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Top of Rail Friction Control Material Influence on Rolling Contact Fatigue and Rail Wear in Revenue Service

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Summary

From April 2016 to April 2018, engineers from Norfolk Southern Railway (NS) and Transportation Technology Center, Inc. (TTCI) evaluated rail performance for two 39-million gross ton (MGT) periods on four curves on the NS 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) materials currently used by NS. The rails were ground in March 2016, and again during April 2017, with the intent of producing similar conditions; after which a 39-40 MGT monitoring effort commenced, each with a different TORFC product. The curve rails differed by rail mill, age, and wear.

This *Technology Digest* summarizes rail performance for the second TORFC material by evaluating wear using MiniProf™ rail profiles, surface conditions using dye penetrant, and rail friction measurements by tribometer while monitoring of TORFC material usage. One curve (the control) was not protected by any TORFC application system, and the other three curves had varying amounts of TORFC material applied. Results of two test curves are discussed. One of the test curves underwent rail change during the testing of the second TORFC product. All curves were protected by gage face lubrication. Based on observations and wear results, the following conclusions can be drawn:

- The second 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 than on rail without any pre-existing surface cracks. After grinding for the start of this second phase, rails exhibited more cracks than at the start of the first phase.
- TORFC materials did not appear to accelerate spalling at existing cracks.
- More deterioration of RCF was noted on the high rail than on the low rail. Although TORFC materials was applied to both rails at each applicator site, the material appeared to help the low rail more than the high rail — which might be related to the specific train operating conditions on this track.
- No adverse top of rail coefficients of rail friction were measured; all readings were at or higher than American Railway Engineering and Maintenance-of-Way Association (AREMA) recommended minimum values.
- TORFC material application amounts varied between sites and at different times; thus, effectiveness may not have been uniform throughout the evaluation.
- Based on rail wear data and coefficients of friction values, TORFC material was most effective on the curve with TOR applicators placed nearby, and less effective on a downstream curve.

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INTRODUCTION

Performance of a second TORFC material on existing in-service rails has been documented as a follow-up to the first period summarized in a previous *Technology Digest.*[1] Performance of the second material was documented by engineers from TTCI and NS.

Under direction of a technical advisory group, this AAR-sponsored field evaluation concludes assessment of two different TORFC products as to effectiveness on mitigating 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.[2] 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 to the industry.

OBJECTIVE

The primary objective of this demonstration is to determine if TORFC materials accelerate rail surface deterioration under typical field conditions. Long-term comparisons of wear between rails with and without TORFC were not considered due to limited length of testing. Secondary objectives included an evaluation of friction values as well as a limited evaluation of carry distance. NS elected to evaluate two products, LBF Keltrack® ER Winter and Whitmore TOR Armor®. Both TORFC products are water-based and have been previously evaluated for basic performance at the Facility for Accelerated Service Testing (FAST) in Pueblo, CO.

PROCEDURE AND SITE LAYOUT

At the start of Phase 1, NS provided four curves on a site on the Whitethorne District, approximately 20 miles west of Roanoke, VA. These curves (designated A, B, C, and D) are of similar curvature, elevation and speed (40 mph). Due to a rail changeout of curve D in late 2017, only three curves were compared in this report: Control curve A and curves B and C. The curves had rails of varying age, wear, and mill/type.[1] Train direction was primarily eastbound and the traffic mix included loaded coal and mixed-freight trains, approximately 39 MGT annually. Rail normally is ground twice a year to control both shape and RCF. At the end of the first phase (April 2017) all rails were ground in an attempt to create close to the same starting conditions for the second TORFC material. After grinding in April 2017, rails were inspected and measured. All curves exhibited varying amounts of RCF which appeared to be higher in intensity than at the start of Phase 1. As with the previous period, 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 gage face (GF) lubrication; no TORFC is applied near this curve. One GF and two TORFC applicators are positioned before curve B.

DATA AND SITE MONITORING

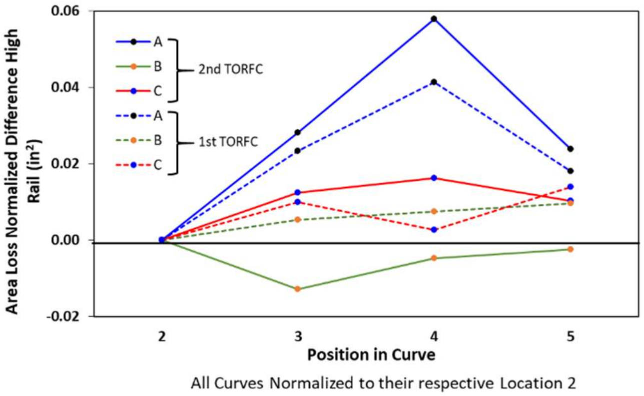
Measurements at beginning and end of this second phase and site inspections included visual inspection of rail surface using dye penetrant, rail profiles using MiniProf, and coefficient of friction using a tribometer. Non-destructive testing using an eddy current device was not done in this phase as the results from the first phase of testing were found to be inconsistent with observations.[1] Additional monitoring of TORFC material usage, applicator system performance, and overall site conditions also were conducted frequently by NS personnel.

For each curve, six measurement locations, numbered 1 through 6 in the direction of primary traffic, were marked as mentioned in the previous TD on this test. For this report, performance at locations 2 through 5 (within full body of the curve) are utilized.

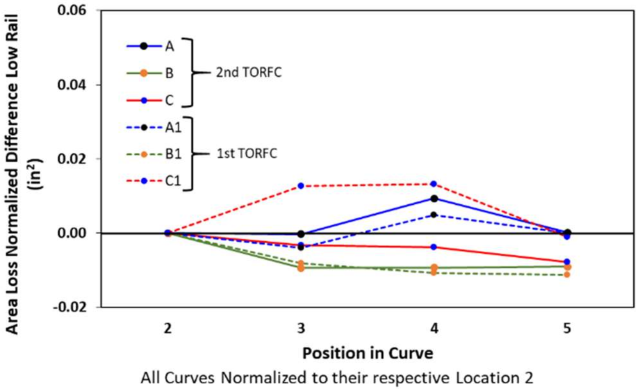
In May 2017, data was collected immediately after rail grinding to establish clean rail conditions for the start of the Phase 2 of the test. Due to rail traffic inhibiting track time, curve C did not receive a dye penetrant inspection, and rail profiles were measured a month later. All subsequent rail wear rate data in this report reflects the slight difference in MGT between curves A, B and C. Also, in May 2017 both TORFC units were activated with the second TORFC product. In April 2018, after approximately 39 MGT, a second detailed inspection was conducted, and final data collected. For this *Technology Digest*, results from the full body of each curve (sites 2–5) were evaluated and compared to a similar period using the first TORFC product.

RESULTS/OBSERVATIONS

Rail wear in the full body of each curve during the second TORFC evaluation phase is summarized in Figures 1a, 1b, and Figure 2. 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 through 5 were normalized to location 2. This allows any change in wear along the full body of a curve to be assessed. Examination of Figures 1a and 1b show higher differences in wear between locations 2 and 4 for the high rails compared to the low rails and suggests the same trend of change in area loss along the body of the curves on high and low rails in both testing phases.



a.



b.

Figure 1. Area loss of high rail (a.) and low rail (b.) in all three curves for the two TORFM test periods

Examination of Figure 2, a comparison of gage face wear, indicates control curve A had a higher wear rate during the second TORFC phase than the first phase. This suggests there was less GF lubrication during the second TORFC period. Curves B and C show similar wear rates for both TORFC testing phases, suggesting similar influence on GF wear. It is noted that gage wear in Figure 2 is accounted in area loss shown in Figure 1a.

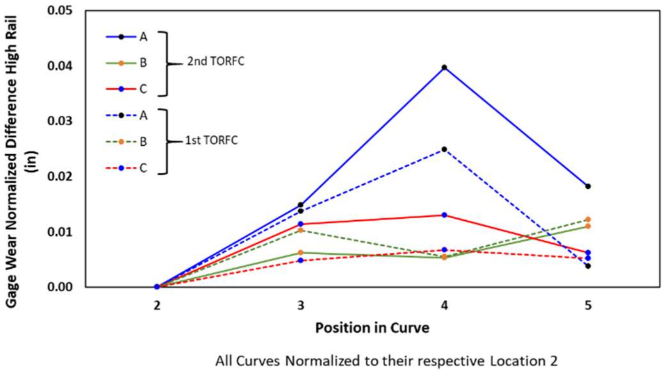


Figure 2. Gage wear comparison of high rail in all three curves between the two TORFC phases

Table 1 shows a RCF performance summary based on visual dye penetrant observations made at locations 2 and 5 (beginning and end of curve) at the start and end of each TORFC period. Differences in rail surface starting conditions (in the form of significantly more RCF remaining after grinding at the start of the second TORFC period) make it unfeasible to directly compare performance of the two products in controlling RCF.

Curve A: At the start of the first TORFC period, neither rail exhibited RCF. After 39 MGT, the beginning of the curve still did not exhibit visible RCF, while the end of the curve showed significant RCF and pitting on both rails.[1]

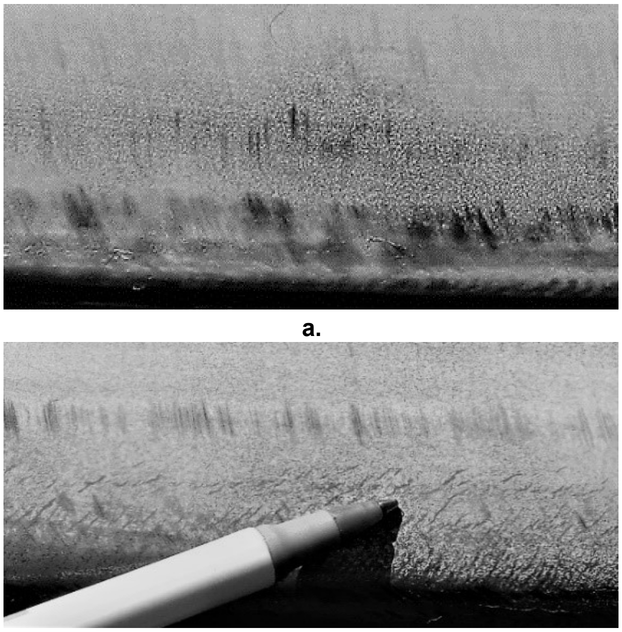
Table 1. Summary of Visual Dye Penetrant Data ">, <" slight increase, decrease ">>"significant increase)

	2nd TORFC				1st TORFC[1]			
Location	**A2 PSC**	**A5 PCS**	**B2 PSC**	**B5 PCS**	**A2 PSC**	**A5 PCS**	**B2 PSC**	**B5 PCS**
High Rail at Start	Moderate longitudinal RCF on upper gage corner (GC)	Significant RCF, GC to TOR	No RCF, only grind marks	Moderate RCF upper GC, some grinding marks on TOR	No RCF	No RCF	No RCF	Minor RCF
High Rail + 39/40 MGT	**>** Minor pitting, moderate 45° deeper RCF on GC	>> Significant GC 45° RCF and longitudinal at TOR center, minor pitting on TOR	No RCF, no grind marks	**>** Significant 45° RCF upper GC	No RCF	>> RCF, Pitting	No RCF	>> RCF Pitting
Low Rail at Start	Very minor RCF on top center, significant grind marks	Spalling on TOR center, moderate RCF on TOR field side	No RCF, upper GC grind marks	Minor RCF TOR center, grind marks on both sides (GC, FC)	No RCF	No RCF	No RCF	No RCF
Low Rail + 39/40 MGT	**<** No RCF, some grind marks (GC)	> Minor RCF and pitting on TOR center	No RCF, no grind marks	**<** No RCF	No RCF	>> RCF, Pitting	No RCF	Minor RCF

During the second TORFC period, similar performance as to the change in RCF was noted, with the exception of the low rail at the beginning of the curve, which exhibited a slight improvement after 39 MGT.

Curve B: At the start of the first TORFC period, the low rail exhibited no visible RCF, while some RCF was visible on the high rail at the end of the curve. After 39 MGT, the low rail remained generally free from RCF; while the high rail had no RCF at the beginning but exhibited significant RCF and pitting at the end of the curve. Again, during the second TORFC period, similar performance as to change in RCF was noted, except for the low rail at the end of the curve, which exhibited slight improvement (less RCF) after 39 MGT.

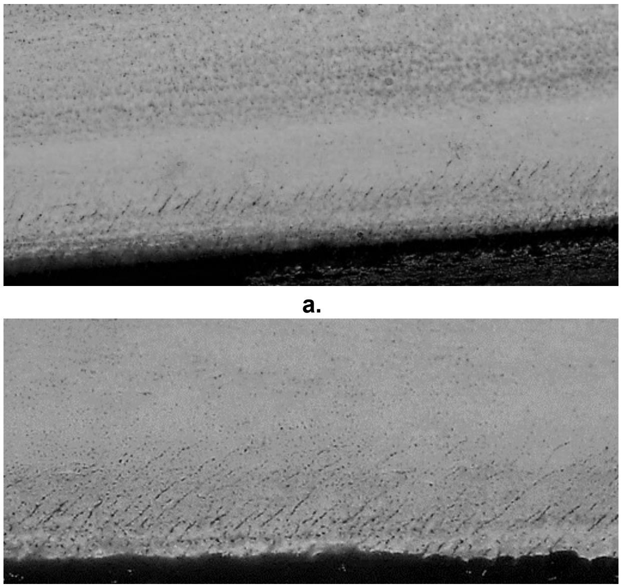
Figures 5a and 5b illustrate the observations summarized in Table 1. Photos of the high rail at mid-curve (location B3) indicate that at the start of phase 1 there was no RCF present (Figure 5a), but at the start of phase 2, RCF was present (Figure 5b). Gage side is at the bottom of all photos. Figures 6a and 6b show the same B3H location after 39 MGT at the end of phases 1 and 2. Dye penetrant inspection of curve C during the initial inspection of phase 2 was missed because of no available time to test the track, thus preventing comparisons in change to RCF performance.


a.

b.

Figure 5. Site B3H post grind at the beginning of Phase 1 (5a.), and Phase 2 (5b.)
(Pen is pointing to upper gage corner RCF)

Measured TOR friction on Curve B low rail (0.33-0.36μ), was within guidelines, with the high rail exceeding 0.46μ. Once into the body of curve, all curves indicated higher top of rail friction at the beginning and end of the test period. Both rails of curve B indicated above recommended practices (0.40-0.53μ) in the body of the curve. This suggests the phase 2 material was most effective at or near the beginning of curve and disappeared with little or no effectiveness after the middle of the curve.


a.

b.

Figure 6. Site B3H after 40 MGT in phase 1 (6a.) and after 39 MGT in phase 2 (6b.)

FUTURE WORK

Results of this evaluation suggest TORFC materials do not accelerate RCF growth or development. When applied in an area also subjected to periodic grinding, RCF does not become excessive. However, extended monitoring would be required to assess long-term effects.

References

1. Banerjee A., Conn K., Kerchof B., Reiff R., “Effects of Top of Rail Friction Control Materials on Rail in Revenue Service” *Technology Digest*, TD-17-035, December 2017, AAR/TTCI, Pueblo, CO.
2. Reiff, Richard and David Lilley, “Preliminary Placement Guidelines Top of Rail Friction Control Application Systems,” *Technology Digest* TD-06-002, February 2006, AAR/TTCI, Pueblo, CO.