

Spray it on, let 'em roll

Performance of top-of-rail friction modifiers, a relatively new technology, can exceed traditional lubrication methods.

By Donald T. Eadie and Joe Kalousek, for *Railway Age*

Top-of-rail (TOR) friction management is not a new concept. It has been employed since reports of TOR lubrication's ability to dramatically reduce fuel consumption appeared more than a decade ago. But since the operating and maintenance challenges associated with lubricating the running surfaces of rails have not been overcome, development has continued, and new technologies like TOR friction modifiers have evolved.

Engineered TOR friction modifiers, which have emerged from the conceptual stage and moved into the developmental stage over the past two years, have been shown to provide several benefits that traditional, grease-based lubricants cannot. They can consistently reduce energy consumption, lateral (curving) forces, and wheel/rail wear, which in turn can lead to savings in fuel costs, track maintenance costs (related to gauge widening), and wheel/rail replacement costs. They also can reduce the incidence of skid flats, corrugation, crack initiation and growth, rolling contact fatigue and, in some circumstances, truck hunting.

As with any new technology, there are questions about the nature of TOR friction modifiers: What do they do? How do they work? How do they compare with traditional lubricants? While the application procedures and delivery systems for TOR lubricants and friction modifiers are similar—and similarly critical to the viability of the overall system—the performance characteristics of the two materials are fundamentally different.

Lubricants vs. friction modifiers

In the simplest terms, lubricants, which include oils, greases,

and synthetic polymers, reduce friction levels but cannot control them. Friction modifiers, which are composed of engineered, dry composite solids suspended in a water-soluble mixture, are able to reduce, control, and maintain friction at an optimal level. This distinction is significant, given that in order to enhance vehicle performance without negatively impacting traction and braking performance, optimal TOR friction levels must be maintained at the point of application (typically, behind the locomotives) and at the last axle on the train.

To demonstrate their differing frictional characteristics, tests of two TOR materials—a synthetic, water-based polymeric lubricant (Figure 1, p. 2) and a water-based, High Positive Friction (HPF) friction modifier (Figure 2, p. 2)—were conducted by Kelsan Technologies, Inc., and the National Research Council of Canada. A thin film of each was hand applied TOR and allowed to dry for at least 15 minutes before friction levels were measured with a push tribometer. (The measured friction level is dependent primarily on the material applied, but also, to a lesser degree, on the dry rail characteristics, and on the types and quantities of iron oxides, in particular).

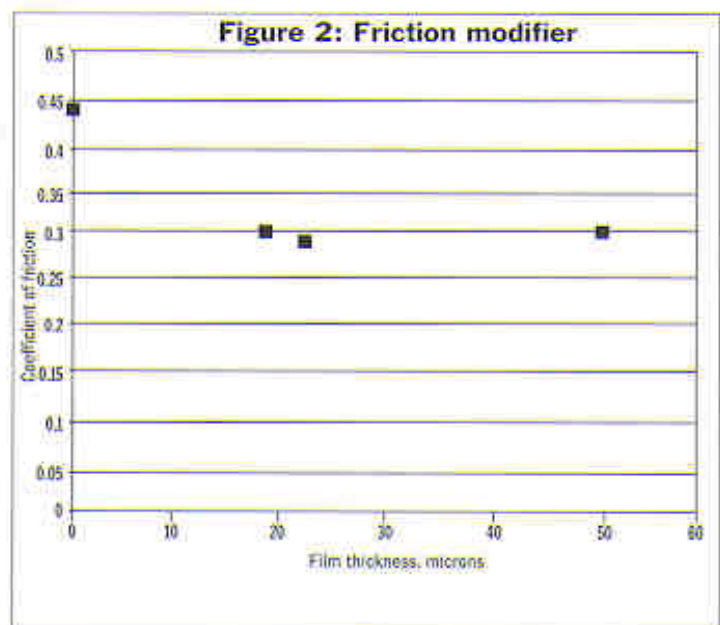
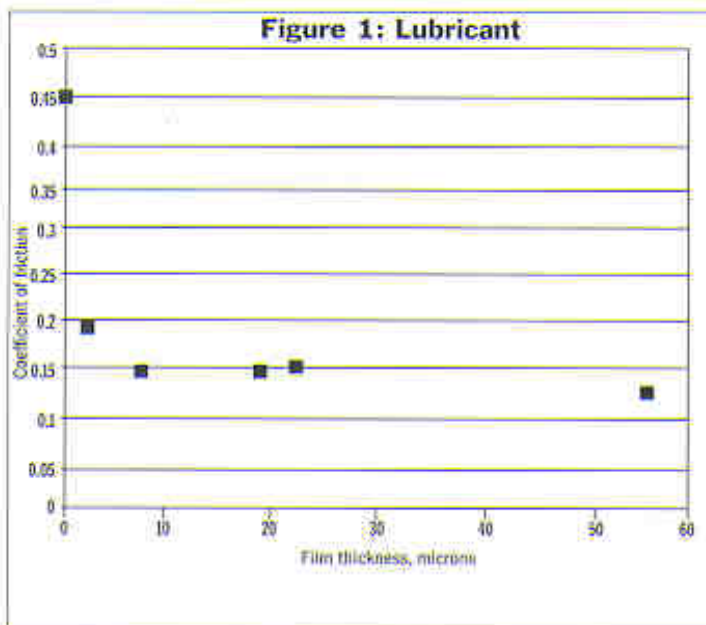
The polymeric lubricant exhibited typical lubricant behavior—an immediate reduction in the “dry” TOR coefficient of friction (COF) from 0.45 to 0.14. The HPF friction modifier showed a reduction from 0.45 to an intermediate level of 0.30. The friction levels associated with each material were maintained over a wide range of film thicknesses, corresponding to different application rates.

What do the differing frictional attributes of these two mate-



KELSAN TECHNOLOGIES, INC.

Above: Kelsan Technologies' Keltrack liquid HPF friction modifier is applied as a fine, atomized spray that dries quickly, leaving a thin, dry film that controls friction at the top of rail.



rials mean with regard to train performance and wheel/rail interaction? The answer lies in examination of the performance characteristics of the materials in typical on-board application approaches on freight railroads.

Lubricant-based TOR systems

In a locomotive-mounted, onboard TOR lubrication system, a stream of lubricant is applied TOR behind the trailing axle of the trailing locomotive. The placement is crucial to enhancing the performance of the cars within the train without affecting locomotive adhesion. The graph (facing page, top) illustrates the frictional changes that occur through the axles of sequential freight consists. With application of a lubricant, friction levels will vary as subsequent wheels pass over the material, but steadily increase throughout the length of the train as evaporation or oxidation occurs. This non-controlled friction level can have potential consequences, such that:

- Wheels within the first part of the train may experience a lower than optimum COF, potentially leading to braking problems or skid flats on these cars.

- Wheels within the later part of the train may experience a higher than optimum COF, leading to higher lateral loads.

- Lateral loads will vary over the length of the train, starting low and increasing as the lubricant is removed.

An additional consequence of TOR lubrication is that in order to ensure adequate adhesion for the locomotives of subsequent trains, all of the lubricant must be evaporated or burned off by wheel/rail interaction so that friction levels return to 0.35 or greater by the last wheel of the train. This requires a sophisticated control system that is capable of adjusting the application rate to accommodate varying conditions. It further requires a control system that is capable of ensuring that enough lubricant is applied to the rail to accommodate the last wheel on the train, but not so much that the lubricant remains on the rail after the last wheel has passed—a condition that could result in too low a friction level for the next train. Given the wide range of operating variables that may influence the rate of lubricant removal, this represents a significant control challenge.

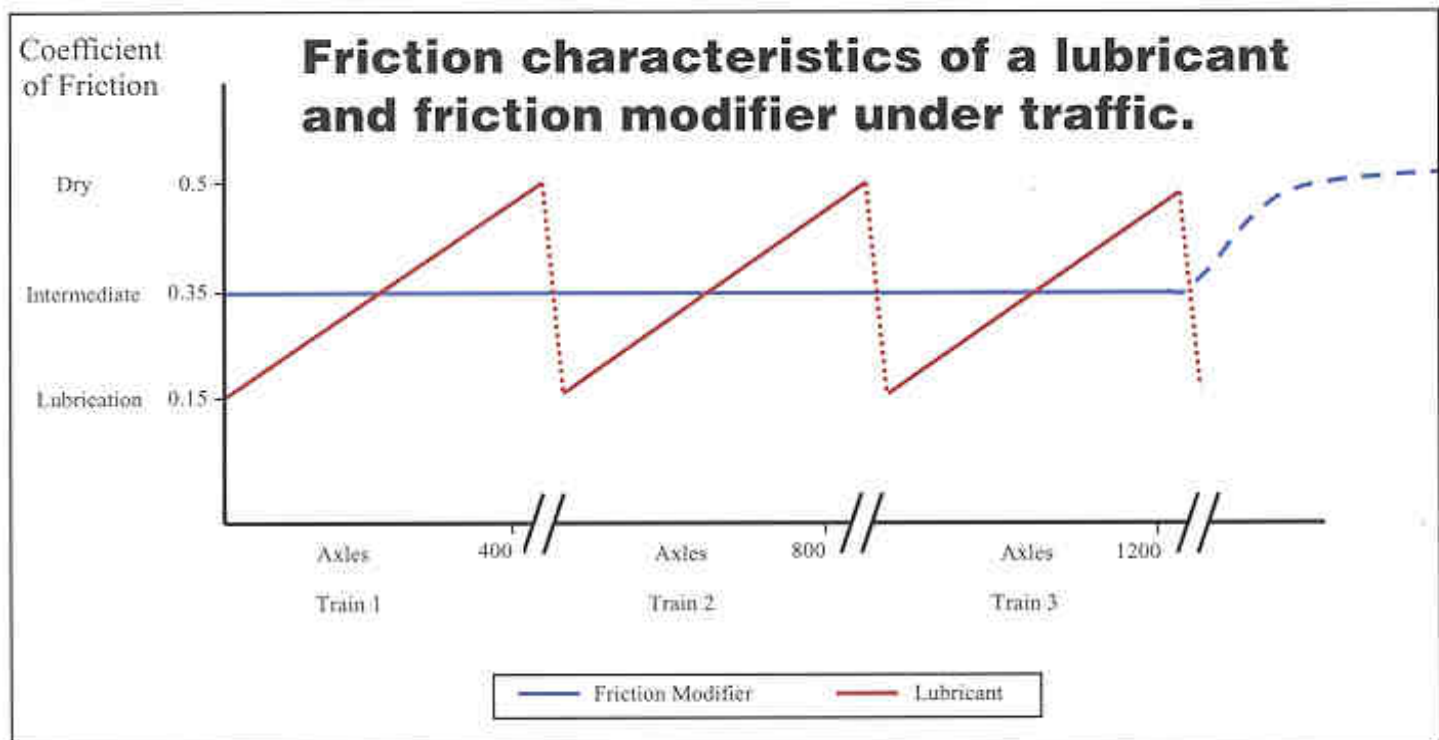
Friction-modifier-based TOR systems

Unlike lubricants, friction modifiers are able to reduce the COF

of dry rail and maintain the desired intermediate level of friction over a given number of trains or wheel passes. Friction modifiers formulated for freight applications contain no oils, greases, or other liquid lubricant components. They are composed of engineered composite solids that are mixed with water and deposited on top of the rail in liquid form. When the water evaporates, the remaining thin, dry film maintains an optimal intermediate level of friction.

A water-based, HPF liquid friction modifier is applied TOR behind the last driving wheel of the trailing locomotive. The water-soluble material is applied as a fine, atomized spray to ensure rapid drying and production of a thin, uniform film. The water in the material is quickly evaporated under the action of the first few wheels, and the dry 0.45 COF is reduced to about 0.35—a level that is maintained throughout the length of the train. Since this intermediate level of friction can be maintained, the material need not be dissipated or removed by the last wheel on the train. In fact, the residual HPF left on the rail can actually benefit a subsequent train by reducing lateral forces and energy consumption—even if the subsequent train has no friction modifier delivery system of its own on board. With no need to remove residual material from the rail, compensation for the range of such operating and environmental conditions as speed, curvature, creepage, temperature, etc., is much less critical. As a result, the friction modifier's application control system is greatly simplified. The chart below illustrates this frictional behavior

Options for TOR application systems		
	Friction modifier	Lubricant
Friction modifying agent(s)	Solids	Liquid
Application methods	On board, Hi Rail, Wayside	On board
Application control	Simple	Complex, sophisticated
COF after application	0.3	< 0.2
Retonivity	Three or more trains	One train
Energy savings	Significant	Significant
Lateral force reduction	Significant	Significant
Crack propagation (spalling/shelling)	No effect	Enhancer
TOR wear rate	Not established	Not established



for sequential axles and consists, and compares it to lubricant behavior.

Testing under controlled conditions has shown an HPF film delivered from an onboard locomotive system to be effective for up to three 100-car trains, or 1,200 axle passes, before the material loses its effectiveness. The implication here is that fewer locomotives on a given system may need to be outfitted with onboard friction modifier systems to achieve the full benefits. Furthermore, alternative methods may be used to apply a friction modifier to the rail in advance of locomotives.

Application options

Since the low friction levels associated with conventional lubricants can potentially compromise traction, TOR lubrication delivery systems are generally limited to onboard units mounted to the trailing locomotive. As shown in the accompanying table, friction modifiers offer greater flexibility. Unlike lubricants, they can be applied to the rail in advance of a freight train, provided that the water has evaporated and a thin, dry film has been obtained. A hi-rail vehicle—an approach that provides greater flexibility—also can apply them and at a lower installed cost. The downside of hi-rail application is that limited track time may put greater demand on the retentivity of the friction modifier to maintain the benefits between applications. In some cases, TOR friction modifiers can also be applied by wayside applicators. A wayside TOR approach is currently being utilized to control wheel/rail squeal at several North American and Japanese transit systems. For example, the Port Authority of Allegheny County in Pittsburgh has reported significant success with this approach on its light rail system.

There are other operating and track-related benefits associated with the use of TOR friction modifiers, as well. On the operating side, TOR friction modifiers have been shown under test conditions to reduce fuel consumption by 13% to 28%. On the track side, they have been shown to reduce lateral forces in

curves—forces that are determined, in large part, by the COF on the top of the low rail.

Tests were conducted on the high-tonnage loop at the Transportation Technology Center, Inc., to determine a friction modifier's impact on lateral forces. Those generated by the leading axles on the high rail of a six-degree curve with a dry top surface and lubricated gauge face are much higher than those of a friction modifier under the same conditions. These lower lateral forces can be translated into reductions in gauge-widening forces and rail wear.

The use of TOR friction modifiers also can mitigate wheel and rail surface damage caused by rolling contact fatigue. While lubricants and friction modifiers behave similarly in their ability to inhibit crack initiation associated with rolling contact fatigue (the potential for which is lowest when the COF is 0.3 or less), friction modifiers provide the added ability to minimize crack growth. Once initiated, cracks propagate (unless removed by grinding or wear). Lubricants, being liquid, tend to pressurize these cracks, causing them to propagate—even at friction levels of 0.3 or less—while friction modifiers, consisting of solids, do not. As a result, friction modifiers help to minimize crack propagation and, thereby, control fatigue-initiated wheel shelling, rail gauge-corner cracking, and related surface damage.

Overall, friction modifiers have been shown to provide all of the benefits of lubrication (reductions in fuel consumption and lateral loads) without the detrimental effects (skid flares and stalled trains) caused by a loss of traction. By providing an engineered solution to an array of persistent friction-related problems, TOR friction modifier technology stands to improve the state-of-the-art of friction management on freight railways.

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