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Evaluation of Load Environment of Flange Bearing Frogs

David D. Davis, Rafael Jimenez, and Xinggao Shu

Summary

Transportation Technology Center, Inc. evaluated the potential load environment of flange bearing frogs (FBF) under heavy axle load service. The study is being performed to assess the potential for operating various types of FBFs at speeds above 10 mph for freight trains and 15 mph for passenger trains per Class 1, Federal Railroad Administration, Track Safety Standards.[1] The tests show that 25-mph operation, over turnout frogs designed to be flange bearing for most wheels, except those with shorter flange heights, will be similar to full FBF operations at this speed.

Industry experience with wheel performance on full FBF crossing diamonds crossings has been successful. Results obtained from testing at the Transportation Technology Center's Facility for Accelerated Service Testing (FAST), Pueblo, Colorado, and in revenue service indicate that partial FBFs for turnouts will provide longer service lives and improved operations in terms of safety and efficiency.

The results obtained will also help the railways request waivers of FRA Track Safety Standards that currently limit FBF operations to Class 1 track. There are many locations, such as switching lead tracks, where 15 to 20 mph operations will allow successful use of partial FBFs.

Dynamic loading of flanges from partial FBFs used in turnouts was measured at FAST using modified tread bearing frogs for turnouts. The frogs were modified to simulate a situation where a new (i.e., short flange height) wheelset operates over a partial FBF. In this case, the wheelset will remain tread bearing through the frog. Some of these wheels may become flange bearing in the wheel transfer zone, where the wheel crosses the flangeway from wing to point. In a conventional tread bearing frog, these wheels will contact the tread bearing surface on the other side of the flangeway. However, in a partial FBF, there may be insufficient clearance for the flange; thus, the wheel contacts the flangeway floor. The tests performed measured the forces applied to the wheel flange from this wheel drop event.

The forces measured are similar to those measured on full FBF crossing diamonds for the same speeds. They are also similar or lower than forces measured on service worn tread bearing turnout frogs. At 25 mph, the maximum dynamic wheel load measured on a No. 11 frog was about 55,000 pounds. With a static wheel load of 39,375 pounds, this is a dynamic load factor of 1.4.

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Please contact **David Davis (719) 584-0754** with questions or concerns regarding this *Technology Digest.* E-mail: david_davis@ttci.aar.com.

INTRODUCTION

Transportation Technology Center, Inc. evaluated the potential effects of operating FBFs for turnouts at speeds above 10 mph. The higher speeds will generate higher dynamic loading on flange tips. This part of the wheel is used to guide the vehicle laterally, keeping it headed in the intended direction. An assessment of the likely vertical load environment for partial flange bearing self-guarded frogs was conducted using load measuring wheelsets.

The load environment at 25 mph is similar to that for full FBF crossing diamonds at this speed. Full FBF diamonds are currently allowed for track speeds up to 80 mph for freight and 90 mph for passenger under a waiver of the Federal Railroad Administration's (FRA) Track Safety Standards.[1]

BACKGROUND

Freight railways began using FBFs for turnouts in 2006. These frogs have been nicknamed "Lift" frogs because of the way they work. The high angle version of this design is used in the OWLS (One Way Low Speed) crossing diamonds. They function by lifting the wheels of the crossing line over the mainline rail. This is accomplished with a tread bearing ramp at the toe of the frog and a flange bearing ramp at the heel. The wheel also jumps a flangeway and is flange bearing on the mainline rail. Figure 1 shows a Lift frog in track at the Facility for Accelerated Service Testing (FAST). There are an estimated 1,000 of these frogs in revenue service today. This frog has brought significant increases in service life for locations in mainline turnouts where there is a low volume of slow-speed diverging route moves. They also have improved ride quality by eliminating any impacts or joints on the mainline route.

Figure 1. Lift Frog in High Tonnage Loop at FAST

A second design has been in service since 2010. This type of frog is similar to the full FBF crossing diamonds because it allows flange bearing for both routes. Figure 2 shows a partial flange bearing self-guarded solid manganese (SGSM) frog in service. These frogs are built so that most wheels will be flange bearing through each route of the frog. Wheels with shorter flanges may be tread bearing or tread and flange bearing in the wheel transfer (i.e., wing to point) zone.

These frogs are installed in heavily used yard turnouts, such as switching leads and ladder tracks. For these applications, having the ability to operate above 10 mph (in the range of 15 to 20 mph) is essential to productivity.

Figure 2. Self-Guarded Solid Manganese Frog In Revenue Service

FRA's current Track Safety Standards limit flange bearing through turnout frogs to Class 1 speeds. This limits applications to 10 mph speed for freight operations.

There are potential wheel and train operations issues with FBFs. The railway industry studied these issues at length from 1995 to 2002 with a series of studies and tests by the Association of American Railroads (AAR).[2-9] Revenue service operations of full flange bearing crossing diamonds began in 2006, with a waiver of the Track Safety Standards for minimum flangeway depth. Since then, approximately nine-million car passes have been successfully operated at three FBF crossing diamond locations. There have been no flange bearing related wheel failures nor any FBF caused derailments under this waiver.

Service Environment

During AAR's feasibility studies, an assessment of the service environment for conventional tread bearing frogs and the proposed FBFs was conducted. The studies compared predicted and actual vertical wheel loads for each type of frog.[2-9]

Tread bearing crossing diamond frogs are well known to be one of the most severe load environments in the railway. The unsupported flangeway gaps on high angle frogs cause wheel impacts that have been measured at 3-5 times static wheel loads for 40 mph speed. Less well documented is the dynamic loading on typical turnout frogs. These can often be 1.5-3 times static wheel loads for 40 to 60 mph speeds. While a wheel can span the flangeway gap on these low angle frogs, there is often a dynamic load due to significant changes in running surface elevation and shape, as well as track stiffness across the frog. Figure 3 shows the maximum dynamic load factors measured from heavy axle load testing of these frogs at FAST.[10]

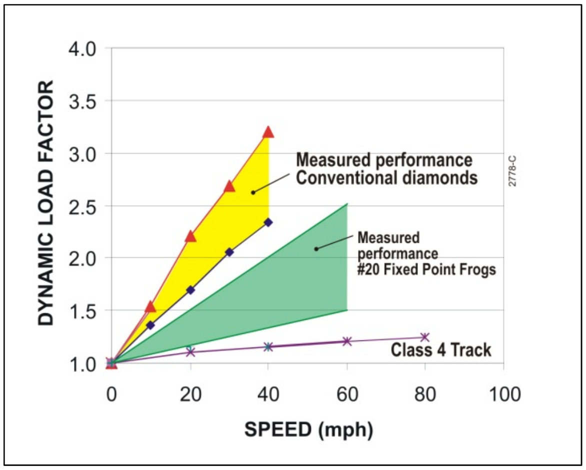

Figure 3. Measured Dynamic Load Factors for Tread Bearing Frogs

Predicted Flange Bearing Frog Forces

A series of simulations were made to develop recommendations on ramp rates for FBF frogs.[11] Figure 4 shows the results of the study. Ramp rate recommendations were developed with the requirement that dynamic wheel loads remain below 1.5 times static wheel load for typical bulk commodity freight cars.

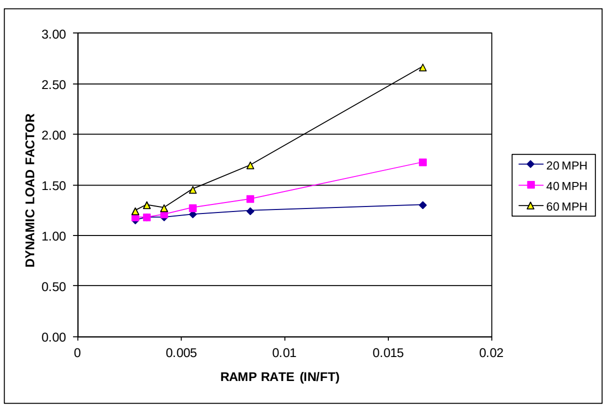

Figure 4. Predicted Dynamic Forces vs. Speed for Flange Bearing Ramps

The predicted forces for flange bearing are significantly lower than forces for high-angle tread bearing frogs at mainline track speeds. Additional measurements of prototype FBF diamonds showed these predictions to be accurate.[10] Additional issues, such as cross grooving in full FBF diamond frogs, were studied. Cross grooves are likely to be smaller than flangeway gaps.

An additional item was evaluated for the SGSM frogs. This issue may occur at the point of frog for wheels with shorter flanges. These wheels may remain tread bearing if the frog is worn until the flangeway gap. At this point, the wheel flange to contact the flangeway floor. This case was simulated by welding some rods in the flangeway of a tread bearing No. 10 frog.

The frog was custom made for the load measuring wheelsets, so that they would contact the flangeway floor only at the point of frog. Figure 5 shows the frog and wheel contact situation.

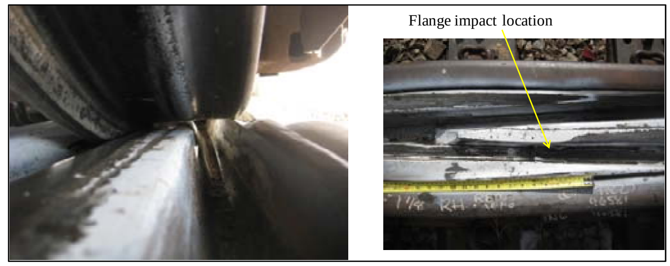

Figure 5. Wheel/Frog Contact in Flange Bearing

Measured Flange Bearing Frog Forces

Figure 6 shows a 40-mph run of the lead axle of a loaded 315,000-pound coal gondola over a No. 11 frog that was modified to simulate a short height flange wheel running over a FBF. The flangeway was modified (filled with steel plates) to simulate the unintended (by the designer) flange contact a short flange wheel may have in operating over such frogs. The test scenario in this situation has been observed at Shelby, Ohio, and Moorhead Junction, Minnesota, where a new wheel is tread bearing through the diamond until it reaches the frog flangeway gaps. The wheelset drops until it contacts the flangeway floor. This scenario will also occur on SGSM FBFs. It is also a milder version of what every wheel potentially sees on an OWLS diamond, where the wheel crosses a full flangeway gap unsupported. Note that with tread bearing frogs, all wheelsets drop until the tread contacts the far side of the flangeway gap.

Figure 6 also shows the vertical loads of the two wheels in the wheelset. VR36 is the right wheel going over the frog. The purple data line labeled “Position Right” shows the right wheel's contact position: "0" is the tread tapeline, positive indicates contact on the field side of the tread, and negative indicates contact towards the flange. Generally speaking, contact at locations less than -1.5 inches are flange bearing or back of wheel (flange) contact. The car was in a facing point move at 40 mph. The first tread impact is from a leg rail to frog joint. The second one is at the point of frog. It is likely a rapid contact location shift at the transition from wing to point. The wheelset becomes flange bearing for very short distances at ~3 feet past the point of frog (p.o.f). This event generated a 72,000-pound wheel load (72.6K/39.4K = 1.84 dynamic load factor). Beyond this point, the wheelset drifts towards the rail opposite the frog for the next 5 to 6 feet, making back of wheel contact with the frog flangeway guard near the heel end of the frog. The rail joint at the heel end of the frog generates the last tread impact. Data was collected at 2,400 samples per second. Thus, we are capturing very short duration events.

Figure 7 shows the average wheel force from two runs at each speed. The dynamic loads on the flange average about 55,000 pounds. This is a dynamic load factor of ~1.4. While this flange impact is not ideal, it is likely to only happen to short (i.e., new and presumably thicker) flanges. These forces are also within the 1.5 dynamic load factor used to design the ramps used on full FBF diamonds.

Figure 8 shows the wheel drop flange impact event at 25 mph as compared to the intended flange impact from the flange bearing ramps at each end of the frog. The flange drop dynamic load is in the range of that expected for wheel flange-ramp engagement on the designed ramps. In effect, the wheel drop event replaces the ramp engagement event for short flange wheels. Wheels in revenue service using tread bearing frogs, full FBF diamonds, and OWLS currently experience this level of dynamic loading.

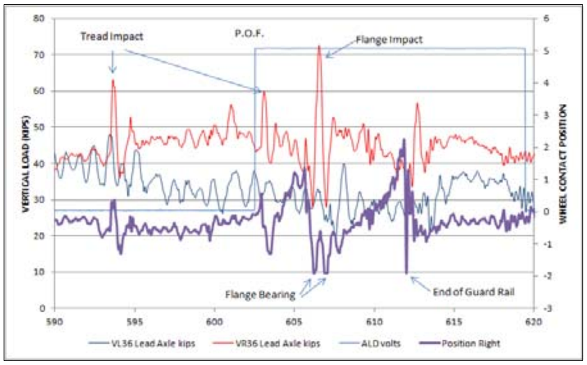

Figure 6. Measured Wheel Vertical Force at Simulated Partial Flange Bearing Turnout Frog

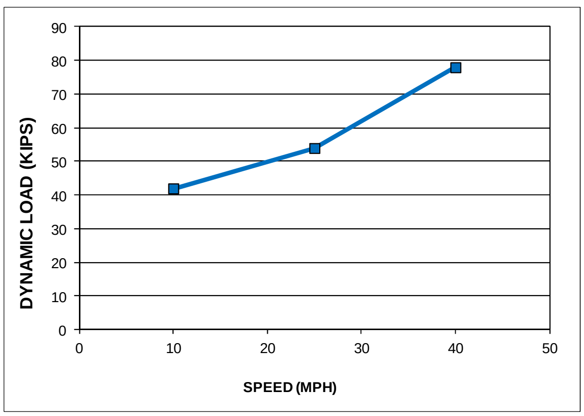

Figure 7. Maximum Dynamic Wheel/Rail Force vs. Speed over Simulated Partial Flange Bearing Frog

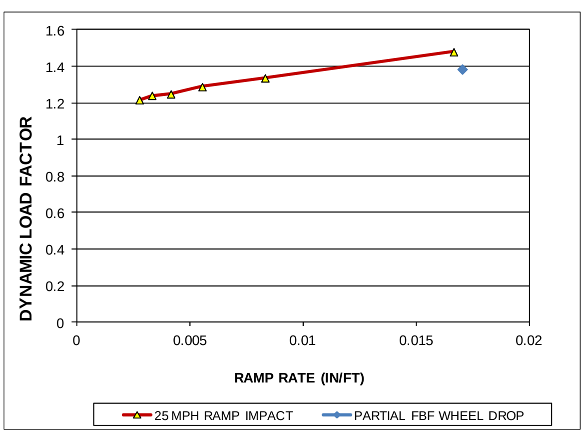

Figure 8. Wheel Flange Dynamic Load from Flange Bearing Ramps and Wheel Drop Events

SUMMARY

Dynamic loading of wheel flanges from partial FBFs used in turnouts was measured at FAST. The forces are similar to those measured on full FBF crossing diamonds. They are also similar or lower than forces measured on service worn tread bearing turnout frogs.

Industry experience with wheel performance on full FBF crossing diamonds crossings has been successful. It is believed that partial FBFs for turnouts will provide longer service lives and improved operations in terms of safety and efficiency. These test results will be useful if railroads choose to seek waivers of FRA Track Safety Standards that currently limit flange-bearing operations to Class 1 track (10 mph for freight and 15 mph for passenger service). There are many locations, such as switching lead tracks, where 15 to 20 mph operations would allow successful use of partial FBFs.

Acknowledgements

John Bosshart and Seth Ogan of BNSF Railway contributed to the planning and testing of FBFs for turnouts. They have been pioneers in the development and implementation of these concepts.

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