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FAST Testing of Latest Top-of-Rail Friction Modification Materials

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Summary

October–November 2013, Transportation Technology Center, Inc. (TTCI) evaluated six friction control materials at the Facility for Accelerated Service Testing (FAST). All testing was for wayside top-of-rail friction modification (TOR FM) water-based and oil-based materials. Testing was carried out on one water-based material from Supplier A (The Whitmore Manufacturing Company – Whitmore Rail) and three water-based and two oil-based materials from Supplier B (LB Foster). TTCI conducted the research at FAST to identify a relationship between application rate of each product and the resulting reduction in lateral curving forces, as well as TOR frictional change.

Based on the current results, the following conclusions can be drawn:

- For all products tested, there was a decrease in lateral forces with an increase in TOR FM application rate.
- Percentage reduction in curving forces was greater on the low rail than on the high rail. In some cases, 99-percent confidence intervals overlapped between low and high rail results for the same products at the same application rates.
- For water-based TOR FM products, the highest percent reduction in lateral curving forces was recorded on Supplier A – Product 1 at 12.26 in^3/1,000 axles' application rate. The reduction was 67 percent for the low rail and 55 percent for the high rail.
- For oil-based TOR FM products tested by Supplier B, the highest percent reduction in lateral curving forces was recorded on Product 4 at 5.49 in^3/1,000 axles' application rate. The reduction was 54 percent for the low rail and 43 percent for the high rail.
- Water-based products offered relatively rapid attainment of steady-state conditions in curving force reduction. However, the force reduction dissipated rapidly once product application was ceased.
- Oil-based products took relatively longer to achieve steady-state conditions in curving force reduction. However, the force reduction took more train passes to dissipate once product application was ceased.

Future work needs to address the optimum distance between wayside applicators, the effects of TOR FM materials on wheel and rail rolling contact fatigue and wear, and material effectiveness in cold weather climates. Revenue service is best suited to accomplish these tasks.

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INTRODUCTION

Friction control is a process of applying lubricants and/or friction modifiers to either the wheel or the rail, with the primary goal of extending rail and wheel life and reducing fuel consumption. Gage face (GF) lubrication is applied to the gage face of the rail, whereas TOR FM material is applied to the top running surface of the rail. Application of both GF and TOR FM materials can be accomplished by either a system mounted onboard the moving vehicle or by a wayside system, next to the track. Onboard systems apply materials directly to the rail or wheel, whereas wayside applicators apply material on the rail and rely on the wheels to deliver the material along the track. Previous wayside application studies have been carried out at FAST[1] and in revenue service.[2]

In line with North American heavy axle load revenue service needs, the three main objectives of TTCI's research into cost-effective friction control materials include the following:

- Determine the optimum friction control material application rate (accomplished through measurements of lateral curving forces and friction coefficients on rail running surfaces)
- Determine optimum distances between wayside applicators (accomplished by investigating material carry distance)
- Determine the effect of TOR FM materials on wear and rolling contact fatigue (RCF) development (requires long-term observation)

The current study was conducted at FAST to determine the optimum application rate for each FM material. Current testing focused on both water- and oil-based materials applied wayside. Two suppliers participated in the testing: Supplier A (The Whitmore Manufacturing Company – Whitmore Rail) and Supplier B (LB Foster). Supplier C (LORAM Maintenance of Way, Inc.) TOR FM products were tested in fall 2014. Results from these tests will be presented in another digest.

Tests were conducted for seven nights of train operation at FAST. The following test metrics were collected wayside:

- Rate of TOR FM material application
- TOR FM material effects on rail friction, through TOR tribometer readings (100 feet and 2,900 feet from the applicator)
- Lateral curving forces (2,900 feet from the applicator)

TEST LAYOUT AND METHOD

FAST is a 2.7-mile loop with approximately 55 percent body of curve, 17 percent spiral, and 28 percent tangent track. Figure 1 shows the layout of the 2,900 foot section of track used for testing. Due to the fixed 2.7-mile length of the FAST loop the maximum spacing between application units for the purpose of this test is considered to be 2.7 miles. Greater applicator spacing distances cannot be tested in the current FAST test setup. Depending on the night of operation, the train was made up of three locomotives and either 89 or 115 fully loaded 315,000 pound gross load railcars operating at an average speed of 40 mph in a counterclockwise direction around the loop. GF lubrication was applied in a short spiral. TOR FM material was applied wayside in a short tangent (Section 5). The application rates were in accordance with manufacturer's recommended practice. As a result, TOR FM application rates were assessed by each supplier and reported to TTCI. TOR friction was measured in a short spiral (Section 6) and a 6-degree curve (Section 25), respectively, 100 feet and 2,900 feet from the TOR FM wayside applicator. Strain gages were applied to the high and low rails 2,900 feet from the wayside applicator (Section 25) to allow measurement of wheel/rail lateral forces. Figure 2 shows a typical TOR FM wayside applicator setup.

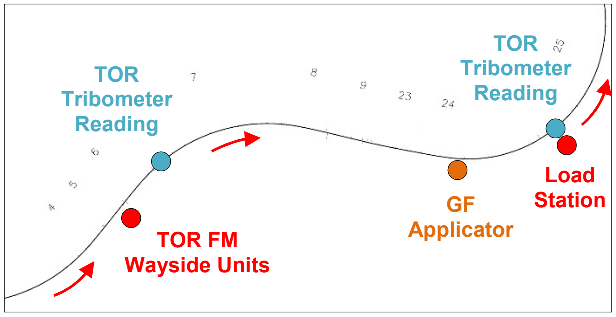

Figure 1. Excerpt of FAST map indicating locations of TOR FM wayside units (Section 5), the load station (Section 25), TOR tribometer measurements (Sections 6 and 25) and GF lubrication application station location. Counterclockwise train travel direction is indicated by arrows.

Figure 2. Typical FAST wayside unit setup in Section 5

Lateral curving force analysis was conducted on the leading axle of each truck for each product application rate. Vertical wheel/rail forces were not considered because of the highly controlled nature of the test (same cars, same loads, consistent train speed, and many laps). The lateral curving force data was compared to baseline (GF lubrication only) conditions. Baseline conditions were established prior to each change in product or application rate by shutting off the TOR FM applicator and using GF lubrication only until the measured forces on the rails reached steady state. The steady-state percent reduction in curving forces of each product application rate was determined from the baseline condition immediately prior to TOR FM application. The baseline runs (prior to application of each product) are included in the steady-state where no statistical difference was observed between runs using the log-rank statistic in nonparametric survival analysis. Results are presented as percent reduction in lateral curving forces over the baseline condition.

Distribution results of this analysis are presented as the median of the per axle calculated reductions. Confidence intervals (CI) of 99 percent are used to represent the range of the results at each application rate (Figure 3). Between TOR FM product changes and before each product was applied, a baseline (GF lubrication only) condition was established for comparison of all TOR FM materials. Steady-state lateral curving forces were established for the baseline condition and were used as a target for dry down (i.e., restoring to baseline condition) before testing different TOR FM products. Supplier A tested one water-based product (red lines in Figures 3–5), whereas Supplier B tested five products, three that were water-based (blue lines in Figures 3–5), and two that were oil-based (green lines in Figures 3–5).

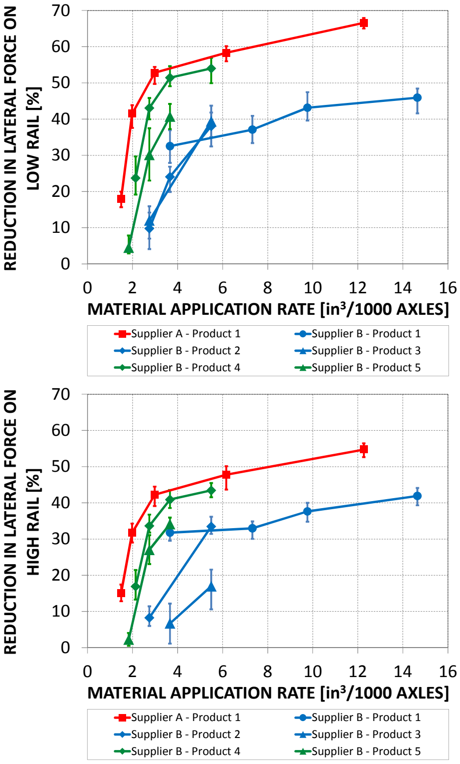

Figure 3. Reduction in lateral curving forces over baseline GF lubrication only conditions on the low and high rail measured 2,900 feet away from the applicator in Section 25

RESULTS

The results indicate that for all products tested there is a decrease in steady-state lateral forces on both the high and low rails as the material application rate increases. The results also show that in most cases the percent reduction in lateral force is greater on the low rail than on the high rail. In some cases, confidence intervals overlap between low and high rail results for the same products at the same application rates.

The highest percent reduction in lateral curving forces for both the low and high rails was recorded for Supplier A – Product 1 at 12.26 in^3/1,000 axles' application rate. The reduction was 67 percent for the low rail and 55 percent for the high rail at that application rate.

Since test setup and equipment availability allowed limited acquisition of tribometer measurements during testing, this data is included here as information, with the lateral force data considered the main metric in this testing. In light of this, rail friction at the site of the lateral force measurements (2,900 feet away from applicator) indicates that values on the low rail remained at or above 0.40μ for most products tested (see Figure 4). However, in the case of Supplier B – Product 4, the TOR running surface friction dropped to 0.32μ at 3.66 in^3/1,000 axles' application rate. TOR friction for the same product 100 feet from the application location was even lower at 0.23μ and 0.26μ for 3.66 and 5.49 in^3/1,000 axles' application rates, respectively (see Figure 5).

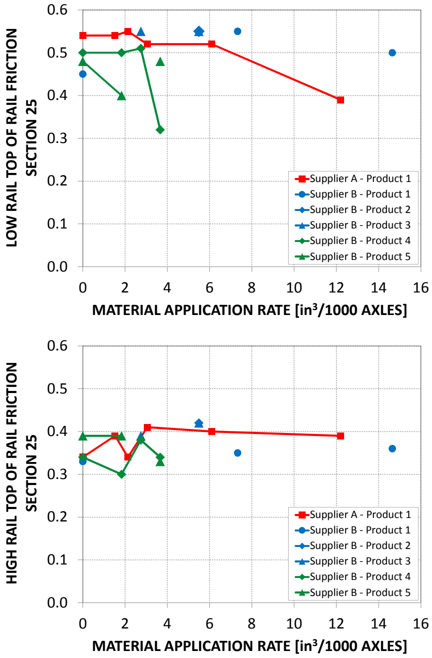

Figure 4. TOR friction on the low and high rails measured in Section 25, 2,900 feet away from wayside applicator

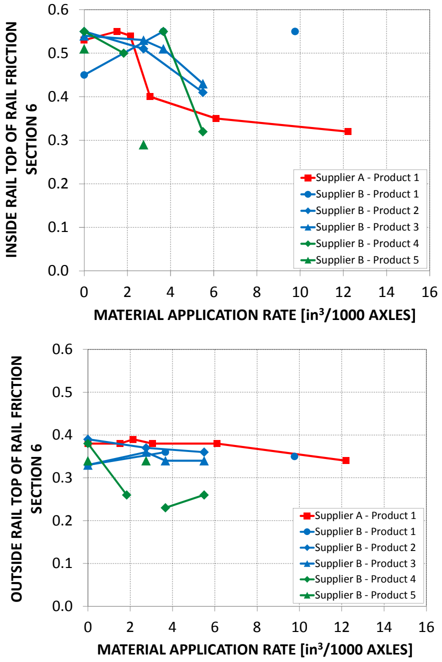

Figure 5. TOR friction on inside (low rail of Section 25) and outside (high rail of Section 25) rails in Section 6, 100 feet away from wayside application location

Coefficient of friction measurements on the high rail in Section 25 showed consistently low values in the range of 0.30μ to 0.42μ, all relatively lower than values for the low rail (see Figure 4).

These are likely due to GF lubrication applied in Section 24 migrating to the top of the rail and mixing with the TOR FM materials. Figure 5 shows similar TOR friction measurements of the outside rail in Section 6. Gage face migration masks the expected drop in TOR friction level due to increased TOR FM application rates on the outside high rail of Section 25 HTL.

DISCUSSION

Analysis of both water-based and oil-based products is best performed by considering the benefits and drawbacks of each material type.

Water-Based Products

Observation of TOR friction values for water-based products suggests that material is not depositing on the rail at low application rates (i.e., TOR friction is relatively high), which would suggest that initially, wheel conditioning takes place to allow a reduction in curving forces.

Pros:

- Rapid conditioning of the wheels resulted in nearly immediate attainment of reduced steady-state lateral curving forces (i.e., it took a relatively low number of laps to achieve steady-state curving force reduction conditions).
- Even low application rates resulted in tangible benefits in lateral force reduction
- Up to a 67-percent reduction in lateral forces was observed at higher application rates for one product (Supplier A – Product 1). However, it required a relatively high application rate of 12.26 in^3/1,000 axles and produced TOR friction of 0.3 near the applicator.

Cons:

- Relatively rapid rise in lateral curving forces resulted once the product application ceased.
- Some products produced low rail friction conditions near the applicator at higher application rates. Additional friction measurements after extended operation at higher application rates are needed to determine if adverse conditions would be created.
- Product fling and waste on the ballast were observed at higher application rates.

Oil-Based Products

Pros:

- Up to a 54-percent reduction in low rail lateral curving forces and a 43-percent reduction in high rail lateral curving forces for Supplier B – Product 4 at 5.49 in^3/1,000 axles' application rate.
- Relatively longer lasting benefits of material once application was ceased as compared to water-based products (i.e., steady-state forces required more train passes to rise).

Cons:

- Relatively longer conditioning times compared to water-based products (i.e., took more laps to reach steady-state lateral force reduction conditions).
- While extended carry distance is a desirable feature, friction at and near the applicator is of critical importance. Additional friction measurements after extended operation at higher application rates are needed to determine if adverse conditions would be created.

General Comments

Although the focus of the current test was on the materials utilized and not the application equipment, it is important to mention the different application practices used by Suppliers A and B. Supplier A selected pump settings that provided small amounts of product at frequent intervals during train passage, whereas Supplier B selected settings that provided larger amounts of material less frequently during the train passes. In the cases where the net material volumetric application per 1,000 axles is the same, Supplier A's product was applied more uniformly along the train, but at lower amounts, whereas Supplier B's products were "lumped" in sections along the train. Future work should evaluate the effects different application processes have on material effectiveness and conditioning of wheels and the rail running surfaces.

The GF lubrication only baseline conditions that were established for comparison purposes in each assessment of lateral curving force reduction should be considered for future revenue service studies. It was difficult to reestablish identical "baseline" conditions for all products. Analysis carried out for some products may have started with baseline conditions that were slightly different than for other products. Future revenue service studies should attempt to establish similar baseline conditions for all comparison purposes.

FUTURE WORK

Products from Supplier C were tested at FAST in fall 2014. A report from this investigation will follow thereafter.

The current TOR FM study at FAST attempted to understand the relation between product application rate and reduction in both curving forces and rail running surface friction., Future work should address: application rate practice (distribution along the train); influence on effective optimum applicator spacing; long-term effects of material buildup that might produce marginal TOR friction conditions; rail and wheel wear and RCF development; and material effectiveness in cold weather climates.

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1. Reiff, Richard and Ted Hawken. June 2008. "Top of Rail Friction Control – Friction Control Materials." *Technology Digest* TD-08-022. AAR/TTCI, Pueblo, Colo.
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