TECHNOLOGY DIGEST
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"THE EFFECTS OF WHEEL BRAKING ON FLANGE BEARING FROGS"

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Summary

The Association of American Railroads is evaluating the Flange Bearing Frog (FBF), an alternative low-impact crossing diamond concept, as part of the Advanced Diamond research program at the Transportation Technology Center, Pueblo, Colorado. While FBFs offer potentially large savings in track maintenance costs and train operations delays, the possible negative effects from FBF operations need investigation before FBFs are placed in service. Industry experts on track, freight car wheels, locomotives, and train operations provided input on possible areas of concern. These potential problems are being evaluated by analytical and experimental methods. The AAR evaluated the potential effects of flange bearing to cause wheel sliding on empty cars should they be braking while traversing an FBF.

For test purposes, test wheels that were forced to slide across the FBF by applying hand brakes on empty 70-ton cars produced damage to the flange tips consisting of metal flow, slid flats, and bluing at the flange tips. A deeper thermal effect occurred on thin flange wheels than on wheels with nominal (in-spec) flanges. The five thin flange wheels had martensite present to an average depth of 0.028 inch. The five in-spec wheels had martensite present to a depth of 0.016 inch.

Metallurgical analysis of the slid flats showed a hard surface layer of martensite 0.01-0.04 inch in thickness. Under this layer is a region where the steel microstructure has been changed to include martensite. In three of the test wheels, the martensite layer had minor cracks extending to the underlying pearlitic or bainitic wheel microstructure.

In subsequent testing of randomly selected, empty 100-ton capacity cars, full-service braking was sufficient to cause the cars to slide wheels across the FBF. This was consistently accomplished with these service-worn cars moving across the frog at speeds of 10-30 mph. Full-service braking caused some wheels to slide after transitioning from tread to flange bearing; they tended to continue sliding after transitioning back to tread bearing.

A fatigue test of slid-damaged flanges resulted in no spalling or cracking of the wheels during 30,000 low speed cycles over a FBF. This suggests that a slid-damaged flange is not, of itself, sufficient to cause a broken wheel.

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Suggested Distribution:

- ☐ Planning & Analysis
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INTRODUCTION

The Flange Bearing Frog (FBF), an alternative low-impact crossing diamond concept, is being evaluated by the Association of American Railroads (AAR) through the Advanced Crossing Diamond research program. While FBFs offer a potential for large savings in track maintenance costs and train operations delays, the possible negative effects from FBF operations need to be investigated before FBFs are placed in service. The AAR is evaluating potential areas of concern as noted by industry experts on track, freight car wheels, locomotives, and train operations. Tests conducted at the Transportation Technology Center (TTC), Pueblo, Colorado, evaluated the potential effects of flange bearing to cause wheel sliding on empty cars should they be braking while traversing an FBF. The FBF concept would be most viable if the effect of slid wheels over FBFs was negligible. However, if required, flange damage due to sliding wheels might be handled by adding appropriate "why made" codes in the AAR interchange rules. Information from these tests will be used by the AAR Special Track Work and Track Component Task Force to guide the Crossing Diamond research program.

In this test, the potential for wheels to slide while flange bearing under braking conditions was evaluated. The reduced contact area between flange and frog, as compared to the contact area between tread and rail, is of concern in developing sufficient traction for locomotives and for train braking. The braking issue is of major concern with empty cars for which braking force ratios are highest.

Empty and loaded freight cars with 33-inch wheels were tested traversing a flange bearing frog by purposely sliding their wheels. The cars had their hand brakes applied just prior to entering the FBF and the resultant slid flats were examined metallurgically. A total of 10 wheels were sectioned and examined: 2 by AAR and 2 each by wheel suppliers Griffin Wheel, ABC Rail Products, Standard Steel, and Edgewater Steel.

Approximately 4700 crossing diamonds are in service on North American railroads; the AAR estimates $240 million is spent annually on replacement and maintenance of these diamonds. The initial cost of a crossing diamond is approximately $100,000 and average maintenance costs are $700 per million gross tons (MGT). Crossing diamonds also affect service reliability and line capacity. High angle crossing diamonds have very short lives (i.e., 100-200 MGT) relative to conventional track or even mainline turnout frogs. In addition, frequent crossing diamond maintenance operations require permanent or temporary slow orders causing disruptions to train service. Crossing diamonds frequently cause traffic bottlenecks on high tonnage lines. These delay costs can easily exceed the actual diamond maintenance costs. An estimated $421 million in annual train delay costs due to slow orders and track outages can be attributed to crossing diamonds. These slow orders generally result from impact load-related damage caused by the unsupported flangeway gaps in the diamonds.

Life expectancy of conventional crossing diamonds operated under heavy axle load (HAL) traffic is dramatically shortened compared to 100-ton or mixed freight operations. Testing at TTC's Facility for Accelerated Service Testing (FAST) has shown that high angle conventional diamonds have very short lives (i.e., 5-15 MGT). Unlike turnouts, the use of premium components in conventional designs does not restore the average life to what it was under 33,000 pounds wheel loading. With conventional diamonds, the limits of the technology may have been reached.

RESULTS

In an effort to assess the potential for damage to wheels from operating over FBFs, AAR conducted a sliding wheel test. Wheels were purposely slid through a FBF to determine what effect this condition would have on the flange. It is assumed that some wheels will slide while negotiating frogs if FBFs are used in the freight railroad network.

As shown in Exhibit 1, damage consisted of slid flats of various lengths on the flange. This resulted in the formation of a hard martensite layer at the slid flat surface.

This layer varied in thickness with the flange and slid flat dimension. The average thickness of the martensite layer was 0.028 inch on the thin flange wheel flats and 0.016 inch on the in-spec wheel flats. The martensite layer was typically cracked and, in two cases, the cracks extended to the pearlitic structure underlying the martensite layer. Exhibit 2 shows the cracking in one thin flange wheel.

Exhibit 1. Wheel Flange Damage Evaluation

Wheel Code	Braking Regime	Wheel Condition	Brake Condition	Speed (mph)	FBF Length (feet)	Flange Damage	Max. Depth Martensite (inches)
15-R	hand brake	thin flange	non-conformal*	2-5	14	24-inch flats,† martensite	0.030
15-L	hand brake	worn flange	non-conformal	2-5	14	30-inch flats,† martensite	0.030
16-R	hand brake	worn flange	non-conformal	2-5	14	2-inch flats, martensite	0.010
16-L	hand brake	thin flange	non-conformal	2-5	14	2-inch flats, martensite	0.025
8-R	hand brake	thin flange	non-conformal	2-5	14	3-inch flats, martensite	0.040
8-L	hand brake	worn flange	non-conformal	2-5	14	1.5-inch flats, martensite	0.023
22-R	hand brake	worn flange	non-conformal	2-5	14	14-inch flats,† martensite	0.008
22-L	hand brake	thin flange	non-conformal	2-5	14	5-inch flats, martensite	0.019
99-R	hand brake	thin flange	non-conformal	2-5	14	4-inch flats, martensite	0.028
99-L	hand brake	worn flange	non-conformal	2-5	14	flats, martensite	0.010
TTC-R	service	worn flange	conformal	30	3	none	NA
TTC-L	service	worn flange	conformal	30	3	none	NA
TL1-R	service	worn flange	conformal	10	14	3-inch flats, martensite	not measured
TL1-L	service	worn flange	conformal	10	14	3-inch flats, martensite	not measured

*** Test wheels were installed in car prior to test. The worn shapes of wheels and brake shoes did not necessarily match.**
† Multiple passes and wheel slippage during sliding produced large areas of continuous small flats.

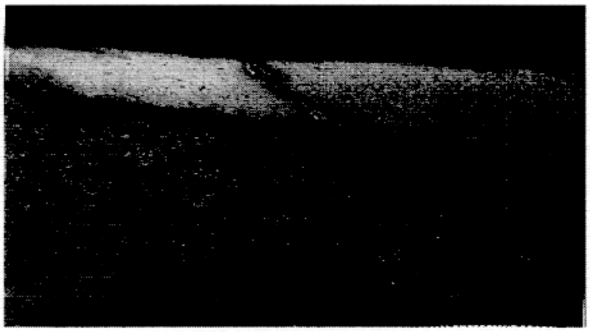

Exhibit 2. Martensite Cracking in Thin Flange

The AAR selected eight wheel sets from a carload of condemned 33-inch wheels supplied by Union Pacific. Each of the eight wheel sets selected included at least one wheel that had a thin and/or high flange. These wheel sets were installed in empty or lightly loaded cars for testing. Due to the non-conformality of the wheels and brake shoes, it was difficult to slide wheels under any normal braking regime. However, slid flats were produced by tightening the hand brakes on the cars just prior to running over the FBF. This caused the wheels to slide on their treads, up onto their flanges, over the frog, and back to their treads. Visible flats were produced on both tread and flange with this process.

Five wheel sets were sectioned for examination. AAR examined the slid flats on one wheel set; wheel manufacturers including ABC, Edgewater, Griffin, and Standard also examined one wheel set each. Exhibit 3 shows the thin flange wheel examined by AAR.

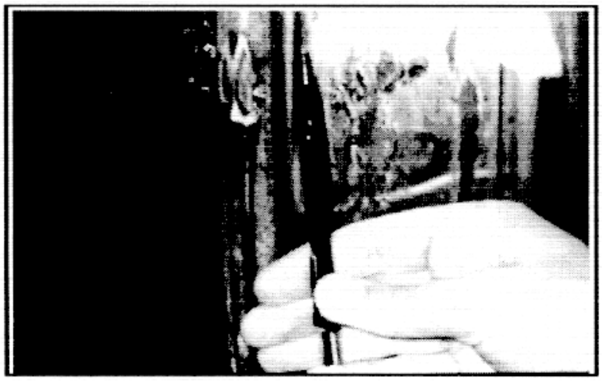

Exhibit 3. Flats Generated by Dragging a Wheel over the FBF

RUNNING ON A SLID-DAMAGED WHEEL

A pair of 36-inch wheel sets were slid over the FBF by applying full-service braking to empty cars. Hardness measurements confirmed that the slid flat areas were transformed to martensite. These wheels were then installed in the Track Lab vehicle at TTC for fatigue testing over transit (i.e., short ramp) FBFs. The wheels were subjected to 30,000 cycles of low speed flange bearing to determine the durability of slid-damaged flanges.

The wheels survived the 30,000 cycles with no spalling or cracking. Visual inspections were supplemented with ultrasonic and magnetic particle inspections before the test and at 5,000-cycle intervals. The encouraging results suggest should a wheel slide on a FBF, it is not likely to break due to running over subsequent FBFs. There will be sufficient opportunities to inspect the wheel under normal wheel inspection cycles before a FBF-induced spall breaks out or a crack grows.

A saw cut analysis was performed on a 33-inch wheel used in previous FBF wheel braking tests. This wheel had several skid flats on the flange that were found to contain martensite. The non-slid flat areas of the wheel were in compression from flange tip to well into the rim of the wheel where saw cutting ended. This agreed with previous AAR testing of service worn Class C wheels. The flange bearing wheel had residual compressive stress in the flange tip; whereas, the tread bearing service worn wheel had some tension in the flange tip. The saw cutting data from the slid flat area of the flange bearing wheel showed a pattern similar to that of the non-slid flat areas with the exception of the surface of the flange tip. The slid flat area had a very thin layer of about .02-.03 inch that was in tension. Undoubtedly, this layer is the thermally damaged martensite found by the metallographic examinations. Below this layer, however, the wheel was in compression.

Saw cut data suggests that cracks originating in the slid-damaged layer are not likely to propagate through the flange, rim, and plate of the wheel because the rest of the wheel remains in compression. The thermal damage caused by flange slid flats is localized and of insufficient energy to alter the residual stress state of the rim or plate of the wheel.

ACKNOWLEDGMENTS

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Note: Contact Dave Davis (719) 584-0754 with questions or comments regarding this document. E-mail: david_davis@aar.com

A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH THE AAR, PUBLICATION ORDER PROCESSING, 50 F STREET, NW, 5TH FLOOR, COG, WASHINGTON, D.C.,20001