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Field Implementation of Flange Bearing in Crossing Diamonds

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Summary

Under sponsorship of the Association of American Railroads (AAR), Transportation Technology Center, Inc. (TTCI) and member railroads are monitoring the performance of One Way Low Speed (OWLS) flange bearing diamonds at several revenue service locations. In 2003, North American freight railroads began implementing OWLS crossing diamonds. System-wide implementation of OWLS and flange bearing frog (FBF) diamonds is expected to save the railroads \$100-200 million per year in maintenance, capital, and train delay costs.

Initial findings, after a year of field monitoring:

- To date, these diamonds are performing well in revenue service and are allowing mainline operating speeds to be increased.
- The effects of OWLS on train locomotive operation have been minimal. No changes in locomotive engineer instructions have been required. Wheel slip has not been a significant issue.
- The effects of flange bearing on locomotive wheels have been minimal. No unusual wheel defects have been reported. As in previous tests at the Federal Railroad Administration's Facility for Accelerated Service Testing (FAST), flange tips have developed a flat facet in cross section. This facet reduces wheel-rail contact stress to the levels seen in tread bearing situations. No additional wheel profile maintenance is expected.
- Offset ramps can be used for locations with low branchline speeds. Offset ramps have been successfully operated at such speed by trains at two OWLS diamonds. Use of offset ramps can lower the cost premium (of an OWLS diamond) over conventional designs to almost nil.
- Initial deformation of the flange bearing running surface at flangeway corners has been high. Additional tonnage is needed to determine long-term wear rates and expected service lives. An obvious design improvement is to build in an allowance for initial deformation. This could be ramping similar to that used on tread bearing diamonds.
- The long-term effects of flange bearing on the mainline running surface (i.e., cross grooving) needs further study. To date, these cross grooves have not adversely affected ride quality.

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INTRODUCTION AND CONCLUSIONS

High-angle crossing diamonds present significant challenges to track maintenance engineers, often causing bottlenecks in train operations. Due to the high dynamic loads generated, they 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. Thus, heavy axle load (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 flange bearing frog (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 Association of American Railroads’ (AAR) Engineering Research Committee, Transportation Technology Center, Inc. (TTCI) has evaluated the flange bearing concept for HAL operations. The concept is 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.¹ The review included input from railroad mechanical and operating officers, wheel and locomotive suppliers, and AAR mechanical committees.

While FBFs are used for many railroad applications, (including in ports where regular freight railroad tracks cross the tracks of Gantry cranes and extensively in transit operations) their use in North American freight applications are 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 Federal Railroad Administration (FRA) Track Safety Standards (Code of Federal Regulations 49, Part 213.137)² 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 allows flange bearing for Class 1 track and a limited waiver to allow testing in Class 2 and above tracks. Unfortunately, the waiver adds significant costs and disruptions to railroad operations. It has inhibited implementation of full FBF crossing diamonds.

Due to the limitations imposed by the FRA waiver, railroads have turned to a flange-bearing/tread-bearing hybrid for certain operating situations — the One Way Low Speed (OWLS) diamonds (see Figure 1). These provide flange bearing for one track only and are legal under the

existing safety standards for Class 1 track. The mainline running surfaces are continuous, with no flangeway gaps. In one design, the mainline running rails themselves can be continuous through the diamond. The branchline wheels become flange bearing as the flangeway is raised to the top of the mainline running rails and then the wheels cross the mainline flangeways. There are many crossings where OWLS would be suitable; specifically, locations where a branchline or low speed line crosses a mainline.

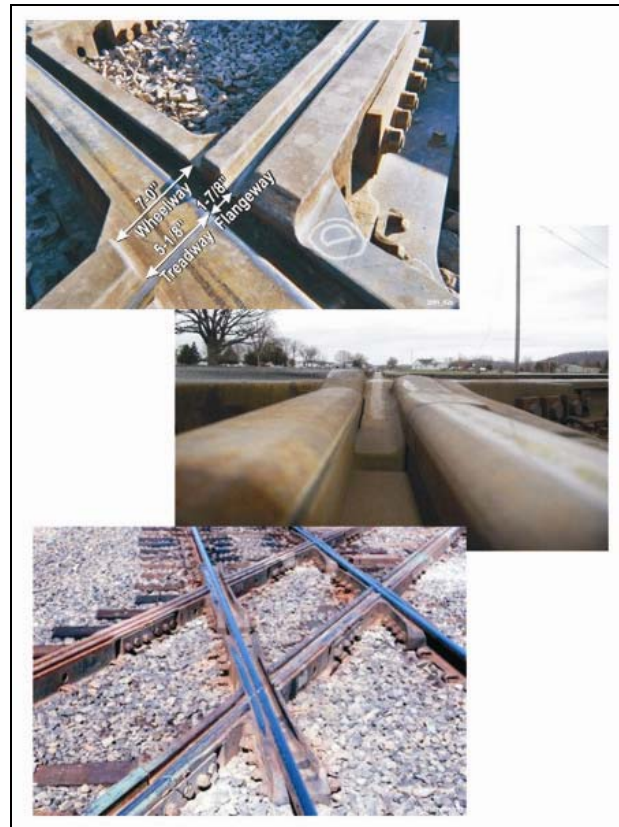


Figure 1. OWLS Frogs in Revenue Service Crossing Diamonds

Figure 2 presents measured data that shows how an OWLS diamond can re-apportion dynamic loading between mainline and branchline.

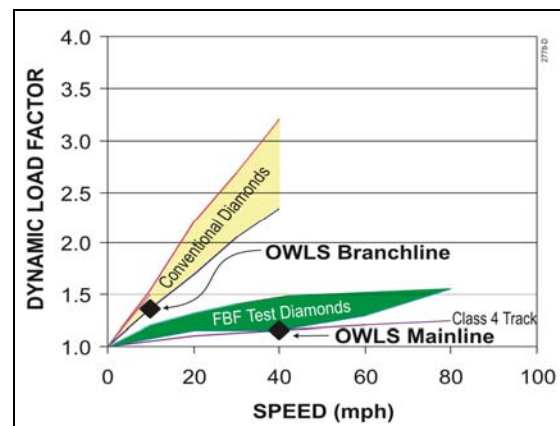


Figure 2. Dynamic Loads Measured at Crossing Diamonds

The mainline can achieve dynamic performance much more similar to that found in open track. The branchline, limited to 10-mph speeds, will generate impact loads in the range of conventional diamonds. In cases where the majority of traffic is on the mainline, OWLS diamonds are ideal for allowing a railroad to raise speeds on the mainline track of the diamond.

DESIGN CHALLENGES

Table 1 lists some of the OWLS diamonds currently being monitored in track. Varieties of designs are being used as the technology evolves. Some of the key design issues remaining involve truck steering through the tread-to-flange bearing transitions, flange deformation rates, and frog running surface maintenance. Conventional wisdom suggests that flange bearing of both wheels on an axle should start at the same time. This would prevent large rolling radius differences for the two wheels on the same axle and prevent adverse steering of the wheelset. But the diamond at Crawford, Wisconsin, has staggered ramps. To date, the diamond has not had truck steering problems; however, cross traffic is very light on the line with trains moving at less than 10 mph. Staggering the ramps allows for a shorter, less costly ramping system.

Wear and deformation rates have been determined by measuring running surface heights in the frogs of each diamond. Higher dynamic load areas, such as the flangeway corners and running surface joints in the flange-bearing surface, show higher height loss rates. These are due to deformation and lateral flow of the austenitic manganese steel at unsupported edges. Future designs should allow for the higher deformation and enable easier repair at these locations.

To date, the OWLS frogs are performing well, in general. Initial wear rates (in terms of flange bearing running surface height loss) have been higher than those seen with tread bearing surfaces. These rates are expected to drop as the running surfaces work-harden. Eventually, the population of wheel flanges at each location will become more conformal — this will also reduce wear rates.

A major issue for frog performance and diamond service life is the development of cross grooves in the mainline running surfaces caused by the wheel flanges of the branchline traffic. Factors affecting the groove wear rate include frog material, cross traffic wheel load and frequency as compared to the mainline traffic. Figure 3 shows the measured cross grooves versus frog material and diamond traffic parameters.

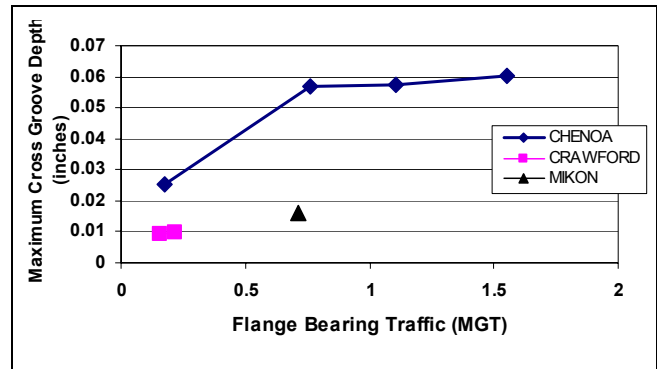


Figure 3. Cross Groove Depth versus Flange Bearing Tonnage

It is obvious that rail steel used in the Mikon diamond has less initial cross groove wear than AMS castings. It also appears that cross groove wear may be largely controlled by matching mainline rail wear with the cross groove wear rate. With more tonnage, the relative rates of mainline tonnage to branchline tonnage to minimize cross grooves will be determined. Currently, the ratio is projected to be about 1,000 to 1. It is expected to drop as the cross grooving rate decreases with tonnage.

LOCOMOTIVES/ WHEELS PERFORMANCE

The Toledo, Peoria, and Western (TP&W) railroad is participating in the Chenoa, Illinois, OWLS study by monitoring locomotive truck and wheel performance. TP&W reports no train operating problems with the OWLS crossing at Chenoa. Additionally, truck component performance has not changed during the first 10 months of operations.

TTCI measured wheel profiles on one locomotive that regularly crosses the diamond at Chenoa. Profiles were measured after approximately 35, 160, and 230 passes. Measures of flange height, flange thickness, and flange tip shape were extracted from these profiles. The wheels being monitored have performed well in flange bearing duty. The locomotives are making an OWLS crossing at the frequency of once per 150-200 miles. This is likely to be similar to the frequency encountered by mainline traffic, if flange-bearing crossings are fully implemented.

Flange bearing may also have a beneficial effect on wheel residual stresses and on retarding flange cracking. It ensures that the flange tip will be in compression, helping to keep any flange cracks from growing.

Table 1. OWLS Crossing Diamond Design and Operating Characteristics

Location	Ramp Length	Ramp Design	Allowable speed (mph)	Mainline Traffic	Branchline Traffic	Ratio Main/Branch Traffic	Comments
Chenoa, IL (UP-TPW)	10 feet	Parallel	UP – 79 (pass) TP&W – 10	0.4 MGT Passenger 79 mph 0.1 MGT Mixed Freight 60 mph	1.5 MGT Mixed Freight 10- 25 mph	1:3	Frogs are AMS castings
Mikon, CA (UP-Yolo)	4 feet	Parallel	UP – 79 (pass) Yolo – 10	30 MGT Mixed Freight 60 mph 2 MGT Passenger 79 mph	2 MGT Mixed Freight 10-25 mph	30:1	Frogs are running rails with bolt-on AMS castings
Crawford, WI (BNSF-WSOR)	2 feet (within frog casting)	Staggered	BNSF – 50 WSOR – 10	40 MGT Mixed Freight 50 mph	0.2 MGT Mixed Freight 10-25 mph	200:1	Frogs are AMS castings

Heavy service braking can cause some wheel flanges to develop residual tensile stresses over time. Flange cracking is one of the leading failure modes for curved plate wheels.

Figure 4 shows the effects of flange bearing on wheel dimensions. As in typical service, flange thickness decreases and flange height increases with use. The relatively infrequent OWLS crossings have not changed these trends. If the trends were reversed, it would indicate that significant deformation of the flange is occurring. This would suggest that periodic re-profiling of wheels due to flange bearing deformation may be needed. However, the initial findings from this study suggest that no flange bearing wheel profile maintenance will be required.

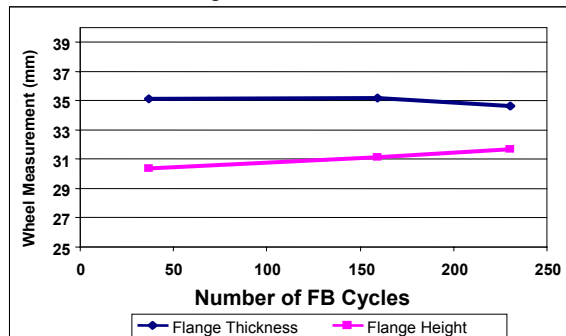


Figure 4. Locomotive Wheel Dimensions versus OWLS Flange Bearing Diamond Passes

Figure 5 shows a time series of profiles for one locomotive wheel being monitored. It is typical of the group. Note that the flange height is still increasing with time, indicating that tread wear is exceeding flange height loss. Short flanges in service are not desirable as they lead to risk of accidents at switches and in curving. However, reducing the rate of flange height gain may prolong the lives of wheels typically removed for high flange (i.e., tread wear) under AAR Interchange Rule 41.³

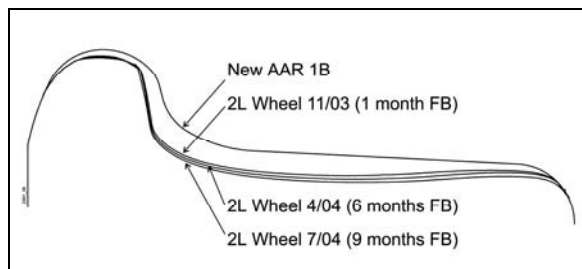


Figure 5. Time Series of Wheel Profiles from Locomotive Operating Over OWLS Diamond

Wheel performance has been measured under flange bearing conditions both in revenue service and at the FRA's Facility for Accelerated Service Testing (FAST), Pueblo, Colorado. While operating conditions have been somewhat different, the performance of wheels in flange bearing has been similar at both locations.

FAST has shown its utility in allowing for greatly accelerated service testing. At FAST, more than 6,000 passes

over a flange bearing frog diamond were made in a few months. It will take more than 20 years to accomplish the same record in revenue service. Results of the FAST tests showed that wheel flanges can withstand more flange bearing cycles than they are likely to see in a lifetime.

With frequent diamond crossings, one per FAST lap (one per 3 miles of operation), flange height decreased over time. The rate of flange deformation and wear was higher than the rate of wheel tread wear. To investigate the practical significance of this effect, a subsequent test was run with an FBF diamond on one track of a double track segment. A number of FAST cars were selectively added and removed from the train to manage the ratio of crossing diamond passes to miles of operation. Using this strategy, a ratio of one diamond per 100 miles of operation was achieved. Under this scenario, designed to approximate revenue service conditions, wheel flange heights grew after an initial high deformation in the first few flange bearing passes.

Figure 6 also shows a comparison of the FAST results with revenue service results. Under typical revenue service operating scenarios, where the ratio of miles traveled per OWLS crossing diamond passes will be 100+, wheel flange height measurements will continue to increase.

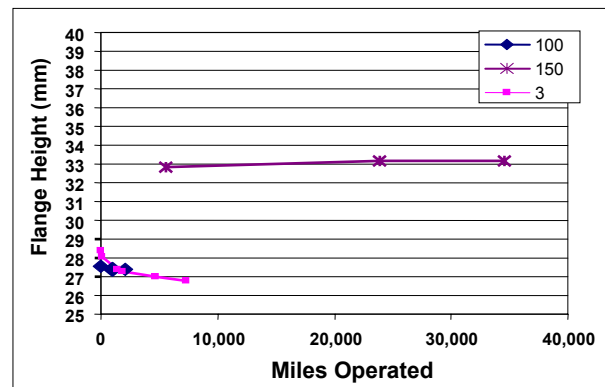


Figure 6. Wheel Flange Heights in FAST and Revenue Service Flange Bearing Operations

FUTURE WORK

TTCI will continue to monitor OWLS diamonds to determine the economics of their design. Additionally, TTCI will support the AAR and its member railroads to implement flange-bearing diamonds in higher speed track.

REFERENCES

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3. AAR Safety & Operations, *Field Manual of the Interchange Rules*, Association of American Railroads, Washington, D.C. 2002.

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