TECHNOLOGY DIGEST

Timely Technology Transfer — 99-031

EVALUATION OF A PROTOTYPE FLANGE BEARING FROG FOR HEAVY HAUL SERVICE

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Summary

The first prototype flange bearing frog (FBF) crossing diamond for heavy-haul service has outlived all eight previously tested tread-bearing diamonds in tests at the Facility for Accelerated Service Testing (FAST), Transportation Technology Center (TTC), Pueblo, Colorado. The performance of this prototype design was evaluated in parallel with the evaluation of the performance of wheels under flange bearing with 39-kip loads.

Significant findings to date include:

- In the closed-loop operation at the FAST High Tonnage Loop, the wear rates of flange bearing surfaces are initially high, but quickly diminish to acceptable levels.
- Flange bearing ramp running surfaces made of rail steel had a projected wear life of 1,000 million gross tons (MGT).
- FBF running surfaces, made of austenitic manganese steel, had a projected wear life of 600 MGT.
- The diamond suffered from pumping at one set of joints between the flange bearing ramps and the frog castings.
- A joint retrofit, to alleviate the abrupt stiffness change at the joint, was effective in mitigating the pumping problem.

Projected life is based on tonnage needed to obtain 0.25 inch of running surface height loss in the flangeway.

The prototype diamond is a completely functional 90-degree crossing diamond. The design is a modification of the Nortrak Lapped Beam™ tread bearing diamond. The Nortrak 90-degree FBF diamond survived 36.8 MGT of heavy axle load traffic. While the FBF diamond outlived previously tested tread bearing diamonds, a diamond with premium bainitic-steel running rails has subsequently survived longer at FAST and is still in service at 46 MGT.

These tests were sponsored by the Association of American Railroads and the Federal Railroad Administration under the FAST Heavy Axle Load experiment. The AAR Special Track Work Research Program has sponsored the evaluation and procurement of FBF diamond prototypes.

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Work performed by TTCI Transportation Technology Center, Inc.
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August 1999©

INTRODUCTION

A flange bearing version of the Nortrak Lapped Beam™ design crossing diamond has outlived eight previously tested designs under heavy-haul conditions at FAST. The purposes of the test were:

- Verify previous theoretical and experimental work that shows 38-inch wheels are capable of flange bearing under 39-kip wheel loads.
- Develop sufficient performance data to obtain a waiver of FRA track safety standards for minimum flangeway depth in truck classes 2 through 5.
- Develop operating and maintenance experience under heavy axle load (HAL) flange bearing frog (FBF) operations.
- Evaluate and refine FBF crossing diamond designs for revenue-service applications.

The diamond consists of four large austenitic manganese steel (AMS) castings, or beams. Two beams in a half-lapped joint form each frog. In the tread bearing version, the casting ends are shaped like rails. Leg rails are flash butt welded to the castings to provide a jointless running surface on the mainline track.

In the flange bearing version, the joint detail remains the same for the tread rail. The flange bearing ramp rail is bolted to the tread rail and butt-jointed to the casting. Also, the castings were modified to provide a raised flangeway bottom and more support under the flangeway. Exhibit 1 shows the diamond as installed at FAST.

Exhibit 1. Nortrak 90 Degree FBF Diamond at FAST

BACKGROUND

The life expectancy of conventional crossing diamonds operated under HAL traffic is dramatically shortened compared to 100-ton or mixed-freight operations. Testing at FAST has shown that conventional diamonds have very short lives (i.e., 5-15 MGT). The goal of AAR's research program on crossing diamonds is to improve performance of high angle diamonds to the point where slow orders are eliminated. This will require reduction of impact loading while increasing speeds.

Flange bearing diamonds have a long history of successful use in less demanding service applications: both medium-speed light-tonnage and low-speed heavy-tonnage situations. Tests of the FBF concept for high-angle diamonds under HAL traffic has been ongoing at FAST using the 39-kip wheel load train under 40 mph operations.

FAST OPERATION RESULTS

The diamond was tested on the High Tonnage Loop (HTL) at FAST in 1998 and 1999, during both lubricated and dry test phases, accumulating 36.81 MGT and 3,376 train passes. The performance of wheels under FBF diamond operation was reported in TD 99-012. The AAR has applied for a waiver of track safety standards for FBF diamond revenue-service testing based on the results of the evaluations done by TTCI. The train is equipped with three types of premium suspension trucks. While the main performance benefit of these trucks is better steering, they also reduce rail batter at joints and welds.

The performance of the running surface materials has been good, with the exception of the joint areas where pumping has been a problem. With flat running surfaces and rounded wheel-flange tips, the initial wear rates of both the frog and wheel running surfaces were quite high. As the frog running surfaces work-hardened and wore to a more conformal shape, the wear rates decreased. Exhibit 2 shows the projected wear life vs. tonnage for the FBF ramp rail and the frog castings. The wear life projection is based on the tonnage needed to reach a cumulative 0.25 inch of running surface height loss at the current wear rate. At this point, the shortest flanges in service would remain tread-bearing through the diamond. The increase in projected life vs. tonnage reflects the constantly decreasing wear rates. Of course, the service life of the components could be extended by building up the running surface or by removing material from the tread bearing running surface to provide clearance.

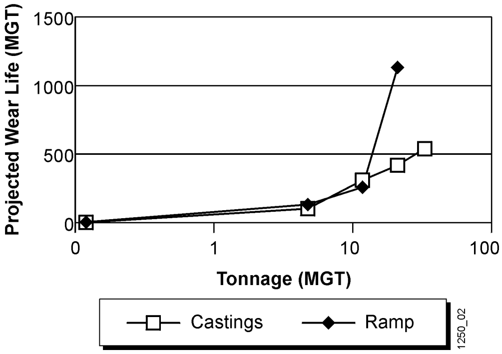

Exhibit 2. Projected Wear Lives of Flange Bearing Diamond Running Surfaces

The joint pumping is related to the abrupt stiffness change resulting from the particular joint design used in this diamond. The large stiffness change is the result of TTCI's desire to have more easily replaceable ramp rails. This detail can easily be remedied on future crossing diamonds; the FAST diamond has been retrofitted with an improved joint. The reason for the original provision to have replaceable ramp rails — concern about high wear rates — has proven not to be a problem under FAST/HAL operation. The wear rates on the heat-treated rail (ramps) and AMS castings have been very low. The projected wear life of each component is more than 500 MGT, well beyond the expected life of a conventional diamond in this service.

CASTING FAILURE

The casting failure is shown in Exhibit 3. The running surface sheared laterally at the end of the casting. This area is weaker than the rest of the casting in that there is a flangeway wall on only one side of the running surface. The other side has a separate guardrail. The running surface had been repaired by grinding and weld buildup on two occasions. The failure initiated from cracks originating in the heat-affected zones of the previous repairs. It was deemed impractical to repair the casting again, and testing was halted until the next set of castings (in bainitic steel) is ready.

Exhibit 3. Casting Cracking That Caused the Diamond Removal

The pumping at one set of casting ramp joints necessitated the frequent weld repairs. There were considerable problems in keeping the ramp rail elevation and the casting flangeway bottom elevation the same under load. This resulted in height mismatches that lead to impacts and running surface batter. The ramp rails were not affixed securely to the casting or its baseplate. They tended to lift off the baseplate between passing wheels.

A broken axle derailment occurred at FAST after about 30 MGT of traffic had been accumulated over the FBF diamond. The derailment did considerable damage to the diamond. While the derailment was unrelated to the diamond, it may have affected its subsequent performance. The diamond was bent out of alignment in the derailment, causing wheels to move sideways at the joints that failed 6 MGT later.

IMPROVED JOINT STIFFNESS TRANSITION

An analysis of the diamond was conducted to determine a solution to the joint pumping problems encountered. Structure changes on the ramp side of the diamond were investigated using an elastic layer model. Results of this analysis confirm that there is a large stiffness change at the ramp casting joint. TTCI investigated several potential modifications to the as-built diamond, focusing on reducing deflection on the ramp rail side.

Exhibit 4 shows the diamond structure as modeled. The casting side was modeled as a casting sitting on a 1.25-inch plate with 10x24-inch crossties spaced at 29 inches. The ballast was an

American Railway Engineering and Maintenance of Way Association No. 4 gradation traprock over a sandy silt subgrade. The ramp side was modeled as the ramp and tread-bearing rail sitting on 9-inch-wide plates with 7x9-inch crossties spaced at 19.5 inches.

The significant stiffness change at the casting/ramp rail joint is not unusual for crossing diamonds in service. The fact that the diamond has an angle of 90 degrees, putting the joints side by side, makes this a worst-case situation. Exhibit 5 shows the predicted loads and deflections for the ramp rail and casting structures.

The model predicts that the rail side will experience about 10 percent more deflection under load than the casting side. This may create a discontinuity in the running surface at the ramp rail/casting butt joint. Furthermore, the ballast pressure is more than 50 percent higher on the rail side than the casting side (about 46 psi vs. 28 psi). This will result in long-term differential settlement of the diamond. In the case of FAST, the north casting/ramp joints required tamping on a very frequent cycle (i.e., about 2 MGT). The north joints were "pumping" severely, resulting in high impacts, loss of surface, running surface batter, and many broken fastener components.

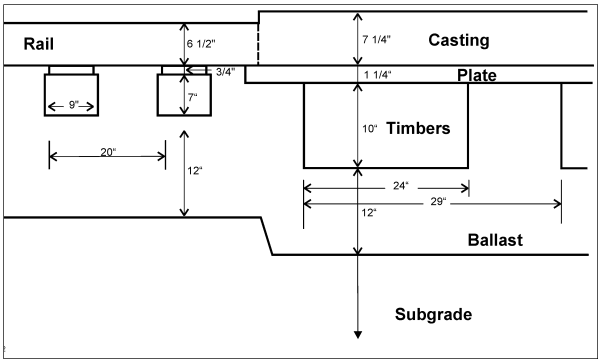

Exhibit 4. Crossing Diamond Modeled Structure

A parametric study of the effects of various rail side structure parameters was conducted. Tie cross-section and spacing were varied to determine their effects on maximum deflection and maximum ballast pressure. For example, changing tie spacing from 20 to 14 inches on the ramp side will decrease the maximum deflection to the level seen on the casting side.

Shortening tie spacing and increasing tie height both appear to be reasonably effective at lowering the maximum deflection of the rail side. At FAST, the joints were modified by shortening tie spacing, butting the first tie against the longitudinal timbers under the castings, and installing a two-tie plate under the rail side of the joint. The modified joint performed better, alleviating the pumping, but running surface problems remain.

The long-term solution is to better align the ramp with the casting under load. This can be accomplished by welding the two together or providing a direct mechanical fastening. A pattern change will be needed to allow flash-butt welding of the ramp rail to the casting.

FUTURE WORK

A pair of replacement castings is being made of J9 (medium-carbon) bainitic steel. The diamond will be reinstalled in the HTL with these castings and the modified joints for further evaluation.

Note: Contact Dave Davis at (719) 584-0754 with questions or comments about this document.
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Side	Tie Depth (Inches)	Tie Width (Inches)	Tie Spacing (Inches)	Tie Length (Inches)	Track Modulus (PSI)	Track Stiffness (LBS/IN)	Max Tie Deflection (Inches)	Max Ballast Stress (PSI)
CASTING	10	24	28.5	168	3,585	393,939	0.099	27.7
RAIL	7	9	20.0	108	3,819	348,214	0.112	46.2

Exhibit 5. Predicted Properties and Performance of Nortrak 90 FBF Diamond

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.