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Effects of Top of Rail Friction Control Materials on Rail in Revenue Service

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Summary

From April 2016 to April 2017, engineers from Norfolk Southern Railway (NS) and Transportation Technology Center, Inc. (TTCI) evaluated rail performance for a 40 million gross ton (MGT) period on four curves on NS's Whitethorne District, near Roanoke, VA. The objective was to document rolling contact fatigue (RCF) development, rail friction, and rail wear as influenced by the top of rail friction control (TORFC) material currently utilized by NS. In April 2017, the rails were ground and then an identical monitoring effort commenced with a different TORFC product. This digest summarizes rail performance under the first TORFC material by evaluating wear using MiniProf rail profiles, surface conditions using dye penetrant and an eddy current device, rail friction, and monitoring of TORFC material usage. One curve (control curve) was not protected by any TORFC application system, and the other three curves had varying amounts of TORFC material applied. All curves were protected by gage face lubrication. Based on the current results, the following conclusions can be drawn:

- Results from other long-term evaluations on new rails where application of TORFC materials started immediately after installation[1,2] indicated TORFC allowed little or no RCF to develop, compared to identical rails installed nearby that were not subjected to TORFC, and which did develop significantly more RCF. During this phase of the current revenue service demonstration (which utilized existing rails of different types, wear, and age), a similar TORFC material did not fully prevent RCF from forming or growing. Observations to date suggest TORFC is less effective in inhibiting RCF formation or growth on rail with pre-existing surface cracks.
- During the 40 MGT period, TORFC material did not appear to accelerate spalling at existing cracks.
- Insufficient time was available to conduct adequate pre-TORFC baseline monitoring, so no data to show TORFC effect on wear rates is available.
- After 40 MGT, RCF tended to become more severe and dense at the middle and end of the curves, suggesting TORFC material became less effective farther into the curve and away from the TORFC applicators.
- After 40 MGT, of the three curves exposed to TORFC, two exhibited more deterioration of RCF on the high rail than on the low rail. Although TORFC material was applied to both rails at each applicator site, the material appeared to help the low rail more than the high rail on these two curves, which might be related to the specific train operating conditions on this track.
- During the 40 MGT period, no adverse rail friction was measured; all readings were at or higher than AREMA recommended minimum values.
- During the 40 MGT period, TORFC material application amounts varied between sites and at different times, thus, effectiveness may not have been uniform throughout the evaluation.

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INTRODUCTION

Performance of top of rail (TOR) friction control (FC) materials on new rails has been documented by the Association of American Railroads (AAR) and member railroads, both at the High Tonnage Loop of the Facility for Accelerated Service Testing (FAST) and under revenue service conditions. Recent long-term revenue service/field tests conducted with cooperation of Norfolk Southern Railway (NS) and Union Pacific Railroad (UP) evaluated wear and surface fatigue with and without the use of TORFC. Results[1,2] confirm territory-wide implementation of TORFC provides significant benefits to rail wear and rail surface performance. Evaluations at FAST[3] were limited scope tests and addressed only immediate effects such as curving forces, rail friction, and carry distance.

Under direction of the technical advisory group, AAR sponsored this field evaluation of two different TORFC products to determine longer term effectiveness on rail wear and rail surface fatigue on existing, older rail. Previous experience has shown that under certain conditions, especially where existing surface cracking is present, TORFC materials can result in accelerated rolling contact fatigue (RCF) and rail surface damage.[4] As most areas where TORFC is being implemented exhibit some form of existing RCF, or develop surface cracking and spalling during extended exposure to heavy axle load traffic, the long-term effect on rail surface performance under TORFC products is a concern of the industry.

Objectives

The primary objective of this demonstration is to determine if TORFC materials accelerate rail surface deterioration under typical field conditions where a variety of rail types, age, and conditions exist. Long-term comparisons of wear between no-TOR and TOR were not considered, as these have been addressed in previous tests and reports.[1,2,4] Secondary objectives included an evaluation of friction values as well as a limited evaluation of carry distance. NS elected to evaluate two products, LBF Keltrak ER Winter and Whitmore TOR Armor. Both are water-based TORFC products that have been previously evaluated for basic performance at FAST.[3]

Procedure and Site Layout

NS provided a site on the Whitethorne District, approximately 20 miles west of Roanoke, VA. Four curves (designated A, B, C, and D) of similar curvature (4.3- to 5-degree), elevation (3.5 inches to 4 inches), and speed (40 mph) were selected. The curves had rails of varying age, wear, and mill/type (Table 1). Train direction is primarily eastbound and the traffic mix includes loaded coal and mixed-freight trains, approximately 39 MGT annually. Rail is ground twice a year to control shape and control RCF. Prior to the April 2016 and April 2017 grinding cycles, rail in all four curves exhibited cracks. Grinding reduced the size of the cracks, but did not eliminate them.

In the direction of primary traffic, curve A is the control curve and receives only normal gage face (GF) lubrication; no TORFC is applied near this curve. One GF and two TORFC applicators are positioned before Curve B. A third TORFC applicator and GF are positioned before Curve D. Curve C located in between Curves B and D.

Table 1. Details of rail types, curvature, and lubricants

Curve ID	Rail Section	Roll Date	Curvature (degrees)	TORFC/GF
A Low	136RE	2011	5.0	No TORFC GF kept ON
A High	141RE	2002		
B Low	136RE	2007	4.3	2 TORFCs and GF kept ON
B High	132RE	2004		
C Low	136RE	2008	4.0	No nearby TORFC or GF, nearest TORFC before Curve B
C High	136RE	2006		
D Low	141RE	2001	4.0	TORFC and GF kept ON
D High	141RE	2002		

Data and Site Monitoring

Periodic measurements and site inspections include: visual inspection of rail surface using dye penetrant, rail profiles using a MiniProf, coefficient of friction measurements using a tribometer, and an eddy current device to determine surface crack conditions. Additional monitoring of TORFC material usage, applicator system performance, and overall site conditions is also conducted frequently by NS personnel.

For each curve (A, B, C, and D), six measurement locations, numbered 1 through 6 in the direction of primary traffic, were marked (Table 2).

Table 2. Measurement locations of all curves

Measurement Location ID	Location in Curve
1	Tangent to Spiral
2	Spiral to Curve
3	1/3 Distance in Curve
4	2/3 Distance in Curve
5	Curve to Spiral
6	Spiral to Tangent

In April 2016, data was collected immediately after rail grinding to establish clean rail conditions for the start of the test. At the same time, the TORFC units were activated. In March 2017, after approximately 40 MGT and prior to the rail grinding, a second detailed inspection was conducted. For this digest, results from the full body of each curve (sites 2–5) are being evaluated.

Interim Results/Observations

This phase of the test documents the rail performance with the first TORFC product, and provides the baseline for comparison with the second TORFC product. Insufficient time was available prior to implementing TORFC to collect enough rail wear data to determine statistically viable results under "no-TORFC" conditions. As each curve has rail of different type and age, no direct rail wear rate benefit can be determined, and each curve represents a separate comparison of the effect of two different TORFC materials.

Wear results for Locations 3–5 were normalized to Location 2 (Table 2). This allows any change in wear along a curve to be assessed. Typically, the high rails exhibited increased total head area and GF wear from start to end of curve (Figure 1), while vertical TOR wear was somewhat more uniform along the curve. The low rail exhibited small but variable differences in total area loss at the end compared to the beginning of the curves (Figure 2).

Table 3 shows an RCF performance summary based on visual dye penetrant observations made at Locations 2 and 5 (beginning and end of curve) at the start of the test and at 40 MGT.

Additional full-curve eddy current data was collected. The eddy current instrument has four probes measuring maximum crack lengths at the top center of the rail and at the gage corner. The results were found to be inconsistent with photographs of dye penetrant inspections. One reason for inconsistency is the detection objective: eddy current measures crack length but not density, while dye penetrant inspections reveal surface crack density but not crack length.

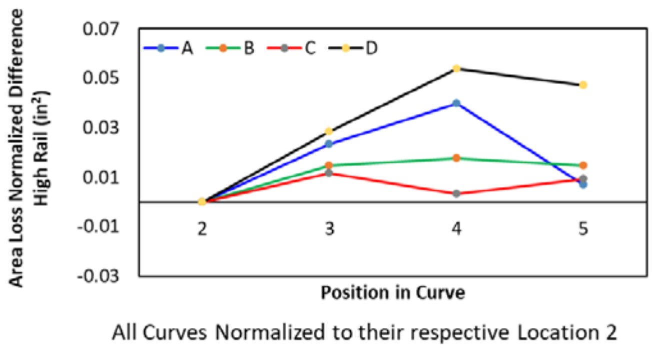

Figure 1. Area loss of rail head of high rails of all curves

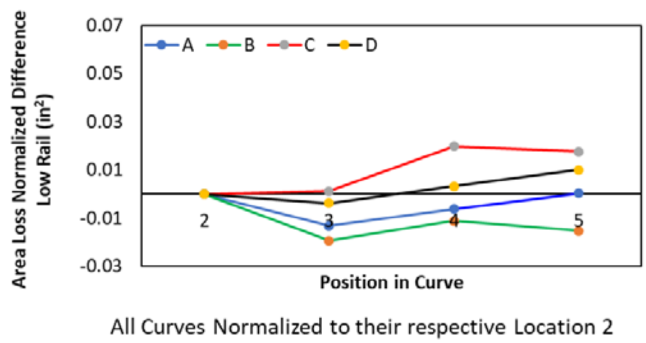

Figure 2. Area loss of rail head of low rails of all curves

Curve A: At the start of monitoring, both high and low rails exhibited no RCF throughout the curve. After 40 MGT, the beginning of the curve still did not exhibit visible RCF, while the middle and end of the curve showed significant RCF and pitting on both rails. Generally, the rail surface deteriorated and became more cracked towards the middle and end of the curve.

Table 3. Summary of Visual Dye Penetrant Data (Legend: ">" means slight increase, ">>" means significant increase) PSC- position at spiral to curve, PCS- position at curve to spiral (refer Table 2)

Location	A2 PSC	A5 PCS	B2 PSC	B5 PCS	C2 PSC	C5 PCS	D2 PSC	D5 PCS
High Rail @Start	No RCF	No RCF	No RCF	Minor RCF	Minor RCF	Minor RCF	Minor RCF	Minor RCF
High Rail + 40 MGT	No RCF	>> RCF, Pitting	No RCF	>> RCF Pitting	>RCF	>> RCF spalling	Minor RCF	>> RCF Pitting
Low Rail @Start	No RCF	No RCF	No RCF	No RCF	Minor RCF	Minor RCF	Minor RCF	Minor RCF
Low Rail + 40 MGT	No RCF	>> RCF, Pitting	No RCF	Minor RCF	Minor RCF	Minor RCF	Minor RCF	>> RCF Pitting

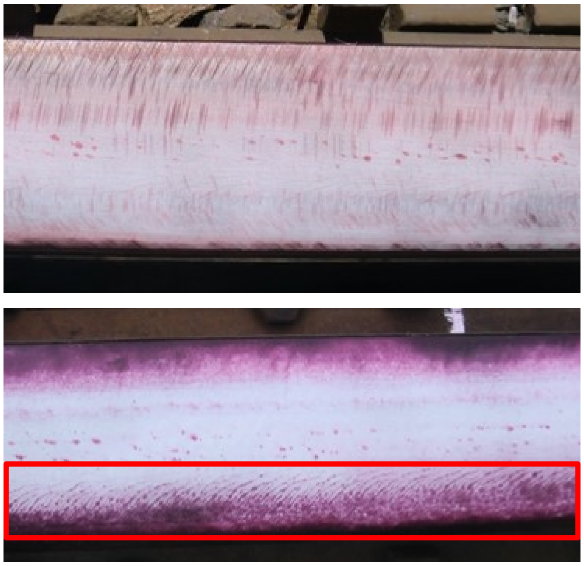

Figure 3. Comparison of Curve C, high rail, Location 5 on April 2016 (top) and after 40 MGT on March 2017 (bottom) showing increase in gage side RCF

Curve B: When TORFC was initiated, the low rail exhibited no visible RCF, while some RCF was visible on the high rail at the end of the curve. After 40 MGT, the low rail remained generally free from RCF, while the high rail had no RCF at the beginning of the curve, but exhibited significant RCF and pitting at the end of the curve.

Curve C: When TORFC was initiated, the high and low rails at the beginning and end of the curve exhibited minor cracking. After 40 MGT, the high rail at the end of the curve exhibited denser RCF and spalling (Figure 3), while the low rail exhibited some RCF, but little change from the start.

Curve D: When TORFC was initiated, the high and low rails at the beginning and end of the curve exhibited minor RCF. After 40 MGT, the beginning of the curve showed little change in RCF, while both rails at the end of the curve exhibited significant RCF and pitting. Both rails of Curve D developed the most RCF during the 40 MGT period compared to Curves A, B, and C.

Discussions and Other Site Issues

Overall RCF development patterns between beginning and end of Curves A, B, C, and D were visually similar, with major differences in density and severity of RCF. Differences between curves in amount and location of RCF are likely influenced by varying metallurgy and age of the rail. After 40 MGT, RCF was more severe at Location 5 on all curves, and two out of the three curves protected by TORFC exhibited less RCF at Location 2. This suggests that TORFC material effectiveness decreases towards the end of curves, especially on the high rails. Curve A exhibited significant TOR contamination on both rails from a nearby GF applicator at the beginning of the curve. However, NS reported there were some periods when TORFC applicators were not properly functioning or material usage was less than expected, suggesting that TORFC was not uniform or constant. Measured TOR friction never fell below AREMA recommendations of 0.30μ. Friction readings on the center TOR tended to increase to 0.50μ towards the end of all curves.

At the beginning of Curve D, for a distance roughly one wheel circumference (~10 feet) beyond the TORFC applicator bar (where the rail is normally flooded with fresh TOR material), the rail exhibited significant surface RCF (spalling). However, during this application period, the RCF did not change. This is in contrast to the observations at another site, described in a previous digest,[4] where significant spalling developed when TORFC was applied to rail with existing RCF. Early experience with rail that had existing RCF at the time TORFC was implemented led AREMA to recommend grinding to eliminate cracks, to prevent the TORFC material from accelerating the growth of those cracks due to hydraulic action.[4]

Future/Next Steps

Curves A, B, and C were ground in April 2017, after which post grind measurements were taken and a similar monitoring period was initiated with the second TORFC material. Curve D had its rail replaced in mid-summer 2017 and will no longer be part of the test. Comparisons of variations in rail wear (within each curve) and RCF development will be made after an additional 40 MGT of traffic.

References

1. Reiff, Richard and Kevin Conn. August 2011. “Implementing Top of Rail Friction Control on Norfolk Southern Preliminary Results of Rail Wear Rates.” *Technology Digest* TD-11-027. AAR/TTCI, Pueblo, CO.
2. Reiff, Richard. June 2007. “Wayside-Based Top of Rail Friction Control: 95 MGT Update.” *Technology Digest* TD-07-019. AAR/TTCI, Pueblo, CO.
3. Szablewski, Daniel et al. December 2014. “FAST Testing of Latest Top-of-Rail Friction Modification Materials.” *Technology Digest* TD-14-024. AAR/TTCI, Pueblo, CO.
4. Reiff, Richard and David Lilley. February 2006. “Preliminary Placement Guidelines Top of Rail Friction Control Application Systems.” TD-06-002. AAR/TTCI, Pueblo, CO.