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Interim Performance Results of Premium Rails in Revenue Service at Mega Sites

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Summary

Performance monitoring of premium rails was started in August 2005 by the Association of American Railroads (AAR), Transportation Technology Center, Inc. as a revenue service experiment at two mega sites to validate improved performance of premium rails in resisting wear and surface defect growths under heavy axle loads (HAL). An accumulation of 130 MGT (million gross ton) of traffic on the four test curves (6.8-10 degrees) at the eastern mega site and 520 MGT on the three test curves (1-2 degrees) at the western mega site was recorded by the end of 2007. The following is a summary of the preliminary results and findings, which are also consistent with those found from a similar test conducted under the HAL Program at the Facility for Accelerated Service Testing.[1,2]

- All premium test rails have shown excellent resistance to rail wear under HAL. The maximum rail wear was only 2 percent of the head area at 114 MGT at the eastern mega site and 2.3 percent at 495 MGT at the western mega site. In terms of the allowable wear limit for a heavy haul track, the minimum rail wear life of those premium test rails is estimated to be 1,000 MGT for a 10-degree curve at the eastern mega site (with excellent gage face and top lubrication) and 2,800 MGT for a 2-degree curve at the western mega site (without ideal lubrication).
- No rolling contact fatigue (RCF) defect has been observed in all four test curves at the eastern mega site. At the western mega site, however, significant RCF occurred between 300-350 MGT on the low rails in the two 2-degree test curves. The factors identified as the main contributors are curvature (no RCF issue at the 1-degree curve), under-balanced operating speed, dry rail surface, and misalignment associated with plant welds. A corrective grinding was done at 375 MGT to remove RCF defects (no preventive grinding for the three test curves, although it is done every 60 MGT for the track around the western mega site).
- No internal rail defects have been identified in the test rails at both mega sites. In addition, no welds (plant flash butt weld) made to connect the test rails have broken.
- All premium test rails had surface hardness measured above 400 BHN after approximately 60 MGT at the eastern mega site and 130 MGT at the western mega site.

The AAR and the Federal Railroad Administration jointly fund this experiment under the revenue service mega site testing program. One site is located in the east with Norfolk Southern Railway, and the other site is located in the west with Union Pacific Railroad.

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INTRODUCTION

One of the objectives of the experiments conducted in revenue service at the mega-sites is to monitor performance of new track components, new track materials, and improved track designs and maintenance procedures intended to mitigate adverse effects of HAL on track infrastructure. Premium rails, with increased hardness and micro-cleanliness, have the promise of providing higher resistance to wear, rail surface, and internal defect growth under HAL train operation, thus extending the life of rails, the most expensive component of the track structure.

To monitor and validate this improved performance of premium rails, a field test was started at the two mega test sites in August 2005. Both test sites are located on a heavy haul coal line with primarily 36-ton axle load trains. One site is near Princeton, West Virginia, on Norfolk Southern Railway (the eastern mega site), and the other site is near Ogallala, Nebraska, on Union Pacific Railroad (the western mega site). A similar experiment is being conducted under the 39-ton axle load train operation at the Facility of Accelerated Service Testing (FAST), Pueblo, Colorado.

This digest summarizes the performance results of the premium rails in revenue service through the end of 2007. The metallurgical and mechanical properties of those premium rails were investigated under the FAST program and are summarized in TD-07-018.[1]

Test Zones at Mega Sites

At the eastern mega site, eight premium rail types from four suppliers were installed in four different curves (two 6.8-degree curves and two 10-degree curves). The track has timber ties with cut spikes. The annual tonnage at this site is approximately 55 MGT per year. Trains operate through the curves between 20-30 mph. All four test curves have excellent lubrication conditions (both the gage and top faces of rails).

At the western mega site, seven premium rail types from six suppliers were installed in three different curves (one 1-degree curve and two 2-degree curves). The track has concrete ties with elastic fasteners. The annual tonnage at this site is approximately 230 MGT. Train operating speed is 50 mph, which is also approximately the balanced speed for the two 2-degree curves. However, a significant number of trains operated at speeds lower than 40 mph in 2006, because of slow orders caused by rain and mud holes in the area. At this site, each curve has a close-to-adequate lubrication condition on the gage face of rails, but the top surfaces are very dry (friction coefficient was measured around 0.35 on gage faces, but at or above 0.5 on top surfaces).

In order to compare the performance of different rail types in each test curve objectively, one rail type was used as the control test rail, and each of the other rail types was welded (flash butt weld in a plant) into the control rail. Rail performance results among different types are then evaluated in terms of ratios of test rails/control rail. In other words, the control rail is used to normalize possible condition variations from location-to-location even in the same curve.

Table 1 shows all the premium test rails at the two mega sites (all 141 lb/yard rails). In addition, the test rails at FAST in a 5-degree curve are included for comparison. As mentioned earlier, the major metallurgical and mechanical properties of those rails, including pearlitic microstructure, tensile strength, elongation and fracture toughness, can be found in TD-07-018.[1]

Table 1. Premium Test Rails

Manufacturer	UP Site	NS Site	FAST
Nippon	HEX*	HEX	HEX*
Rocky Mountain Steel Mill	HCP OCP	HCP OCP DHH*	OCP
JFE Steel Corp.	SP2		SP2
Mittal	HCHH	HCHH HH hypereutectoid	HCHH
Corus	HCLA	HCLA HH	
Voest-Alpine	UHC420		UHC420 LAHC

* Control test rail

Hardness Results

Rail surface hardness measurements were obtained at the mega sites. Figure 1 shows average hardness results obtained for all the test rails at various MGT levels. As illustrated, surface hardness increased with traffic, obviously as a result of work hardening effect of wheel/rail interaction. Although there is variation of hardness among different test rails, all rails had hardness measured above 400 BHN after approximately 60 MGT of traffic at the eastern mega site and 130 MGT of traffic at the western mega site. At FAST, the average hardness of all test rails after 200 MGT was measured to be 410 BHN. Note that AREMA (American Railway Engineering and Maintenance Way Association) requires 370 BHN as a minimum of hardness for high-strength rail.

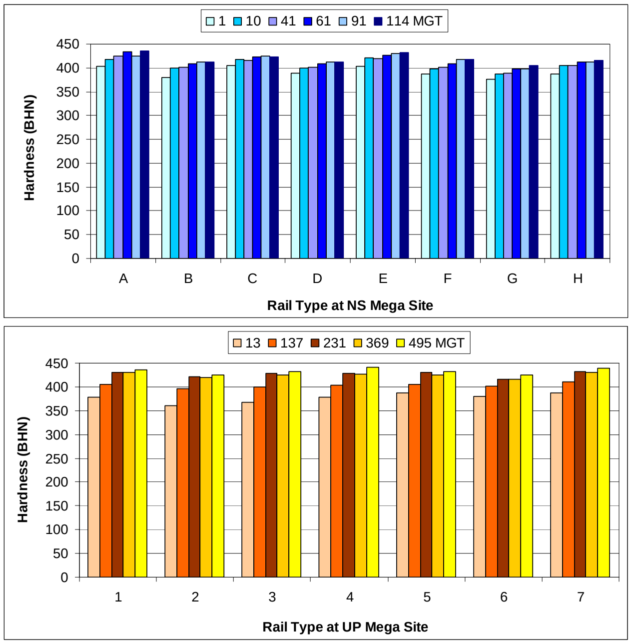

Figure 1. Average Rail Surface Hardness Test Results

Rail Wear Results

Excessive wear is one of the reasons for rail replacement. Premium rails with higher hardness are manufactured to provide higher resistance to wear under HAL traffic. However, other factors such as curvature, lubrication, and track conditions can also affect rail wear rate under HAL train operation.

For all premium test rails at the two mega sites, rail wear is measured approximately every six months. For each rail type in each test curve, rail profile is measured twice at the preselected locations.

Figure 2 shows the measurement results for the test rails (high rail) in a 10-degree curve at the eastern mega site and in a 2-degree curve at the western mega site, respectively. As illustrated, the maximum head area loss due to wear was 70 mm^2 for the 10-degree curve at 114 MGT and 80 mm^2 for the 2-degree curve at 494 MGT. Compared to the total railhead area (3466 mm^2), the amount of wear was essentially insignificant (counting less than 2.4% of the total head area). At FAST, rail wear was 7.2 percent of the head area at 300 MGT in a 5-degree test curve (Note: 1 in^2 = 645 mm^2).

In terms of gage or top face wear, the maximum wear rate was 1.75 mm (gage) at 114 MGT at the eastern mega site and 2.78 mm (gage) at 494 MGT at the western mega site. Assuming an allowable wear limit of 16 mm (gage or top surface), the minimum wear life of the premium rails can be estimated to be 1,000 MGT for a 10-degree curve at the eastern mega site (with excellent gage and top face lubrication) or 2,800 MGT for a 2-degree curve at the western mega site (Note: 1 in. = 25.4 mm).

Because of insignificant rail wear, no comparison was made among all premium test rails. When a comparison is necessary, a chart of wear ratios of test rails over their adjacent control rail (unlike what Figure 2 shows) should be used, as described previously.

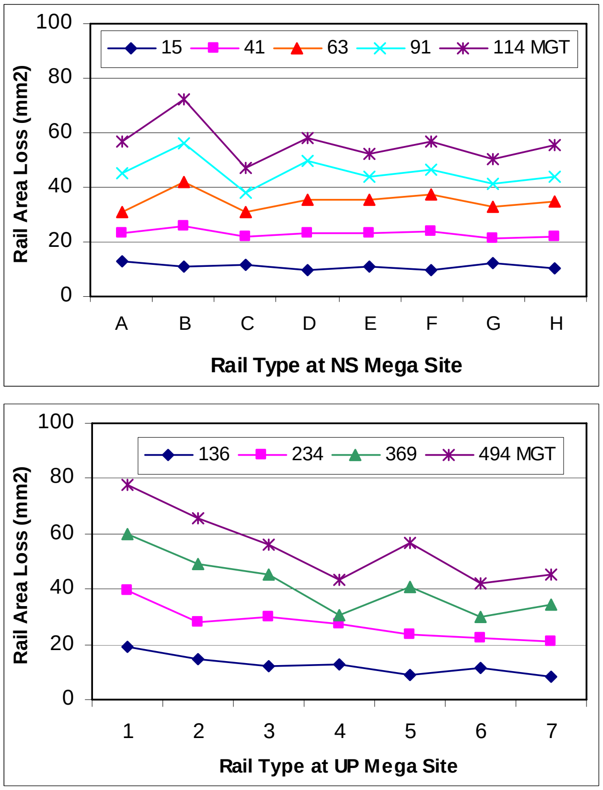

Figure 2. Average Rail Wear (High Rail, 10-Degree NS Curve and 2-Degree UP Curve), 1 in^2 = 645 mm^2

Rolling Contact Fatigue

For all test curves at the two mega sites, no preventive grinding has been conducted to allow monitoring of rail performance in resisting RCF. In general, preventive grinding is done every 60 MGT for the track around the western mega site and every 30 MGT around the eastern mega site.

To date, all test rails at the eastern mega site have shown no surface issues or RCF after 130 MGT, although wheel burns were observed at several rail spots caused by a grinding train braking and stopping.

At the western mega site, however, significant RCF started to show up on the low rails in the two 2-degree curves at about 300-350 MGT. Figure 3 shows an example of RCF observed at approximately 370 MGT. However, no significant RCF has been observed after about 520 MGT on the high rails for the two 2-degree test curves. In addition, no RCF has been observed on both the high and low rails in the 1-degree test curve.

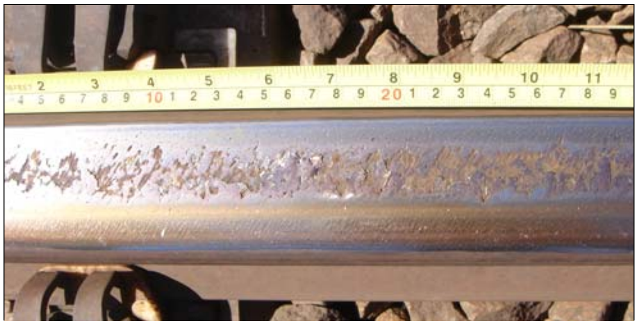

Figure 3. Example of RCF on Low Rail of 2-Degree Curve at UP Mega Site

Figure 4 shows the RCF mapping results for the low rails in the two 2-degree curves obtained at approximately 370 MGT. As shown, the length of each rail type that was covered with RCF ranged from 14 percent to 87 percent. Similar RCF problems were also observed at FAST between 100-150 MGT, and the investigation at FAST suggested that the variation of RCF extent from one rail to another was caused by change of microcleanliness (the extent or quality of nonmetallic inclusions observed by examination under a microscope).[2]

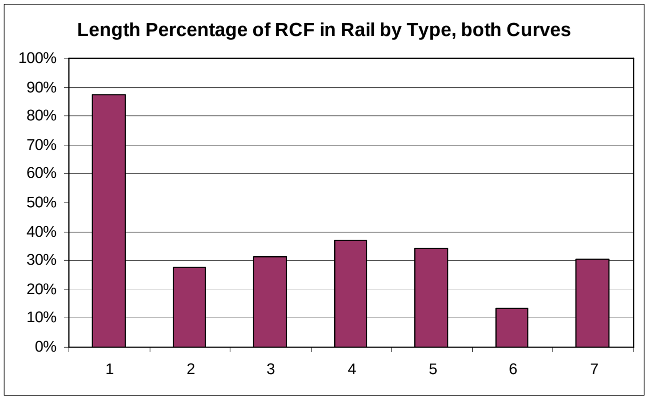

Figure 4. RCF Distribution among Different Rail Types

Microcleanliness was not the only factor that contributed to RCF on the low rails. An investigation of the RCF issue at the western mega site suggested that the following four factors be the main contributors to the RCF problem observed:

- Curvature – only the two 2-degree curves had RCF issues on the low rail, whereas the 1-degree curve did not.
- Under-balanced speed (as mentioned earlier) caused higher normal and tangential wheel/rail forces on the low rails in the two 2-degree curves.
- Very dry rail surface (with friction coefficient measured at or above 0.5).
- Misalignment related to plant welds used to connect all test rails, which were spaced 40 feet from one rail type to another.

To remove RCF on the low rails in the two 2-degree curves, a corrective rail grinding was performed at 375 MGT. Figure 5 shows the changes of rail profiles as a result of the grinding. As illustrated, the amount of rail removed from grinding was more than the loss of rail due to wear from the first 375 MGT.

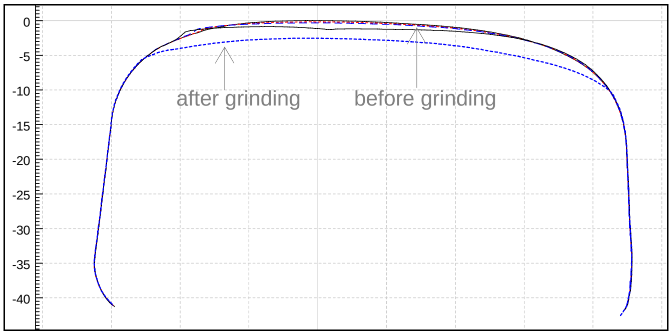

Figure 5. Rail Profile Change due to Grinding

ADDITIONAL OBSERVATION AND COMMENTS

At the two mega sites, no internal rail defects have been found to date. In addition, no welds (plant flash butt weld) made to connect the test rails have been broken.

The test results obtained at the two mega sites are being used for a cost benefit analysis concerning rail grinding versus top-of-rail lubrication in preventing RCF problems. In addition, the test results were used to verify a RCF and rail wear prediction model developed under the SRI research program.

Acknowledgements

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