TECHNOLOGY DIGEST
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Top of Rail Lubrication Implementation Issues

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Summary

Evaluation of top of rail (TOR) lubrication systems under closed-loop testing has demonstrated that lubrication applied in this manner can lower energy consumption, reduce curving forces, especially when mixed with controlled flange lubrication, and reduce rail wear. However, these benefits can be obtained only if the application systems are properly installed, and remain correctly aligned and continue to function.

Tests conducted on the High Tonnage Loop at the Transportation Technology Center's Facility for Accelerated Service Testing replicated an operating railroad in which every train was equipped with a fully functional TOR and/or flange lubricator. Systems that applied coverage only to the top of rail provided significant benefits, but visual observations indicated that the gage face remained dry, resulting in accelerated rail gage face wear and wheel flange wear.

Data collected suggests that when a system that reduces gage face friction is combined with one that controls top of rail friction, results are optimized and are highly beneficial. Evaluations included six systems for controlling friction on the rail, including three different systems for applying TOR lubrication. Energy, wheelset angle of attack, curving forces, rail friction, train braking, and other train operating conditions were documented. Friction control, when applied by only a single type of system (wayside, hi-rail, locomotive-mounted) produced distinct benefits; however, when operated alone each system had some drawbacks. Over a 3-month period a variety of methods for lubricating FAST were utilized. Initially the TOR systems were installed and operated as the sole means of lubricating FAST, after which one TOR system was tested in tandem with other more conventional lubrication systems. Trackside performance data and observations made by engineering staff, train crews, and wayside inspectors have been summarized into recommendations and concerns for implementation.

One TOR system applied a thin bead of lubricant to the top of rail, and required extensive adjustments to nozzle alignment when train direction was changed. The other TOR system utilized an atomized spray pattern, which reduced the criticality of nozzle alignment, but resulted in significant amounts of product being wasted. Data collected from FAST evaluations suggests that during the initial stages of implementing TOR in revenue service a process of track inspection and feedback to the locomotive department of adjusting application systems will be required to ensure optimum results. As TOR lubrication offers the potential of significant benefits, additional efforts are being conducted to investigate implementation issues. An ongoing effort is monitoring field implementation of TOR lubrication on a revenue railroad. TTCI engineering staff is conducting a number of NUCARS simulations to investigate issues surrounding high angle of attack and wear indices. Results of these investigations will be used to further develop TOR lubrication implementation guidelines.

Suggested Distribution:
☐ Maintenance of Way
☐ Planning & Analysis
☐ Track Maintenance
☐ Locomotive/ Transportation

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BACKGROUND

Tests of top of rail (TOR) systems at the Transportation Technology Center, (TTC) were conducted on closed loops using dedicated test trains. Application of lubricant or friction-modification product was monitored and controlled, and only limited operations (miles or laps around a test loop) were performed under any given mode. Data provided recommendations for implementation of TOR lubrication systems. To assess conditions not readily obtained at TTC, TOR implementation is also being monitored on a member railroad.

APPROACH

Using existing FAST train operations and track, a number of rail friction controls and lubrication systems were evaluated. FAST is a 2.7-mile kidney-shaped loop configured with short tangents connecting 5-degree and 6-degree curves. The loop typically operates with a 12,000 gross ton loaded 70-car (34-ton axle load) freight train running at 40 mph. Approximately 1,200 miles of train operations are accumulated weekly.

An instrumented coupler, and a data collection system, mounted in a "locomotive slug" collected drawbar force during all runs. Two wayside load stations on a 6-degree curve monitored each passing axle and recorded lateral and vertical loads, and axle angle of attack (AOA). Rail friction was monitored using a hand-operated tribometer.

LUBRICATION SYSTEM DESCRIPTIONS

The systems evaluated included a variety of conventional application systems (fixed and mobile) and a range of lubricants and friction modifiers. The conventional systems (wayside, locomotive flange and hi-rail) are commonly used by railroads and are thus not described in any detail. The TOR systems (two locomotive based, one hi-rail based) were offered by vendors as complete, integrated packages.

- **TOR1:** Locomotive mounted combined application system and friction modifier, which produced a stream of lubricant directly on the top of the rail. The gage face remained dry when using this concept.

- **TOR2:** Locomotive mounted combined lubricator with friction modifier in which the product was atomized to allow the carrier to evaporate upon application to the rail. The pattern produced by atomization coated both TOR and gage face.

- **LocoFlange:** Locomotive mounted flange lubrication system using a 000 lubricant/oil.

- **W.S.:** Gage face, electric-driven lubricator feeding two 18-inch applicator bars, utilizing a calcium-based 11 percent graphite grease.

- **Hi-Rail:** Hi-rail application system applying a friction modifier to the top of the rail.

- **TOR plus LocoFlange:** Simultaneous operation of TOR1 and the LocoFlange systems, adjusted output rates for combined operation.

- **Friction Modifiers versus Lubricants:** Lubricant development has resulted in products that, once applied in the proper amount and thickness, provide a fixed or near fixed friction level over a specified range of wheel/rail creepage. Traditional lubricants reduce friction with respect to amount or thickness of applied product; the more lubricant the more friction is reduced. Observations during FAST implementation suggested that when too little or too much friction modifier was applied performance closely followed that of a traditional lubricant. Exhibit 1 shows the concept of a friction modifier compared to that of a traditional lubricant. The "target" friction level is achieved with the friction modifier when it is in place over a relatively wide thickness range, while the lubricant provides this same friction over only a narrow range of thickness. The shape and rate of the friction/thickness relationships are shown only as an example.

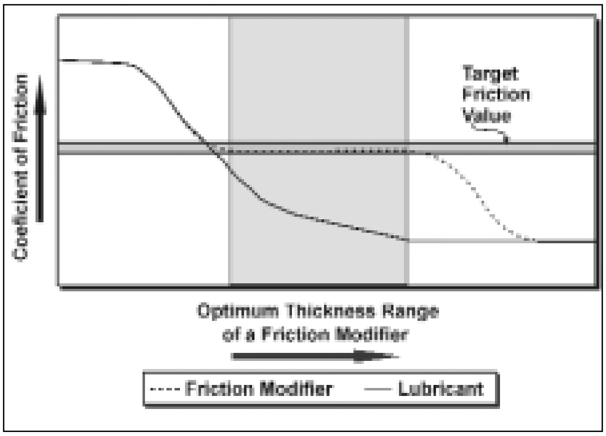

Exhibit 1. Conceptual Performance of a Lubricant and a Friction Modifier. Increased product thickness left to right

RESULTS

For each scenario, average energy consumption is shown in Exhibit 2 and lateral force performance is shown in Exhibit 3. The hi-rail system, which varies considerably for each train, is not included as the standard deviation was very large. Due to restrictions limiting the number of “dry” laps on FAST, a total dry condition was never achieved. Dry down conditions represent a dry top of rail (friction approximately 0.5) and a mildly contaminated gage face, with a friction of about 0.35.

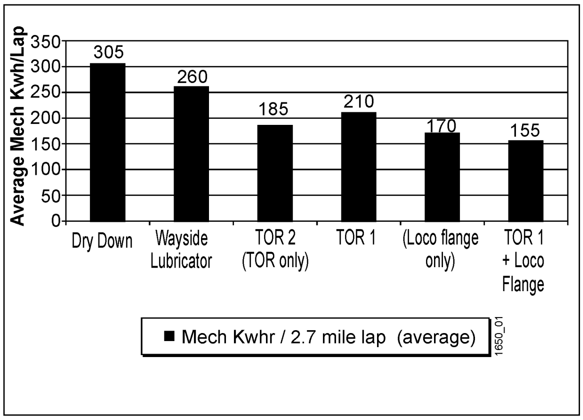

Exhibit 2. Energy Consumption Per Lap, Various Lubrication Options

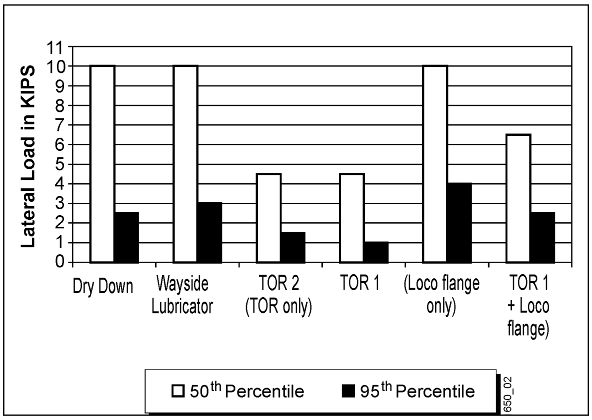

Exhibit 3. Lateral Load Performance, High-Rail Lead Axle, 50 and 95 Percentiles

Exhibit 4 shows the top of rail and gage face friction measured during dry, wayside lubricated and TOR testing. TOR1 provided only top of rail application, and the gage face remained dry during these tests. The large amount of metal flaking that occurred during these runs caused erroneous tribometer readings. Dry conditions were produced, however, based on observations from car and track inspectors reporting higher wear rates and rough surfaces.

Recent testing conducted on FAST indicated premium trucks produced a 50 percent reduction in lateral curving forces. Even with this significant reduction in lateral load, when gage face lubrication was ceased the wear of both wheel flanges and rail gage face increased by approximately 400 percent, suggesting that reducing lateral load alone is insufficient to eliminate gage face wear, and supplemental gage face lubrication is required.

Exhibit 4. Friction Values for Dry, Wayside Lubricated, and TOR

	Top of Low Rail	Top of High Rail	Gage Face High Rail
Dry Conditions	0.56	0.58	0.23
Wayside	0.47	0.37	0.18
TOR/TOR2	0.29	0.29	0.19
TOR/TOR1	0.34	0.32	*

*Gage face friction was not measured due to metal flakes causing false readings

CONCLUSIONS

Top of Rail

Data suggests a mix of TOR and gage face application systems produced optimum results, as long as each system is periodically inspected and necessary adjustments are made. For revenue service implementation of either TOR system, direct feedback from track inspection is needed to prevent the creation of friction conditions, which could impair train handling, increase braking distances (increased braking distance was observed only with the TOR2 system), or result in excessive lateral curving forces. During these tests, a TOR target friction level of 0.3 to 0.35 was met by both TOR options, as long as amounts of product applied were kept under control so that the rail was not over- or under-lubricated. During TTC trials, once too much product was applied, the buildup resulted in friction values of less than 0.3, which resulted in locomotive wheel slip.

Nozzle alignment was shown to be a critical item during TOR1 testing. The nozzles, attached to the sand brackets, were on a relatively long lever arm from the truck center. Thus, truck skewing, or other alignment issues resulted in relatively large movement of the nozzle, requiring occasional adjustment. When the locomotive direction on the FAST loop was reversed (from clockwise to counterclockwise), the nozzles had to be re-adjusted to maintain a proper lubricant pattern on the rail. TOR2 utilized an atomized spray pattern, which significantly reduced the criticality of alignment; however, this resulted in about half of the product being wasted onto the ballast and coating the locomotive and leading car.

Basic nozzle adjustments and system operation (pumps working, nozzles spraying, etc.) can be inspected and adjusted during routine locomotive servicing and fueling. However for revenue service applications, the only indication of proper system operation *and* alignment is to inspect the condition of rail in the field. This will require a feedback/dialog be established between track inspectors and locomotive maintenance shops to ensure that lubricator output and nozzle adjustments are made in a timely fashion and to the proper locomotives.

Other Systems (wayside, Hi-rail and Locomotive)

The primary objective of this evaluation was to assess TOR implementation issues. Attempts were not made to fully optimize or evaluate other application systems. They were operated as specified by manufacturers or as recommended by railroads for routine operations for comparisonswith TOR performance.

Wayside Lubricators

The benefits of wayside lubricators can be substantial; however, they must be located at frequent intervals to avoid over-lubrication at any applicator site. Lack of maintenance will substantially reduce benefits.

Hi-Rail Applicators

The hi-rail system evaluated during these tests used a friction modifier that required a “dwell/dry off” time of at least one hour. The amount of product applied was effective for less than 15 trains, and usually less than five trains. Previous evaluations at FAST have shown that hi-rail systems, with alternative products (greases, heavy oils, open gear lubricants), can offer effective friction reduction substantially longer than that observed during this test. These earlier tests were not conducted using TOR or other current technology lubricants or application systems.

Locomotive Flange

When operated alone, the onboard flange system did provide significant energy savings. However, the applicator configuration resulted in a lubricant pattern which kept the TOR dry. This system did not provide a reduction in curving forces.

SUMMARY

TOR lubrication can provide significant benefits by reducing train energy and lateral loads. TOR lubrication by itself, with no other application method, does not provide sufficient gage face protection and could lead to accelerated wheel flange and rail gage face wear, when compared to conventional rail lubrication systems. Both TOR concepts evaluated provided similar reductions in lateral loads, differing somewhat in energy savings due to one system providing some reduction in gage face friction. During implementation of TOR, the full benefits shown cannot be reliably and safely generated until the entire fleet is fully equipped with operating units. Data suggests that if locomotive flange lubricators are to be used for supplemental gage face protection, virtually every train must also be so equipped; and if wayside lubricators are to be used for this supplemental protection, then properly operating lubricators will be required at relatively frequent intervals, depending on site-specific curvature.

Future Work

The potential benefits afforded by Top of Rail Lubrication are of such magnitude that additional evaluations and monitoring are being conducted to refine and develop implementation guidelines.Implementation of TOR concepts is being monitored on a revenue service railroad. Lateral load, angle of attack and system wide rail friction will be monitored during the period when at least five of each of each of two TOR applicator concepts are operated over a limited territory.

TTCI engineering staff are evaluating angle of attack (AOA) and rail/wheel wear indices using NUCARS predictive modeling techniques. Potential concerns regarding high AOA generated by certain trucks, as well as gage face and wheel flange wear generated by friction patterns observed under TOR operations is being addressed. Results of these studies will be reported and used to determine if additional closed loop evaluations on FAST are warranted.

Note: Please contact Richard Reiff at (719) 584-0581 with questions or comments about this document.
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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.