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Premium Rail Performance Under 39-Ton Axle Loads at FAST

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Summary

The current test at the Facility for Accelerated Service Testing (FAST) of high-hardness premium rails from five suppliers has again demonstrated that rail performance is affected by a combination of parameters. Wear, though important, is only one factor in determining rail life. Poor fatigue performance can significantly shorten the life of rail that excels in wear resistance. Testing that began in 2005 has identified differences in wear and fatigue performance among the rails. In addition to differences that can be attributed to metallurgy, track geometry also has affected rail performance. This *Technology Digest* (TD) describes results of the tests at FAST through 425 million gross tons. A separate TD will focus on the metallurgical reasons for the observed performance. Results from this test include:

- There is about 20 percent more wear on the worst (wear) performing rail compared to the best performing rail.
- The relative wear rates among the rails have changed over time, most likely due to differences in the work hardening characteristics of the rails.
- Rolling contact fatigue (RCF) on the low rails in test is more severe than was observed on the rail that was tested from 2001 to 2005. The current rail is about 15 HB* harder.
- There are differences in the severity of RCF through the 5-degree test curve. The differences are attributed to rail metallurgy and to variations in track gage in the test curve.
- Relative RCF performance, comparing rail types, is different on the high rail than on the low rail.
- There have been no rail breaks due to railhead defects at this time.
- There have been two rail breaks that initiated in the rail base to date.

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BACKGROUND AND INTRODUCTION

The rail manufacturing industry continues to develop and improve its product. Rail is a high-value asset for the railroad industry, and higher axle loads, tonnage, and speeds place ever increasing demands on the rails. This is the driving force behind the development of longer lasting rails. Wear resistance has always been an important factor in assessing rail performance, and wear performance has typically been improved by increasing rail hardness. However, harder premium rails have shown higher notch sensitivity, higher crack propagation rates, and an increased tendency to develop RCF.[1] Testing can provide valuable safety and economic information on the interaction among these performance factors. The current rail experiment at FAST is evaluating the performance of the following five high-hardness premium rails:

- Nippon Steel Corporation – HEX
- JFE Steel America, Inc. – SP2
- Mittal High Carbon Steel
- Rocky Mountain Steel Mills – OCP
- Voest-Alpine – Low alloy high-carbon rail type UHC-HSH

One rail type, NSC HEX, has been designated as the control rail. Every third rail through the curve (both high and low rails) is a control rail. For wear performance, comparisons are made 4 and 8 feet from the weld between the control rail and the respective test rails. Thus, the comparisons are made at similar locations in the curve, reducing the effects of curve position on rail performance. Figure 1 illustrates a short portion of the test layout. Each noncontrol rail is adjacent to a control rail six times; i.e., three each on the high and low rails.

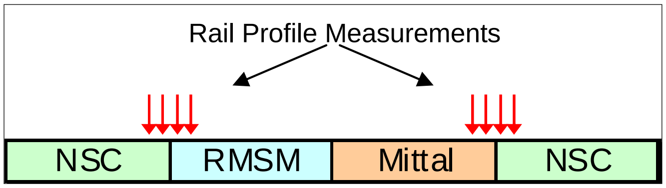

Figure 1. Rail Layout and Measurement

RESULTS

Wear

Figure 2 shows a comparison of the wear on the high rails. Area loss is measured, and the ratio between the control rail and each of the noncontrol rails is calculated. The control rail was wearing less than the other rails early in the test. The early advantage may be attributable to a better initial profile match between the control rails and the FAST wheels, and less decarburization on the rail surface. Neither was quantified.

Relative wear performance has continued to change during the test. Two of the rails have worn less than the control rail after 400 MGT; one is nearly the same, and one is wearing more than the control rail. The change in wear can be attributed to variations in the metallurgy of the rails that affect the way the steel work hardens. The rail with most wear is wearing about 15 percent more than the control rail; the rail with least wear is wearing about 7 percent less than the control rail. Area loss after 400 MGT averages just over 0.4 square inch, which is about 8 percent of the head area.

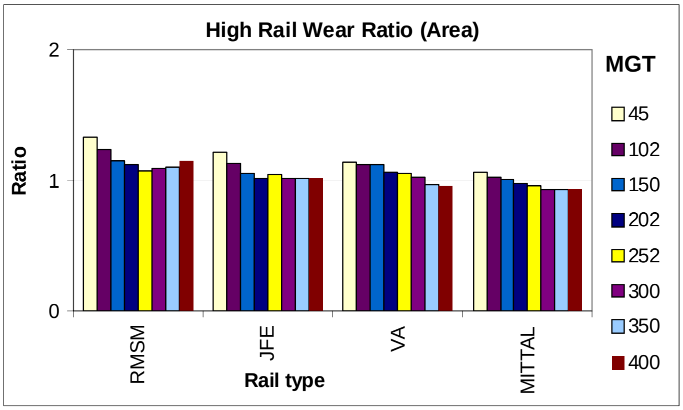

Figure 2. High Rail Wear Ratios

Although the 8 percent of head area loss is only about 1/4 of the total wear allowed by some railroads, the high rail is nearing the end of its wear life. A disproportionate share of the wear is lateral wear because the rail is installed in a nonlubricated 5-degree curve. With lateral wear approaching 1/2 inch, the rail has an estimated 100-150 MGT of wear life remaining under current operating conditions. Figure 3 shows a new rail profile and compares it to a rail profile worn with 400 MGT of traffic.

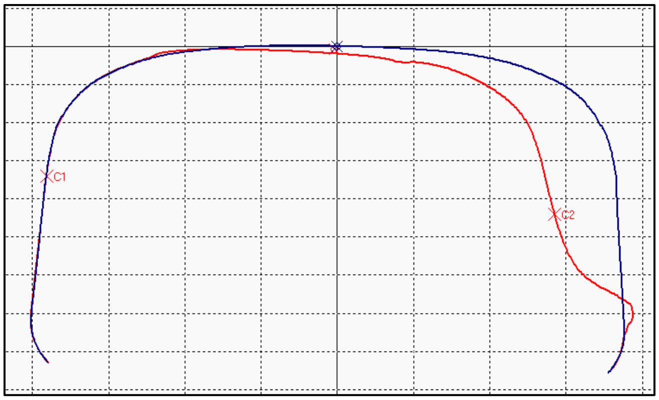

Figure 3. New Rail Profile (Blue) Worn Rail Profile (Red)

Rolling Contact Fatigue

RCF can be detrimental in several ways. The cracks can grow into the rail and cause rail breaks, the poor rail surface conditions can diffuse the ultrasonic signal that rail flaw detection vehicles use to find rail defects, and the need to remove RCF with rail grinding reduces rail wear life.

RCF developed with less tonnage on the low rails in this test compared to the rails in the previous test (2001–2005). The low rail in the current test had to be ground after 270 MGT; the low rail in the previous test was not ground through 478 MGT. The current rails average 15 HB harder than the rails in the previous test. But, hardness alone does not determine a rail's propensity to develop RCF. Metallurgical characteristics including detrimental phases (e.g. pro-eutectoid cementite) and hard inclusions affect the development of RCF. A separate TD will examine these aspects.

There are differences among the rail types in the amount and severity of RCF. Figure 4 shows two rail types with an electric flash weld between them. Note that the rail on the right has more RCF than the rail on the left.

Figure 4. Difference in RCF

The rails were inspected, and the degree of RCF was characterized for each rail at each tie. The conditions were grouped as (0) little or none, (1) mild to moderate, or (2) heavy RCF. The rail on the right in Figure 4 would be classified as having heavy RCF; the rail on the left would be little or none. The low rail was characterized at 270 MGT, prior to grinding. Both low and high rails were characterized at 400 MGT (see Figure 5). The best and worst rails had RCF on 20 and 75 percent of their respective low rail lengths at 270 MGT. Performance was different after 400 MGT. The low rail that had the most widespread, but not most severe RCF after 270 MGT was best after 400 MGT.

This can be attributed to the depth of the RCF. Almost all of the shallow RCF was removed by rail grinding, while some of the deeper damage remained. Since crack initiation is a major portion of crack development and growth life, rails with cracks that remained after grinding developed RCF more quickly than rails without cracks. Also worth noting is that the high rail conditions do not match the low rail condition. The rail with least RCF on the low rail has the most RCF on the high rail. The nonlubricated high rail at FAST wears rapidly, but the low rail wears very little. The difference in wear rates in combination with the different characteristics of the rails produces the difference in RCF conditions.

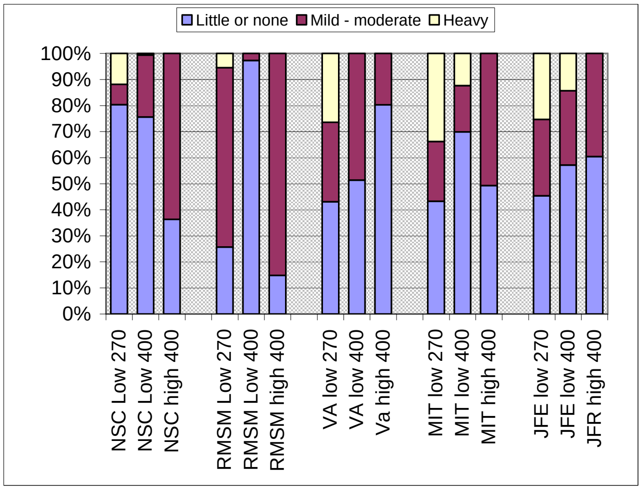

Figure 5. RCF Characterization

There are also nonmetallurgical factors that affect the occurrence of RCF. There were several locations in the test curve where track gage exceeded 57 inches (the FRA limit for Class 4 track is 57.5 inches). Heavy RCF was more prevalent at 270 MGT where the gage was above 57 inches (see Figure 6). There was heavy RCF at a few locations where rail gage was less than 57 inches, but it was more common where the gage was wider. But, 57 inches is not a standard number that can be applied to all tracks as a gage measurement that will promote RCF. Wheel and rail profiles at FAST are atypical compared to those in revenue service. There is a single train at FAST that runs on the 2.7-mile track. The wheels and rails wear to a conformal shape. The wider track gage causes the inside wheels to contact the low rail differently than they normally do, increasing contact pressures. Nevertheless, there is anecdotal information from railroads that wide gage contributes to RCF development on their lines. The wide gage locations were corrected soon after the rail was ground at 270 MGT. RCF is returning more uniformly through the curve, with the primary differentiating factor being rail type.

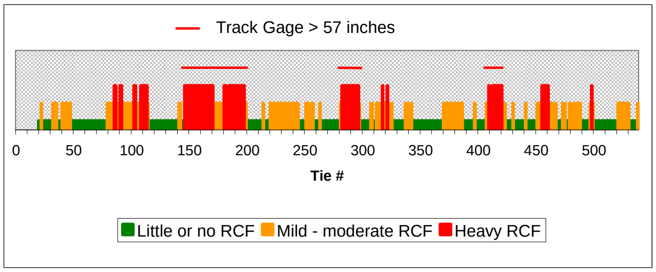

Figure 6. Relationship between Track Gage and RCF

Rail Breaks

There were seven rail base breaks in 478 MGT during the previous test, raising concerns that rails with harder bases might be more likely to break from base defects.[2] Despite the bases of the rails in the current test averaging 4.1 ksi√in K_{1C} lower in fracture toughness than the rail bases in the previous test,[1] there have only been two rail breaks in 400 MGT during the current test. Fracture toughness is a measurement of a materials resistance to fracture in the presence of a crack. While fracture toughness can be a valuable tool in predicting rail performance, resistance to crack initiation also plays an important roll in limiting base fractures. Railroads continue to be concerned about base breaks, and further study is underway.

There have been no rail breaks due to railhead defects during the current test; there were none in the previous test.[1] Clean premium steels have proven to be resistant to defects of the railhead under a wide range of conditions.

Description of Test Curve and Test Train

The 141RE rails are installed in a 5-degree curve with 4 inches of superelevation and no direct high-rail lubrication. The test train at FAST (Figure 7), typically consisting of 75-80, 315,000-pound gross rail load coal cars, is operated at 40 mph, resulting in approximately 1.7 inches of superelevation deficiency. Traffic is bidirectional with approximately 50 percent of traffic in each direction.

REFERENCES

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2. Kristan, Joseph. October 2005. "FAST Rail Evaluation Test – Fracture Performance and Discussion," *Technology Digest*, TD-05-024, Association of American Railroads, Transportation Technology Center, Inc. Pueblo, Colo.

Figure 7. Test Train at FAST