ABSTRACT

Controlling top of rail (TOR) friction provides significant benefits to the stress state of the railroad by reducing truck curving forces. Investigations and demonstrations of locomotive, mobile, and wayside based application methods suggest that the wayside method is currently the most easy to implement means for addressing site specific problem areas for North American railroads.

Results will be presented from a number of prototype demonstration sites. This will include data utilized to develop implementation guidelines and updates to the current AREMA manual for wayside TOR. These include positioning, spacing, and application rates of TOR friction control applicator systems and materials. Also included will be data supporting the need to optimize and properly deploy gage face lubrication (which is still needed to control side rail wear) when mixed with wayside TOR application systems. Demonstration sites include Union Pacific, BNSF, CN, and Norfolk Southern railroads.

A review of alternative application technologies and considerations for implementation and deployment will also be provided. This will include a summary of remaining issues being addressed to allow optimization of not only wayside, but car-based, locomotive-based, and mobile application methodologies.
1.0 OVERVIEW

Railroad engineers have a number of resources by which to extend the life of rail in-track. The most common methods include rail profile grinding and friction control (commonly referred to as lubrication). Both rail grinding and friction control have recently been targeted by AREMA Committee 4 as a key area needing updated recommended practices to ensure optimized implementation.

Although rail grinding and friction control methods work in harmony as a system, this paper will concentrate on recently implemented best practices for traditional and alternative friction control methodologies.

2.0 LUBRICATION AND FRICTION CONTROL

Lubrication of the gage face (GF) surface has been utilized by railroads for over one hundred years. In the heavy freight railroad environment, lubrication has, until recently, been implemented primarily as a means of controlling friction at the GF with the intent to extend rail life. In the last 20 years, the railroad industry has developed a better understanding of the relationship between friction control and subsequent system behavior. This has allowed top-of-rail (TOR) friction control to be included as a railroader’s arsenal of tools for improving rail life.

In order to evaluate and determine optimum GF and TOR friction values, work conducted by Transportation Technology Center, Inc. (TTCI), Pueblo, Colorado, included an extensive investigation using a matrix of wheel/rail friction variations under a wide range of curvatures and truck conditions. This study was conducted using NUCARS® software to predict curving performance and system wear indices (1). This information was utilized to determine optimum friction patterns that could reduce poor curving performance of trucks, yet provide improved rail and wheel life. These friction guidelines can also be utilized by designers of new friction control methodologies so that not only is system wear reduced but, when properly implemented, this system can also reduce curving forces, improve running surface fatigue performance, and control noise.

With the knowledge of optimum friction values, a track inspector now has a more scientific means of determining where to improve friction control. This includes the following major steps:

- Field inspection and assessment of current conditions
• Review of railroad policies and site specific issues for improving friction control

• If needed, demonstrate applicator and material performance to determine if railroad specific situations require alternative deployment

• Coordination of friction changes with the wheel/rail profile maintenance (grinding) program

• Implementation of improved friction control

• Management oversight and long-term monitoring

2.1 Field Inspection

The initial effort to improving rail friction is an assessment of existing field conditions to determine if they comply with target values. Using results from NUCARS predictions and a number of field demonstrations, AREMA Committee 4 has recently incorporated new recommendations in Chapter 4, Section 4.7 of the AREMA manual. The following are current friction guidelines:

• GF friction value < 0.20 µ

• Gage corner friction value < 0.20 µ (note: Gage corner recommendations are currently being reviewed for inclusion into the AREMA manual)

• Top of rail (TOR) friction value 0.35µ +/−0.05 µ

• Left to right rail friction value differential < 0.1 µ

With the knowledge of optimal rail friction values, the inspector must first determine if these recommendations are being met. The old tried and true method of “wiping and looking” may suffice for determining if a film of lubricant is present, but is not sufficient to determine friction control effectiveness and adequacy. A number of tools are available for measuring rail friction. Figure 1 shows the most commonly utilized tool for freight railroads, a hand-push tribometer. This unit is manually adjusted to measure a specific location on the rail, at any location from the TOR to GF.

For longer territories, high speed tribometers are also available, which can produce a database of friction values in a format similar to that of a track geometry car. While measuring rail friction is straight forward, this
technique only determines part of the wheel/rail interface condition. Wheels are also subjected to, and become conditioned with, lubricants and friction modifiers. Measuring rail friction alone provides a spot indication of rail friction conditions and does not always fully correlate with total system performance.

Field locations are subjected to a wide range of trains, truck configurations, train weight, and wheel/rail profiles. If additional information on system performance is needed, other indices can also be monitored. Some of these inspection techniques require a long time or the passage of one or more trains to collect the necessary data and may include:

- **Curving Forces**: Strain gages installed on the rail are used to determine lateral curving performance. Curving performance has been shown to change with friction patterns. Recent work to evaluate TOR systems has made extensive use of curving forces to optimize system deployment and adjustment.

- **Wear (rail or wheel)**: Long-term implementation of any friction control system is also reflected by reduced system wear. Most demonstrations conducted over a short period of time or short distances do not have a sufficient number of applicators nor provide adequate coverage to properly affect system wear.

- **Rail Head Deflection**: Some success has been experienced measuring dynamic rail-head deflection under passing trains (2). Changes in curving forces with friction patterns are reflected by reduced gage widening deflections. This method is being considered for use as a portable means for determining TOR effectiveness at site-specific locations.

Figure 2 shows an example of how friction control policies can alter some of these performance indices. This data was obtained on the Facility for Accelerated Service Testing (FAST)/Heavy Axle Load (HAL) loop at the Transportation Technology Center in Pueblo, Colorado, during a period when the train was operating at the normally prescribed 40 mph speed. During a 45 lap period, the lubrication was purposely altered from the “normal” condition, which consists of moderate GF lubrication applied to the outside rail curves and a small amount of lubricant applied to the top of the inside rail.
In this example, higher lateral curving forces occurred when the high rail of the curve remained fully lubricated from a nearby wayside lubricator; however, the low rail application was turned off (laps 12 through 18). Such a condition can be found when a wayside lubricator over applies grease on one rail only with the low rail disabled. This generates very low friction values on the top and GF of the high rail (µ < 0.20), while at the same time maintaining a dry friction value (0.50 µ) on the top of the low rail. This condition violates two of the three recommended friction levels as stated in Section 3.1. Data in Figure 2 was generated with the same train and speed, which shows that significant (and even detrimental) curving forces can be generated simply by changing friction patterns.

By conducting one or more monitoring methods at various locations, the inspection will allow documentation of where friction values need to be changed in order to improve system performance.

### 2.2 Achieving Friction Control Goals

After assessing existing friction values and determining the status of any presently installed applicators, improvements, if any, can be specified. If inspection suggests a large friction value number, the existing wayside lubricators are not working or are improperly adjusted, then the first step will be to establish a program to correct these deficiencies. In many cases, the original installations of such systems were based on protecting key curves and locations; however, over time, some systems may have failed or components become worn or damaged. In some situations, due to localized budget restrictions, crews not having kept applicators filled, repaired, or maintained.

Such deficiencies must be rectified and followed by re-inspection of the site to determine if proper application of lubricant or friction control materials is now being conducted. Coordination and site inspections and visits with vendors and suppliers is suggested to ensure the latest techniques and upgraded parts are in use. Often such feedback, followed by adjustment and repair efforts, will return many of the areas initially indicating inadequate friction back to a properly performing system.

Based on the change needed to meet desired friction values, a number of technologies are available. These fall into two major categories:

- GF lubrication
• TOR friction control

The most significant difference between conventional GF lubrication and TOR friction control is the use of a friction modifier (FM) for TOR applications rather than a lubricant (grease or oil), as is used for GF applications. TOR friction control achieves the most benefit when the top of both rails are at the target friction value of 0.3µ to 0.4µ. While theoretically a lubricant could be used for this application, it is difficult to control such products to produce the desired friction value on a consistent basis. Figure 3 shows the conceptual relationship between a lubricant and FM relative to product thickness on the running surface.

As product thickness of a lubricant or FM is increased, the resulting rail friction is reduced from a dry friction value of 0.5 µ. A typical lubricant produces a friction value of 0.35 µ over a very narrow band of film thickness, while a FM produces a desired 0.35 µ friction value over a wider range of thickness. This feature of a FM is what allows TOR application systems to produce desirable friction levels over a wider range of product thickness than a lubricant.

2.3 Application Systems

The two most commonly utilized application methods for either GF lubrication or TOR friction control are variations of:

1) Fixed (wayside) applicators

2) Mobile (usually locomotive mounted) applicators

The deployment method selected (fixed- or mobile-based) depends on a number of issues. While space limitations in this report prevent detailed discussions of all options, generally when curves are uniformly spaced and less concentrated into localized bunches, the use of mobile-based systems becomes more attractive. When curves are concentrated in specific locations as well as being severe, the use of wayside-based applicators becomes more attractive. Other issues to investigate include access for wayside applicators, temperature variance, solar power capacity, operating environment, interchange of locomotives, labor policies, and past experience.
2.4 Fixed- and Wayside-Based Application Systems

Wayside-based application systems are presently the most widely used applicator format in North America. Typical wayside-based GF lubrication or TOR systems are similar in appearance, with the most notable difference in applicator bar configuration. Figure 4 shows how wayside-based TOR systems are mounted on the field side of the rail, whereas the more traditional GF lubrication systems are mounted on the gage side of the rail.

Curving force data collected in territories equipped with multiple wayside-based TOR applicators suggests that more effective friction conditions are established with multiple applicators over a set distance than with a single unit (3, 4, and 5). This is likely due to wheels of a train becoming conditioned with grease or FM material after passing multiple applicators sites.

The wayside applicator spacing needed to achieve optimum benefits is a function of product carryover. Product carryover is affected by a number of parameters that can be divided roughly into two major categories: (1) track- and (2) train-based. By incorporating these parameters into one or more formulas (some of which are proprietary), spacing of applicators can be predicted. Obviously, field conditions can override optimum spacing as specific locations must consider accessibility for filling and maintenance, clearance space (e.g., clearance next to cliff), proximity to streams or running water, solar coverage, etc. Currently AREMA Committee 4 is evaluating a number of formulas for use in specifying applicator spacing. Future editions of the AREMA manual will incorporate examples.

As a rule of thumb, for TOR applicators, spacing of 2 to 2.5 miles has been shown to produce benefits of 30 percent reduced curving forces in territories with 4 to 8 degree curves and mild (<1 percent) grades. Where curves are significantly sharper and/or track is on steeper grades, either the benefits will be less, or a closer spacing has been required. Spacing of GF lubricator application systems follow a similar trend, but tends to be more dependent on density of curves; thus, extensive back to back curves may reduce the carry distance and require less than 2-mile spacing in some severe territories.
Examples of major parameters affecting applicator spacing include:

Track factors:

C – Length of curve
R – Curve radius
S – Percent tangent track per mile
G – Lubricant durability
P – Use of short or long applicator bars
P1 – Use of single pair or double pair bars
O – Application rate per passing axle
TBD – Others to be discussed during meeting

Train factors:

T – Train direction (bi-direction or single direction traffic)
L – Locomotive truck wheelbase
A – Axle load (pounds)
V – Speed (mph)
M – Truck alignment factor (good-poor)
B – Use of train braking (air and/or dynamic)
B5 – Use of steering trucks
S – Sanding
G – Gradient (up, down, and percent)
WT – Wheel temperature in zone
TBD – Others to be discussed during meeting

2.5 Mobile- and Locomotive- (or On-Car-) Based Application Systems

Locomotive-based GF and TOR friction control concepts are similar except for the point of application. GF lubrication systems spray lubricant directly onto the flanges of most if not all wheels. TOR application dispense nozzles are configured to apply FM product directly onto the top of the rail behind the last driven axle of a locomotive consist. For this reason, control systems require data input to determine last locomotive in consist and
trailing end to activate only one pair (one nozzle for each rail) of applicators. Figure 5 shows a typical locomotive-based applicator configured for a TOR system.

Ongoing Association of American Railroads (AAR) and Federal Railroad Administration (FRA) programs are evaluating effectiveness of various mobile-based systems in order to develop deployment guidelines. Initial observations suggest that when properly operating, the products applied by a mobile-based system will not fully dissipate by the end of the train, leaving a small residual amount of lubricant or FM on the rail. This residual lubricant or FM is present when the next train passes a site; thus, the long-term site effectiveness is dependent on the percentage of trains equipped with a TOR application system. As effectiveness is a function of applicator design, TOR and GF material properties, and application rates (all of which have proprietary issues), development of mobile-based implementation guidelines has not progressed as much as wayside-based systems.

2.6 Demonstrations of Applicator and Material Performance

In some instances, railroad specific requirements prevent standard deployment of friction control systems. For example, spacing of wayside applicators may need to be extended to fit site access and curve limits. In such cases a short demonstration to evaluate that particular deployment scenario would be conducted, utilizing one or more of the measurement techniques outlined in Section 3.1. This will allow the railroad to quantify the benefit of alternative application rates, lubricants or FM products, or application methodologies before implementation on a wide basis.

In most cases, however, deployment would follow vendor or recommended practices, such as those found in Chapter 4 of the AREMA manual. Minor adjustment or verification of improvements should be considered, using the same measurement tools. An important aspect of implementation, however, is to ensure that the friction levels produced are indeed optimized so that interaction with profile grinding and other maintenance methodologies proceeds as intended.

3.0 MANAGEMENT OVERSIGHT AND LONG-TERM MONITORING

While vendors continue to improve products, the day to day operations over a territory can become routine and employees will sometimes follow a “whatever works” approach. In the case of friction control, periodic inspection, and feedback to the staff, maintaining these systems is essential in ensuring a viable return on investment. Also, as
some systems age and wear, application output rates and patterns may vary and eventually create undesirable friction patterns, such as that shown by performance displayed in Figure 2.

On site inspection of the applicators (be they wayside- or on-board-based) and the rail in curves is essential. Feedback from such inspections to the applicator maintenance crew is needed to ensure proper operation and adjustment is conducted. In the case of wayside applicators, inspection and adjustment is normally conducted by the same person. This is an advantage as direct feedback of rail conditions created by each wayside applicator eliminates communication issues. Where on-board applicators are utilized, the feedback requires communication between ground inspectors and the mechanical departments. The development and maintenance of such communication paths will require management support and enforcement.

Long-term monitoring of rail wear and surface conditions will also provide valuable information to management on the reliability and effectiveness of friction control systems. Such information is becoming easier to collect and summarize, with modern inspection cars often being equipped with automated rail profile monitoring equipment.

AKNOWLEDGMENTS

Field support for conducting demonstrations has been supplied by member railroads and the supply industry. TTCI would like to acknowledge railroad support and special efforts from: Marty Gearhart (Union Pacific Railroad), Tom Brueske (BNSF), and Kevin Conn (Norfolk Southern) and the suppliers who provided test equipment and field support, with special thanks to Portec Rail Products and Kelsan Technologies. Data analysis was provided by TTCI’s Bea Rael and Rachel Anaya.
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