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Premium Rail Performance and Rail Life Extension at the Mega Sites

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Summary

Effective rail life extension strategies are essential for maximizing service life of rails under heavy axle load (HAL) operations. For this purpose, Transportation Technology Center, Inc. (TTCI) has been investigating practices at two mega sites in an effort to optimize rail life extension strategies in revenue service.

Thus far, the results obtained from testing at the mega sites have been very promising:

- With more than 2,000 MGT accumulated to date at the western mega site and more than 450 MGT at the eastern mega site, the premium test rails in both locations continue to show excellent wear performance and resistance to internal defects.
- There is a statistically significant reduction in the rate of wear for both high and low rails in the 2-degree curve located in a high-tonnage HAL traffic line following the implementation of top-of-rail (TOR) friction control. The estimated wear life is approximately 7,800 MGT for the low rail and 5,700 MGT for the high rail within this curve.
  - The low rail received the most benefit from the application of TOR friction control, which showed a reduction in the median rate of wear from 0.01 in^2 to 0.004 in^2 per 100 MGT.
  - Only intermittent rolling contact fatigue (RCF) growth was detected after approximately 1,000 MGT.
  - The median railhead area loss for the curve using TOR friction control was 7.1 and 3.0 percent for the high and low rails, respectively. For the curve using preventative grinding, the median loss was 11.6 and 7.9 percent, respectively.
  - With preventative grinding, the estimated wear life is estimated to be approximately 4,300 MGT for the low rail and 5,500 MGT for the high rail.
- Without friction control or grinding, the 1-degree test curve developed moderate, yet isolated, areas of RCF after approximately 960 MGT. Corrective grinding was implemented following this discovery. The rail was later removed at 1,782 MGT due to severe sporadic spalling.

TTCI has been conducting rail performance testing in revenue service since the fall of 2005 at the eastern and western mega sites, located near Bluefield, West Virginia, and Ogallala, Nebraska, respectively. Initially established to supplement rail performance testing conducted at the Facility for Accelerated Service Testing in Pueblo, Colorado, the scope of testing in revenue service has since been expanded to include evaluation of rail life extension strategies. This includes evaluation of the long-term effects of gage-face lubrication, TOR friction control, and corrective or preventative grinding practices. Test results are providing valuable feedback regarding the effect of such strategies on the service life expectancy of rail in HAL revenue service.

This investigation is being undertaken by TTCI under the HAL revenue service program co-sponsored by the Association of American Railroads and Federal Railroad Administration.

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INTRODUCTION

Rail performance testing has been integral to the HAL revenue service testing at the western and eastern mega sites since 2005. The initial objective of this testing at the mega sites was to supplement the testing at the Facility for Accelerated Service Testing in order to provide more diverse operating and climatic conditions to further investigate the performance of the latest premium rails available to the industry. Starting in 2008, the scope of testing was extended to include rail life extension strategies, namely gage-face (GF) lubrication, TOR friction control, and preventative grinding practices. This *Technology Digest* reports on the latest results from this new phase of testing at both mega sites. Previous articles and reports summarize the earlier results of the premium rail performance testing and rail life extension strategies.[1-4]

TEST CURVES AT THE MEGA SITES

The western mega site, located on the Union Pacific Railroad's South Morrill Subdivision, has three different test curves containing seven premium rail grades from six manufacturers[1] and typically sees 200-250 MGT of traffic annually. Operating speeds on this heavy haul coal route range between 40 and 50 mph over near-flat grades (see Table 1). The curves are comprised of two 2-degree curves and one 1-degree curve, both employing standard concrete ties with elastic fasteners.

The eastern mega site, located on Norfolk Southern Railway's Virginia Division, has four different test curves containing eight premium rail grades from four manufacturers[1] and sees an estimated 55 MGT of traffic annually. Operating speeds on this heavy haul coal route are typically between 15 and 25 mph over grades as steep as 1.4 percent in some areas (see Table 1). The curves are comprised of two 6.8-degree curves and two 10-degree curves made up of timber ties and cut-spike fastening system.

Table 1. Summary of Operating Conditions at the Mega Sites

	1°	2°	6.8°	10.2°	10.5°
Operating Speeds (MPH)	40 – 50	40 - 50	15 - 25	15 - 25	15 - 25
Balance Speed (MPH)	50	48	23	19	20
Superelevation (Inches)	1.75	3.25	2.5	2.5	3.0

RESULTS FROM THE WESTERN MEGA SITE

At present, the premium rails installed in the test curves within the western mega site have accumulated more than 2,000 MGT of traffic and have maintained excellent wear performance throughout the course of the experiment. In 2008, the subject of this testing shifted from rail performance to the evaluation of life extension practices using two different methods to control wear rates and RCF growth.

For all three test curves, no rail life extension strategies, except for the application of lubrication to the GF, were implemented during the early stage of the experiment. For the 2-degree curves, RCF started to appear on the low rails at approximately 300-350 MGT. As a result, two corrective grindings were implemented before 700 MGT to remove the RCF. After 700 MGT, TOR friction control was implemented for one of the 2-degree test curves while the other began receiving scheduled preventative grinding every 70 MGT, as per the recommendations from earlier modeling results.[3] As a result of TOR friction control, a corrective grind was not required until 1,650 MGT of traffic to remove RCF, which took much longer to recur (i.e., 950 MGT, see Figure 1).

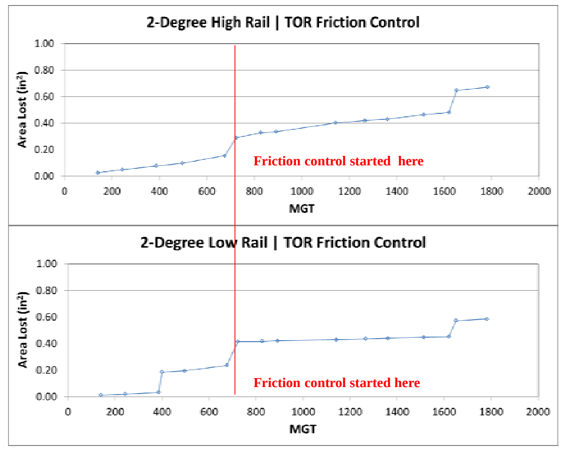

Figure 1. Average Rail Wear Results from Traffic and Grinding Prior To and Following Rail Life Extension Implementation at the Western Mega Site

Figure 2 shows the distributions of the rates of wear for all test rails before and after the implementation of TOR friction control for the 2-degree curve. Statistical testing was conducted to compare the rate of wear before and after implementation of TOR friction control within the 2-degree test curve. Results show that there was a reduction in the rate of wear following the implementation of TOR friction control for both the high and low rail. Moreover, results of statistical testing show that railhead area loss through grinding per MGT was also reduced for both the high and low rails following the implementation of TOR friction control. Table 2 summarizes the rates of wear and amounts of metal removed with each grind for all test curves.

Since the implementation of rail life extension strategies at 700 MGT, the median railhead area loss for the 2-degree curve using TOR friction control is measured at 7.1 and 3.0 percent for the high and low rails, respectively. In contrast, the median railhead area loss for the 2-degree curve implementing preventative grinding is approximately 11.6 and 7.9 percent for the high and low rails, respectively. Though preventative grinding is effective in controlling the spread of RCF, this method can lead to more railhead area loss. At the same time, preventative grinding, generally consisting of a single pass, saves on railhead area loss when compared against corrective grinding actions, which typically require multiple passes to be made.

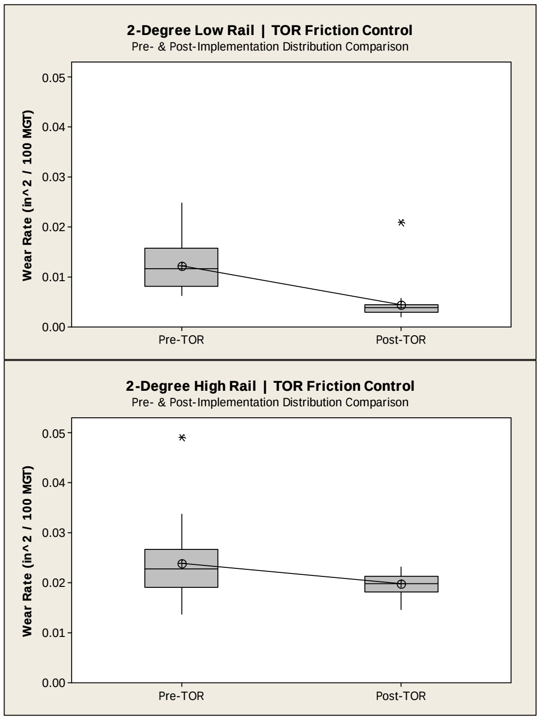

Figure 2. Wear Rates for All Test Rails at the Western Mega Site

Table 2. Summary of the Median Railhead Area Loss for High and Low Rails at Both Mega Sites

High Rail:

Curvature Degrees	Natural Wear from Traffic	Traffic & TOR	Preventive Grinding	Corrective Grinding	Railhead Area Loss (TOR)
1	0.006 in²/ 100 MGT	-	-	-	-
2	0.023 in²/ 100 MGT	0.020 in²/ 100 MGT	0.03 in²/ Grind	0.14-0.16 in²/ Grind	6.8-7.3% (1059 MGT)*
6.8	-	0.047 in²/ 100 MGT	-	-	3.4-3.7% (396 MGT)
10.2	-	0.11 in²/ 100 MGT	-	0.01 in²/ Grind	7.5-10.3% (414 MGT)
10.5	-	0.09 in²/ 100 MGT	-	0.02 in²/ Grind	6.9-8.2% (414 MGT)

Low Rail:

Curvature Degrees	Natural Wear from Traffic	Traffic & TOR	Preventive Grinding	Corrective Grinding	Railhead Area Loss (TOR)
1	0.003 in²/ 100 MGT	-	-	-	-
2	0.01 in²/ 100 MGT	0.004 in²/ 100 MGT	0.02 in²/ Grind	0.11-0.14 in²/ Grind	2.9-3.1% (1059 MGT)*
6.8	-	0.039 in²/ 100 MGT	-	-	4.1-5.0% (396 MGT)
10.2	-	0.19 in²/ 100 MGT	-	0.14 in²/ Grind	18.0-21.6% (414 MGT)
10.5	-	0.11 in²/ 100 MGT	-	0.096 in²/ Grind	12.4-15.2% (414 MGT)

* Tonnage accumulated since implementation of TOR friction control

The 1-degree test curve did not incorporate any of the rail life extension strategies seen at the 2-degree test curves at the western mega site. As such, this test curve developed moderate yet isolated areas of RCF after approximately 960 MGT and multiple corrective grinds were undertaken subsequently to prevent further progression of these spots. Figure 3 shows the average rail wear attributed to both traffic and grinding for the 1-degree test curve. Though no internal fatigue defects have been identified, severe sporadic spalling (i.e., RCF) developed at multiple locations on the high rail, which led to the eventual removal of the test rail at 1,782 MGT.

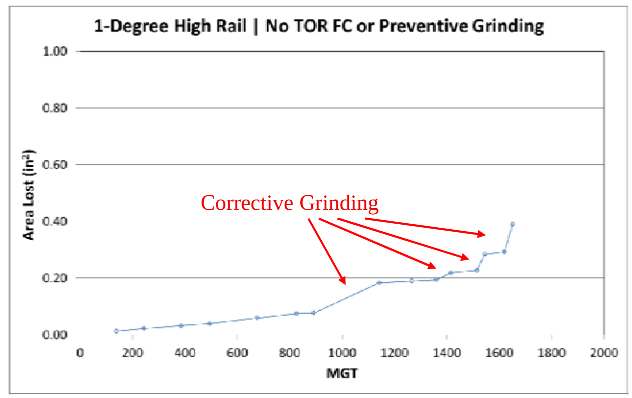

Figure 3. Average Rail Wear Results from Traffic and Corrective Grinding without Friction Control or Preventative Grinding at the Western Mega Site

RESULTS FROM THE EASTERN MEGA SITE

With more than 450 MGT accumulated to date, the premium test rails within the eastern mega site continue to show excellent wear performance and resistance to internal fatigue. GF lubrication and TOR friction control have been used at each of the four test curves since the initiation of the test in 2005. As well, corrective grinding was implemented on three separate occasions to remove RCF and plastic flow during the course of testing.

The surface condition of the rails within the test curves was in excellent shape until approximately 250 MGT when the low rails within the two 10-degree test curves began to show signs of RCF. An additional 100 MGT was accumulated before the 6.8-degree test curves began to show similar signs of RCF growth on the low rail. A corrective grind to address RCF was performed at 275 MGT and 365 MGT for the 10- and 6.8-degree test curves, respectively.

Figure 4 shows the average rail wear test results attributed to both traffic and grinding on the high and low rails for the 10.5-degree test curve. For the 10.5-degree test curve under normal traffic, the median area railhead loss per 100 MGT is more than twice that of the 6.8-degree test curves for both rails. (See Table 2 for a complete summary of the railhead area loss associated with both traffic and grinding.)

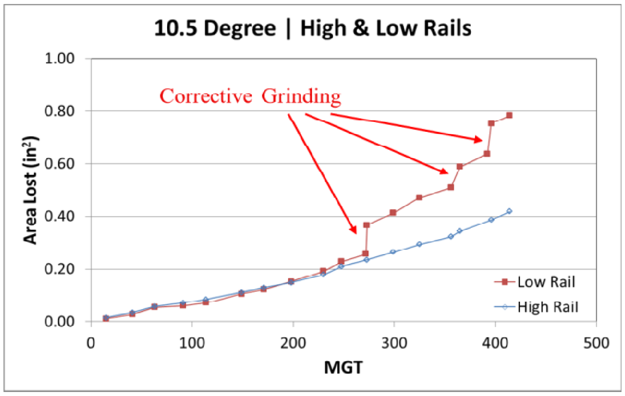

Figure 4. Average Rail Wear Results from Traffic and Grinding at the Eastern Mega Site

Figure 5 presents the variations of test results measured at various MGT levels across all rail grades for the 10.2-degree test curve. As shown, the variations across all rail grades were smaller for the test results on the high rail than on the low rail. Furthermore, variations were smaller still for the 6.8-degree curves. For the 1- and 2-degree test curves in the western mega site, the ranges of wear performance across all rail grades follow a similar trend.

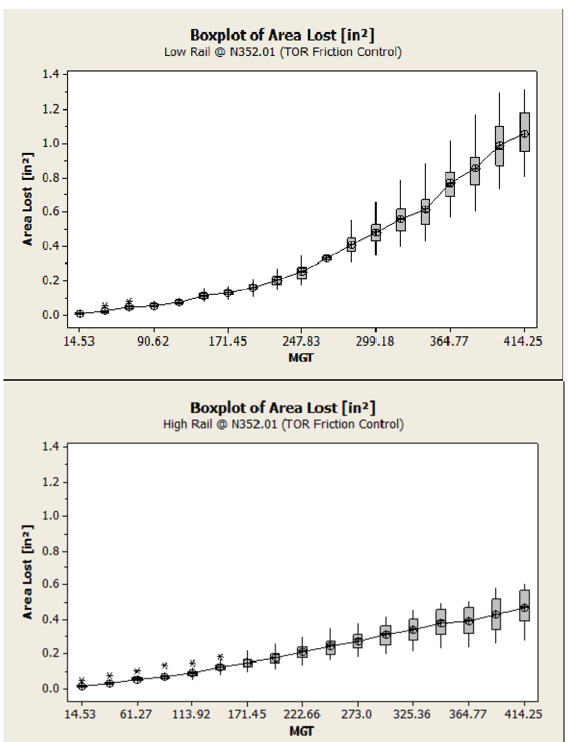

Figure 5. Variation Between Rail Grades at the Eastern Site

Among the rail grades tested at both mega sites, no consistent rank in performance was identified between the high and low rails. Although steps were taken to ensure all variables were accounted for in the design of the experiment, there are unidentified factors influencing the variation between rail grades that have yet to be taken into account. This will require further investigation to ensure accurate results with regard to rail grades.

FUTURE WORK

TTCI and host railroads are in the process of installing additional test curves at both mega sites with the goal of evaluating a hybrid/optimized strategy combining the benefits of TOR friction control and some preventative grinding on an optimized schedule to further extend the service life of rails. In addition, another test curve will be established to evaluate the long-term effects of similar rail life extension strategies on intermediate strength rail in high-degree curvatures. Installation is expected to be completed by spring of 2014.

ACKNOWLEDGEMENTS

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REFERENCES

1. Li, Dingqing, Sam Atkinson, and Russell McDaniel. February 2008. "Interim Performance Results of Premium Rails in Revenue Service at Mega Sites." *Technology Digest* TD-08-008. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
2. Li, Dingqing, Daniel Gutscher, and Luis Maal. September 2011. "Prevention of rail rolling contact fatigue under heavy-axle-loads." *Railway Track & Structures*. Vol. 107, No. 9, pp. 16-18. Chicago, Illinois.
3. Li, Dingqing et al. June 2011. "Recent Advances in Rail Life Extension in North American Heavy Haul Railways." *Proceedings of the International Heavy Haul Conference*, Calgary, Canada.
4. Reiff, Richard, Kevin Conn, and Dingqing Li. March 2006. "Eastern Mega Site Wayside Top of Rail Friction Control Implementation Status." *Technology Digest* TD-06-006. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.