in North American heavy axle load (HAL) freight service have been negligible. In controlled tests and in general revenue service use, flange bearing provides safety and efficiency benefits to railway operations without degrading wheel performance. Wheels are capable of flange bearing under typical operations without causing wheel failures.

Controlled tests at Transportation Technology Center evaluated the FBF concept for HAL diamond crossing applications. These tests were conducted at the request of by the Association of American Railroads (AAR) mechanical committees. The results of these evaluations showed that the concept was technically feasible for freight service. With approval of AAR mechanical committees, prototype FBF diamond crossings were evaluated at the Facility for Accelerated Service Testing. Wheel durability under FBF diamond crossing applications was confirmed with more than 6,000 train passes of test diamonds.

Based on the proof test results, a waiver of the requirement for minimum flangeway depth (under CFR part 49, 213.137) was obtained from the Federal Railroad Administration for revenue service tests. As a result, CSX and BNSF railways installed FBF crossing diamonds under the waiver granted to the AAR. The waiver requires quarterly truck rollout inspections of a small group of cars that routinely travel across a FBF diamond. These inspections include visual and nondestructive inspection of truck, axle, and wheel components. Visual, dye penetrant, and ultrasonic inspection of the wheels and visual and ultrasonic inspection of the axles were conducted. Additionally, profiles and surface hardness measurements were made on the wheel running surfaces. After 3 years of operation on CSX track and more than 6 months of operation on BNSF track, the following findings are presented:

- No FBF caused failures have occurred in FBF fleet wheels or axles.
- No skid flats were found on the flanges.
- Wheel tread wear (vertical height loss) exceeded flange height loss, except for the first few FBF diamond passes. This means that wheels will wear in the usual way.
- Flange bearing wheels developed a flat facet on the flange tip. The orientation of this facet was roughly horizontal, but it varied with the wheel back-to-back spacing of the particular wheelset. For wide spacing, the facet was angled toward the tread.
- Flange tip shelling can occur on worn wheels. This is due to flow of metal from the tread side of the flange due to curving. The flowed metal is folded over during flange bearing. In the test fleets, the folded metal wore off without causing subsurface cracking.
- Nicks and gouges to the flange did not affect flange bearing performance. Typical flange and tread rim nicks, dents, and gouges were observed in the FBF fleet wheels. These were not caused by the FBF diamonds and did not affect wheel performance in flange bearing.

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INTRODUCTION

Controlled tests at Transportation Technology Center evaluated the FBF concept for HAL diamond crossing applications. Based on the proof test results, a waiver of the minimum flangeway depth requirement was obtained from the Federal Railroad Administration (FRA) for revenue service tests. The limited number of installations granted was intended to allow testing of a wider range of operations and wheel conditions, while limiting exposure of the North American car fleet.

FBFs have been used for many years in specific, non-HAL situations. They are used where the railroad requires minimization of impacts, noise, and vibrations due to unsupported wheels crossing flangeway gaps. FBFs are currently allowed under FRA track safety standards for low speed operations only. The waiver granted allows higher speed operations.

FBF diamonds are expected to greatly reduce the dynamic loading generated by conventional high-angle tread bearing diamond crossings. The elimination of unsupported flangeway gaps, which wheels must cross, is a method of improving dynamic performance. A summary report describing the wheel related findings of FBF proof of concept testing and subsequent waiver implementation was compiled. Its findings are summarized below.

FBF EXPERIENCE IN REVENUE SERVICE

Additional experience under the revenue service waiver granted to AAR has shown good wheel performance results. In 3 years of operation on CSX track and more than 6 months of operation on BNSF track, two fleets of hopper cars have been monitored. To date, there is no flange bearing related wheel failure. The following conclusions are derived from the wheel fleet monitoring:

- No flange bearing related wheel, axle, or truck component failures were experienced.
- Flange profile measurements show that the flange tips have stabilized into consistent profiles. This indicates that wear, not deformation, is the principal mode of degradation.
  - Flange tips develop a flat facet that is conformal to the frog running surface.
  - There is no plastic deformation of the flange (i.e., no change in flange shape) below the tip.
- With the CSX fleet, after 140,000 miles of FBF operations and previous revenue service, 67 percent of wheelsets were replaced due to wheel tread and bearing related degradation. This is expected for freight cars with an average wheel life of approximately 300,000 miles.
  - It confirms that current tread bearing and braking related wheel failure modes will continue to govern wheel life.
- Measured wheel flange heights are increasing with mileage. This indicates that wheel tread wear is greater than wheel flange wear and suggests that no additional wheel profile maintenance will be required for flange bearing wheels.
- New wheels in the waiver inspection fleets developed a more conformal flange tip profile than worn wheels. This suggests that as flange bearing becomes more common, the high initial flange wear seen in the waiver fleets will be less common.

REVENUE SERVICE WHEEL AND AXLE TESTS

Each railroad has implemented operation of a fleet of company owned cars over the FBF test diamonds to meet the requirements of the waiver. The truck rollout inspection requirement virtually eliminates the use of revenue earning cars for the inspections. Thus, complying with the waiver is expensive and logistically difficult. The CSX waiver fleet has been operating since September 2006. It consists of 12 covered hopper cars of 100-ton capacity. The BNSF waiver fleet has been operating since September 2008. It consists of 12 ballast cars (open top hoppers) of 100-ton capacity. Eight cars in each fleet have been loaded to nominal capacity. Each fleet is inspected quarterly.

FBF FLEET WHEEL REMOVAL ANALYSIS

The CSX and BNSF waiver fleets have been operating at relatively high rates of usage for up to 3 years. The waiver requires that 60,000 miles per year are accumulated. For loaded cars in the fleets, this is a high amount of traffic, which is equivalent to the loaded mileage accumulated by 120,000 miles of operation. Each fleet contained components that had been in service before FBF diamond-crossing operation began. Thus, a wide range of wheel conditions were present at the start of the tests. Figure 1 shows a plot of wheelset replacements versus miles operated since the beginning of FBF diamond operation.

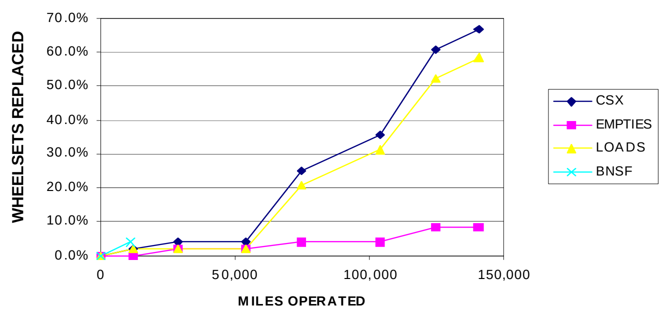

Figure 1. Wheel Removals for FBF Inspection Fleets

As expected, the removal rate of wheelsets in the loaded cars is higher than the removal rate of wheelsets in the empty cars. Note that two-thirds of the CSX fleet wheelsets were replaced during the 2.5 years of FBF diamond operation. None of the replacements were due to flange bearing. They were typical wheel axle and bearing failures found in freight car operations, with mostly wheel tread defects, wheel tread wear, and bearing related defects. Figure 2 shows typical tread shell defect wheels.

Figure 2. Typical Tread Shell Defects

FBF FLEET WHEEL WEAR

One running surface profile per wheel was measured at each truck rollout inspection. A location was selected and marked on each wheel for the profile and flange surface hardness measurements. The same location was used for each measurement. The profiles were measured using a Miniprof™ profilometer. The Miniprof used was upgraded to measure more of the flange back. This allowed better alignment of the profiles on nonwearing surfaces, such as the vertical face of the wheel back. Typically, a time series of Miniprof profiles is aligned using the flange tip and the field side edge of the wheel tread. With flange bearing, conventional profiles are difficult to align properly, as only a small section of the flange back is available to align.

Using the time series of wheel profiles taken, the wear of each wheel can be determined. In addition, the flange height of each wheel is determined. For tread bearing wheels, the flange height change rate is an indicator of wheel tread wear. For flange bearing wheels, the flange height wear rate is an indicator of the relative rates of tread wear and flange wear. Note that total tread wear exceeds flange wear for the fleet.

Thus, flanges are growing taller with use, as happens in wheels that do not experience flange bearing. This suggests no additional wheel profile maintenance will be needed for cars that travel over FBF diamonds. If flange heights decrease over time, then safety issues with switches, and eventually curving, will be of concern.

Figure 3 shows a time series of wheel profiles for car 221143 3L — a loaded car. The profiles show very little change in shape over time. The flange tips flatten from their nominal 0.5-inch radius to a 5- to 7-inch radius surface with sharper corners. As Figure 3 shows, there is no gross deformation of the rest of the flange.

The profile match over eight inspections is good on the back side of the flange. Wear from curving is seen on the tread side of the flange. These profiles demonstrate that contact stresses are manageable in flange bearing. Wheels do stabilize under these operating conditions with minimal plastic flow. Wear of the flange quickly becomes the dominant cause of flange height loss. However, wear of the tread is likely to be higher for most revenue service operations.

Figure 4 shows a time series of wheel profiles for car 225530 2R — an empty car . These profiles show even less change in shape over time. The empty car shows less vertical and lateral (curving) flange wear than the loaded car, as would be expected.

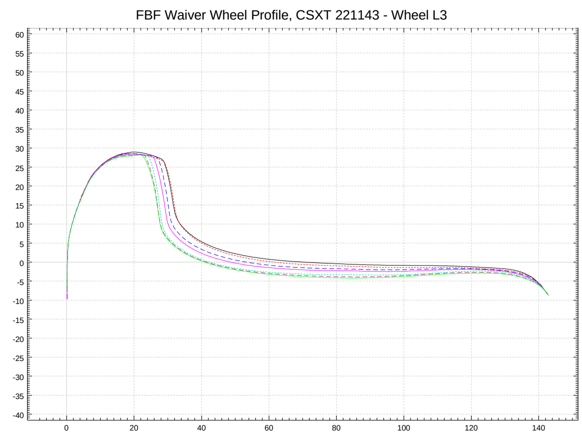

Figure 3. Time Series of Wheel Profiles for CSXT 221143 L3 (Load)

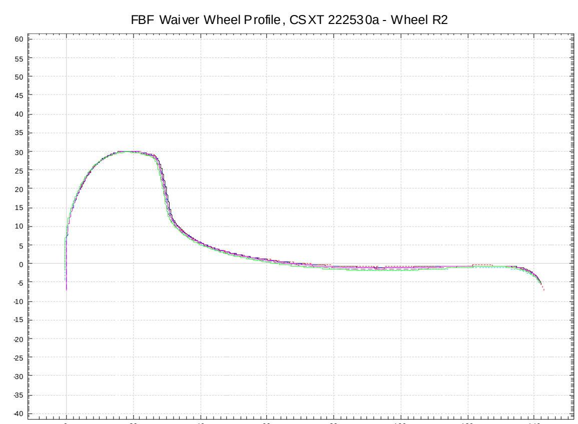

Figure 4. Time Series of Wheel Profiles for CSXT 225530 R2 (Unloaded)

The effect of FBFs on wheel wear was determined from the running surface profiles taken during quarterly inspections. Figure 5 shows the time series of wheel flange height measurements for a range of flange bearing operations. The CSX FBF fleet (500 miles per FBF pass) is performing similarly to Rail America locomotives using a One Way Low Speed (OWLS) diamond at Chenoa, Illinois (150 miles per FBF pass), the BNSF waiver fleet operating over FBF diamonds at Moorhead, Minnesota (337 miles per FBF pass), and the train cars at FAST running over test diamonds at the rate of one diamond per 100 miles. CSX FBF fleet loaded car data are shown for direct comparison to the other loaded car operations. On this graph, the CSX FBF fleet is divided into two groups (1) original wheels and (2) replacement wheels. Original wheels were in the cars prior to the start of FBF operations, and replacement wheels were installed after the start of FBF operations.

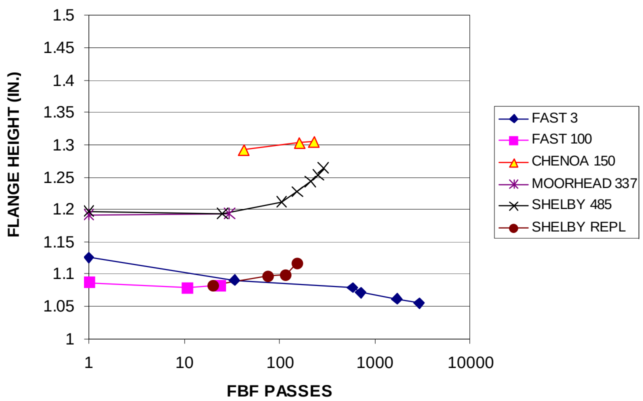

Figure 5. Comparison of CSX FBF Fleet Flange Height to Various Flange Bearing Operations

All groups, with one exception, show the same trends. Flange height remains relatively constant for the first 10-30 FBF passes. Beyond about 30 FBF passes, flange heights increase. This indicates that initial flange height losses are similar to wheel tread height losses. Initial flange height losses can be larger than subsequent losses due to the deformation of the flange tip to a conformal shape. After the initial "wear-in" period, the flange tip shape stabilizes and flange height loss rates are reduced below tread height loss rates. After the first few passes, wheels behave as they do in preflange bearing days, with wheel flange heights increasing over time.

The fleet that did not follow this flange height growth scenario was the train at FAST during the initial prototype tests. During the first prototype test at FAST, most of the train ran over a FBF diamond every 3 miles. Under these operating conditions, the wheel flange heights decreased with mileage. Also, note that the CSX replacement wheels are performing similarly to the CSX original wheels. The replacements, which are either new or reprofiled wheels, have shorter and wider flanges. Yet the rate of flange height change is similar to the original wheels.

The shapes of the flange tips have been stable since the third inspection. The original wheels are now at 253 passes over the FBF diamond. Two factors are affecting the flange tip shape. The first is the initial shape of the flange tip. For new wheels, the flange tip develops a flat facet oriented roughly parallel to the axle (i.e., horizontal). For worn wheels with metal flow (from curving) into the flange tip, the flange bearing worn flange tip profile typically has a flattened ridge of metal on the tread side of the flange tip.

The other factor affecting the flange tip shape is the back-to-back spacing of the wheelset. On wider-spaced wheelsets, the flange bearing surface is sloped toward the tread side of the wheel. On narrower-spaced wheelsets, the flange bearing surface is sloped away from the tread. This reflects the relationship of the wheel flanges to the worn grooves in the one FBF diamond they encounter. Because the cars are not turned at either yard, the same wheels contact the same side of the diamond on each pass. Figure 6 shows a typical full flange tip contact shape.

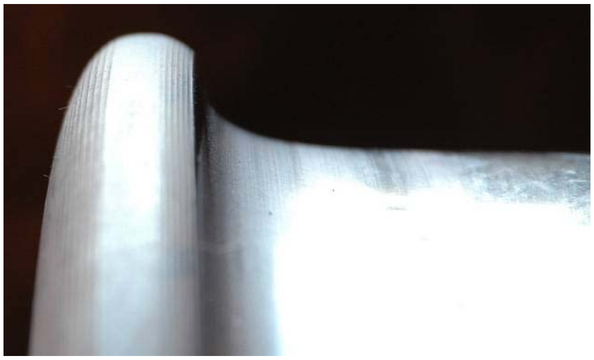

Figure 6. Flange Tip Shape for a Full Flange in Flange Bearing

CONCLUSION

The effects of FBF crossing diamonds on wheel performance in North American HAL freight service have been negligible. Test results indicate FBF diamonds provide safety and efficiency benefits to railway operations without degrading wheel performance.[2]

FUTURE WORK

FBFs, where allowed under current FRA regulations, are proliferating in North American freight operations. Installation of 10 mph, one route FBFs (e.g., OWLS diamonds and lift or jump frogs for turnouts) continues. After 6 years of service in some locations, the railways have developed confidence in these frogs.[3]

REFERENCES

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