TECHNOLOGY DIGEST

TD-15-022
©JULY 2015

TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Evaluation of Latest Top-of-Rail Friction Modification Materials at FAST

Richard Reiff,+ Daniel Szablewski,* and David Davis*

Summary

During October 2014, the Transportation Technology Center, Inc. (TTCI) evaluated two additional friction control materials, one water-based product and one oil-based product, at the Facility for Accelerated Service Testing (FAST), Pueblo, Colorado, for comparison to six previous materials evaluated during October–November 2013 and reported on in TD-14-024.[1]

The 2013 evaluation included four water- and two oil-based products, all conducted with a wayside applicator. TTCI conducted the evaluation to identify a relationship between application rate of various products and the resulting reduction in lateral curving forces, as well as top-of-rail (TOR) frictional change.

For this update, lateral forces (rather than percentage reduction in curving forces from dry baseline) were compared between products evaluated in 2013 and 2014 because of significant differences in baseline rail conditions. Thus, only steady state lateral force conditions at various application rates will be used for performance comparisons.

The updated results are for all products evaluated, with the following conclusions drawn:

- For all products tested, there was a decrease in lateral forces with an increase in TOR friction modifier (FM) application rate. Reductions of lateral forces ranged from 50 to 65 percent from base line values were measured for various products and application rates.
- Application rates above 5.4 cubic inches (3 fl oz)/1,000 axles produce smaller lateral curving force decreases as measured 2,900 feet from the applicator. In addition, the higher application rates may result in unacceptably low rail friction (<0.30 µ) at or near the applicator.
- For all TOR FM products evaluated, the lowest steady state curving force was produced by water-based products, at application rates of more than 10.8 cubic inches (6 fl oz)/1,000 axles.
- One water- and two oil-based products consistently produced friction levels below AREMA recommended minimum values near the applicator, even at relatively low application rates.
- After application ceased, water-based products tended to lose effectiveness more rapidly than oil-based products. In the closed loop operation at FAST, water-based products lost effectiveness in as little as two train passes. Oil-based products were effective for about 10 trains.
- Other factors in determining TOR FM performance include potential waste (excess lost into the ballast) and low friction produced near the application site.

Future work will 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.

+Consultant, *TTCI

INTRODUCTION AND OBJECTIVES

Friction control is achieved by applying lubricants and/or FMs to either the wheel or the rail, with the primary goals of extending rail and wheel life and reducing fuel consumption. Friction of the gage face (GF) and/or TOR can influence rail-wheel wear and performance, and rolling train friction. Lubrication is applied to the GF of the rail with the objective of lowering friction; whereas, TOR FM materials are applied to the top running surface of the rail with the objective of controlling friction to a target level. Either type of material can be applied by a system mounted on board the moving vehicle or by a wayside system. For these evaluations, a wayside based application system typically used by North American heavy haul railroads was selected.

Primary 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 conducted at FAST was a short-term evaluation and could only determine the effect of application rate on curving force performance for each FM material. Three suppliers participated in the evaluation. Products provided by Supplier A (The Whitmore Manufacturing Company — Whitmore Rail) and Supplier B were evaluated in 2013. During 2014, Supplier C (LORAM Maintenance of Way, Inc.) provided materials.

See *Technology Digest* TD-14-024 for a full description of the testing procedures, track configuration, and applicator system.[1.] Most details are not repeated here. This TD presents updated results and includes the two additional products from Supplier C.

TEST LAYOUT, METHODOLOGY, DATA

All evaluations were conducted during night train operation at FAST. The following test metrics were collected wayside:

- Rate of TOR FM material application
- TOR FM 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)
- Each TOR FM material was applied to both rails by a wayside system in a short tangent, with application rates in accordance with each manufacturer's recommended practice. 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 applied to the high and low rails 2,900 feet from the wayside applicator (Section 25) measured wheel-rail lateral forces. Lateral curving force analysis was conducted of the leading axle of each truck for each product application rate. Only data collected when the train was operating at a steady state speed of 40 mph was used.

The normal procedure for assessing product performance is to compare lateral curving force data during a steady state TOR condition with that of a baseline (GF lubrication only, no TOR) condition. Baseline conditions are 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 and TOR friction indicated dry by friction readings of ~ 0.5µ. This allows percent reduction in steady state curving forces of each product's application rate to be determined from the baseline condition. However, tribometer measurements collected on the outside rail indicated significant differences in TOR coefficient of friction between the 2013 and 2014 periods. During 2013, the top of both inside and outside rails exhibited very dry (> 0.50µ) friction values during baseline periods; whereas, during 2014 evaluations, there was physical evidence of contamination on top of the outside rail during dry baseline periods, with friction readings of 0.30 µ to 0.39 µ. At the same time, the inside rail routinely exhibited friction at typically dry (> 0.50 µ) values. While extended dry operation might have eliminated this contamination, rail and wheel wear at FAST would have been severely impacted. For this evaluation using percent reduction from baseline between all products is not valid for comparison purposes; therefore, this update will use only steady state curving forces. The effect of initial contamination can be seen in Figure 1, which shows significantly different starting points ("0" application rate) for each product. Distribution results of this analysis are presented as the median of the per axle calculated performance during steady state periods. This was generally the median curving forces produced by the train on the high or low rail over a 5- to 10-lap period after steady state conditions had been reached.

Results shown in Figure 1 (high and low rails) include both oil- and water-based materials. As different application rates were selected over multiple days of testing (and starting from different baseline values) some products are shown in two segments. The following three materials were oil based: Supplier B, products 4 and 5 and Supplier C, product 2. Five water-based products include Supplier A, product 1, Supplier B, products 1, 2, and 3 and Supplier C, product 1.

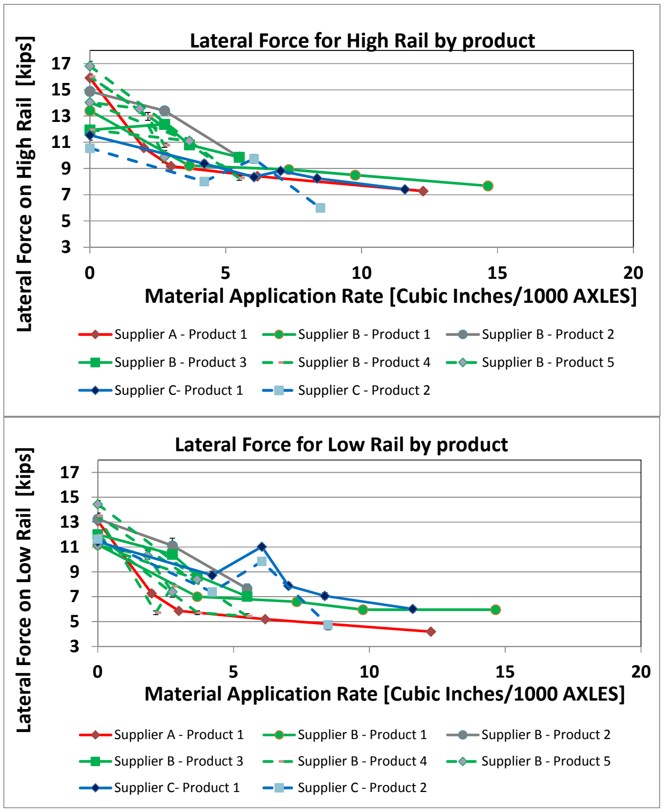

Figure 1. Section 25, Steady State Lateral Curving Forces on the High and Low Rail, 100 feet from the Applicator in Section 06

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 lowest steady state lateral curving forces for the low rail were produced by Supplier A (water based), product 1, and Supplier C (oil based), product 2, both at > 8.5 cubic inches (4.7 fl oz)/1,000 axles. For the high rail, the lowest steady state curving force was produced by Supplier C (oil based), product 2, at 9.02 cubic inches (5 fl oz)/1,000 axles. Water based materials from Suppliers A, B, and C, all at application rates exceeding 11.7 cubic inches (6.5 fl oz)/1,000 axles, produced the lowest curving forces.

However, products at specific application rates producing the lowest curving forces may not always be viable. Users must also consider the rail friction produced to obtain this performance as part of the product evaluation. While a very low friction will produce significant reductions in curving forces, if too low it can also produce undesirable side effects.

Due to the configuration of the test loop and the nature of the measurement, a limited number of tribometer measurements are possible between train passes. Key rail friction measurement locations are considered to be in Section 6 of the test loop (100 feet after the applicator), where undesirable TOR friction of < 0.30 µ can be determined from too much product. TOR friction lower than this recommended minimum (based on current AREMA Chapter 4 recommended practice[2]) may result in train adhesion and handling problems. While unacceptably low rail friction was generally not an issue, 2,900 feet from the applicator data exhibited in Figure 2 shows in several instances products that either produced friction below 0.30 µ or were trending so that at a higher application rate the minimum threshold would likely be exceeded. In some instances, readings of 0.25 µ were produced after several consecutive train passes.

Application rates of the water-based product that produced the lowest curving forces (Supplier C, product 1) concurrently produced unacceptably low rail friction just beyond the applicator. Oil-based products (Supplier C, product 2, Supplier B, products 4 and 5, all reached 0.3 µ. Thus while not exceeding the limit, caution is advised to ensure extended operation or high application rates do not create unacceptable friction levels.

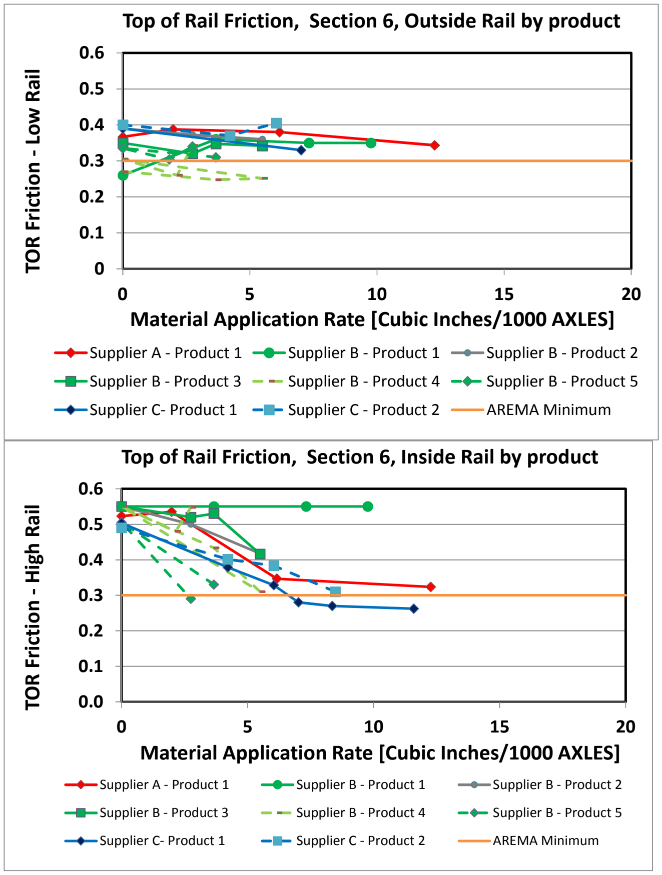

Figure 2. TOR Friction on Inside and Outside Rails in Section 6, 100 feet Away from Wayside Application Location

Rail friction at the site of the lateral force measurements (2,900 feet away from applicator) indicates that values on the low rail generally remained at or above 0.40 µ for most products tested (see Figure 3). However, in the case of Supplier C, product 2, the TOR running surface friction dropped to between 0.32 µ and 0.34 µ at the higher application rates. TOR friction for this same product 100 feet from the application location was even lower at 0.25 µ.

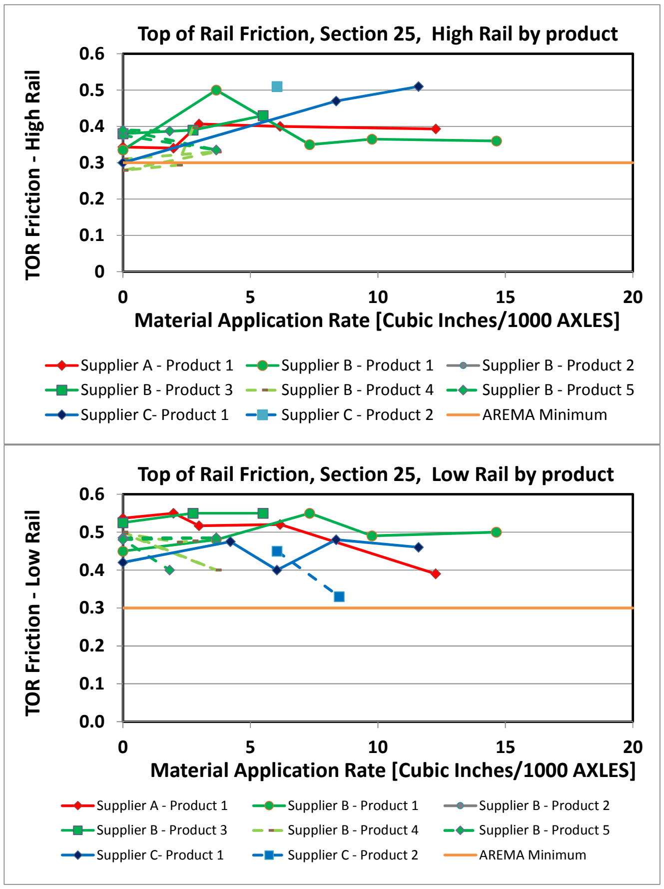

Figure 3. TOR Friction on the Low and High Rails Measured in Section 25, 2,900 feet Away from Wayside Applicator

Due to test budget and time limitations, it was not feasible to operate a full shift (100 or more train passes) at a given application rate. Past experience has shown that long term buildup of a product, especially near the applicator, can create even lower friction levels than was measured during the short 15–20 lap steady state periods of this test. For this reason, any product that is approaching the lower friction limit should be used with caution until performance after continued long term application can be monitored with a tribometer or other friction measurement device.

During steady state conditions when TOR material was being applied, friction measurements on the high rail in Section 25 exhibited consistently lower values than the low rail. This is likely due to GF lubrication migrating to the top of the rail and mixing with the TOR FM materials. Gage face migration can alter friction produced by TOR materials and the influence of variations in GF products must also be evaluated.

CONCLUSIONS AND DISCUSSION

The "knee" in product performance for most products appears around 5.4 cubic inches (3 fl oz)/1,000 axles. Data suggests that at low application rates small increases in application produce larger gains (greater reduction) in curving forces, while at higher application rates little is gained by increasing the amount of product applied. As FAST is a unique, highly curved continuous loop, an optimum application rate for the products evaluated has been shown to be in the 5–7 cubic-inch (3–4 fl oz/1,000 axle) range. This would likely be different in revenue service.

Although the focus of the current test was on the materials used and not the application equipment, it is important to note that suppliers used different application practices. For the same effective amount of product, some suppliers elected pump settings that provided small amounts of product at frequent intervals during train passage; whereas, others selected settings that provided larger amounts of material less frequently during the train passes. A smaller amount applied more frequently results in the product being applied more uniformly along the train, but at lower amounts at any given location; whereas, the higher but less frequent approach tends to "lump" the product in sections along the train. This nonuniformity likely contributed to variable friction, especially near the applicator. In some instances, different mechanical and control features and applicator bar configurations of application systems can influence desired application patterns.

The variability of baseline "GF lubrication only" conditions for comparison purposes should be considered when comparing TOR FM products. As stated earlier, it is difficult to reestablish identical "baseline" conditions.

FUTURE WORK

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.

REFERENCES

1. Szablewski, Daniel et al. December 2014, "FAST Testing of Latest Top-of-Rail Friction Modification Materials," *Technology Digest* TD-14-024, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.
2. American Railway Engineering and Maintenance of Way Association (AREMA), 2012, *Manual of Railway Engineering*, Chapter 4, Part 4.11 Recommended Practices for Rail/Wheel Friction Control, Lanham, MD.

ACKNOWLEDGEMENTS

Special thanks to Beatrice Rael (TTCI) and Ivan Aragona (Consultant) for their contribution to this project.