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DEMONSTRATION OF THE VIABILITY OF TOP-OF-RAIL LUBRICATION FOR FREIGHT RAILROADS

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Summary

Three prototype top-of-rail (TOR) lubrication systems tested at the Federal Railroad Administration's Transportation Technology Center have demonstrated the ability of these systems to achieve energy savings and reductions in lateral curving forces. The systems were evaluated for their ability to lubricate the rail sufficiently without overlubricating the rail and causing wheel slip. Findings from the tests include:

- TOR concept for lubrication can be applied on a continuous basis and not lead to a detrimental amount of lubricant buildup.
- Energy savings due to a reduction in curve resistance were approximately 13 percent.
- Curving forces were reduced from 5 to 45 percent, depending on curvature and car type.
- Certain empty cars exhibited very high angles of attack during periods when TOR lubrication was applied.
- Train braking was not adversely affected.
- Premium trucks with improved steering did not show any improvement when TOR lubrication was applied.
- Noise levels were reduced for trains under TOR lubrication conditions.

Each of the three TOR systems was unique with various proprietary features, however all shared the concept of lubricating the train behind the last locomotive. Lubricant application rates were adjusted based on curvature, speed, and other parameters with the intent that all lubricant would be consumed by the end of the train and/or the remaining lubricant would not result in a detrimental buildup. During the test, the minimum target friction after the end of the train was 0.3. As long as this level of rail friction or higher was maintained, no significant wheel slip or other conditions detrimental to train operations were encountered.

Suggested Distribution:
☐ Maintenance of Way
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INTRODUCTION AND CONCLUSIONS

Tests conducted during 1998 on three top-of-rail (TOR) lubrication systems suggest potential energy savings of 13 percent could be obtained on a conventional freight train traversing mostly curved track under full implementation of this concept. These evaluations were conducted as a follow-up to a 1997 demonstration of a prototype TOR system (ref DOT/FRA/ORD-98/01, Top-of-Rail Lubrication Energy Test) which exhibited significant energy savings (up to 30 percent) and reductions in lateral curving loads; however the amount of lubricant applied during these demonstrations resulted in problems with wheel slip and train handling. The TOR concept is based on each train applying only a sufficient amount of lubricant to protect itself, with virtually all traces of lubricant consumed by the time the last car passes. Excess lubricant remaining after the last car can build up after successive train passes, and thus may cause wheel slip and braking problems. Sufficient interest by the railroad industry was shown in the TOR concept to conduct a series of demonstrations in 1998.

The primary objective of these demonstrations was to determine if the TOR concept could be controlled such that every train on a system could be equipped with an operating lubricating system, yet excess carry-over of lubricant would be limited to a non-detriment level.

Results of evaluating three TOR concepts indicated that on the TTC's closed-loop Wheel Rail Mechanism (WRM) track, TOR lubrication could be applied on successive trains without detrimental lubricant buildup. With the 6,800-ton train utilized for these trials, observed energy savings ranged from 10 to 13 percent, while lateral load/curving performance indicated reductions from 5 percent to 45 percent for standard-truck cars. Premium trucks exhibited a slight increase in lateral curving loads when the TOR system was activated. Angle-of-attack performance ranged widely, from virtually no effect, to some empty cars exhibiting a significant (up to 26 milliradians) angle of attack on a 7.5-degree curve. Two different lubricants applied by one system exhibited significantly varying results; the lubricant containing extreme pressure (EP) additives showed virtually no dissipation by the end of the train, resulting in a rapid buildup and locomotive wheel slip after three laps. Testing stopped after the buildup was noticed. A nearly identical lubricant, but without the EP additive produced the desired end-of-train performance and was evaluated more fully. The friction modifier concept did exhibit its intended performance (by not dissipating within the train) and created a uniform TOR friction of 0.35.

During periods of steady-state operation while the top of rail was lubricated, the gage face exhibited wear in the form of noticeable amounts of fresh metal flakes on ties after each train pass. Also a 5-foot length of the gage face was painted before each train pass. During dry operation, the paint disappeared after the 5th to 9th car. During TOR lubricated operation, the paint disappeared by the 11th car. This suggests that even though the TOR concept reduces lateral loads on sharper curves, it does not eliminate gage face contact and there may be a need for supplemental gage-face lubrication. Additional developments in lubricant performance, as well as application reliability and adjustment, is suggested before widespread application of the TOR concept in revenue service.

SYSTEM DESCRIPTION

TOR application systems were provided by Tranergy Corp., Kelsan Lubricants, and KLS/Lubriquip. Lubricants were provided by Kelsan and Texaco. Although differing in design, complexity, control, and product development, all three TOR systems followed the same basic concept. Lubricant is applied to the top of both rails directly behind the last locomotive. The lubricant amount and/or characteristics is such that most, if not all, the lubricant is consumed by the end of the train, leaving little or no residual amount after the last car. Or if the lubricant is not dissipated, a non-detrimental friction reduction would be achieved so that the next train's locomotives will operate over essentially dry rail, again applying lubricant behind the power. Thus the TOR concept differs significantly from other locomotive-based systems in that lubricant is applied behind the locomotives, not on the locomotive flanges. Before fully implementing the TOR concept, effectiveness of other lubrication systems (wayside, hi-rail) must first be considered as subsequent non-TOR-equipped trains will operate over essentially dry track and will receive little or no energy savings, depending on the residual amount remaining on the rail.

TEST PROCEDURE

All three systems evaluated were installed on locomotives. Vendors were then allowed up to two days to adjust their equipment to ensure no excessive or detrimental residual lubrication remained on the rail or became built up. For TTC testing purposes, this was defined on being able to operate at least 10 consecutive laps without obtaining top-of-rail friction less than 0.3, with the preferred minimum friction of 0.35. Once a vendor adjusted its system to this rate, a full range of energy, wayside L/V, angle of attack, rail friction, and limited noise data were obtained.

Although additional data was obtained during the adjustment periods, for purposes of comparison and evaluating potential implementation benefits, only data obtained during the official test period was used. It should be noted that under certain conditions higher or lower energy savings, or different curving performance results could be obtained. In addition, route-specific conditions such as train speeds, slow orders, curvature, and grades will make the energy savings unique to a particular railroad.

TEST RESULTS

Train consist: Cars and locomotives for this evaluation were donated by member railroads. The consist included 2 GE C-44W locomotives (supplied by the Norfolk Southern and CSX railroads) and up to 70 cars of loaded 100-ton hoppers, empty covered hoppers, intermodal flat cars, double-stack articulated equipment (supplied by Burlington Northern Santa Fe, Canadian Pacific, Union Pacific and TTX), and loaded 125-ton heavy-axle-load (HAL) equipment with premium trucks. Average train speed per lap was held constant at about 29 mph.

Energy: Energy was monitored on board the locomotives by two methods. The total electrical demand for each lap around the 3.5-mile test loop was recorded, along with the average drawbar pull behind the last locomotive. These totals were averaged for at least five laps under dry, and again during steady-state conditions. Since it was noted that none of the systems left a completely dry track after the last car, all systems were operated for several laps of TOR application before average readings were taken. Average energy savings for each system evaluated ranged from 10 percent to 13 percent.

Lateral Loads: A L/V circuit was attached to the high and low rails of 3-, 7.5-, and 10-degree curves to monitor the performance of each train pass for all the cars. This data was collected for each system during dry and TOR lubricated operation. Average lateral loads for the lead axles during dry and lubricated conditions for system 1 is shown in Exhibit 1. Exhibit 2 shows the summary for the same curve during dry and TOR lubricated runs for system 1, broken down by car type. The loaded F and loaded R signify 100-ton cars with three-piece trucks located at the front and rear of the train. The data indicates that for this location TOR lubrication reduced lateral curving loads for most cars, except for the HAL cars with premium trucks, which indicated an increase.

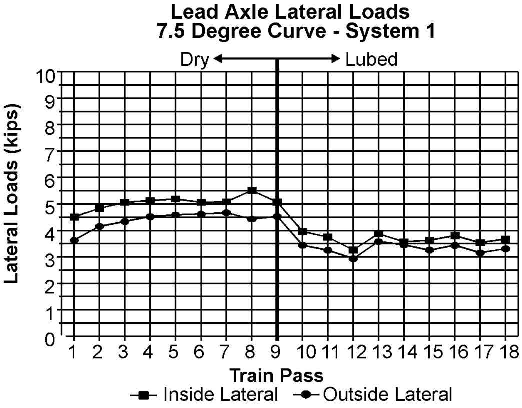

Exhibit 1. Lap History of System 1, Lead Axle Lateral Loads, Dry/Lubed on 7.5-Degree Curve

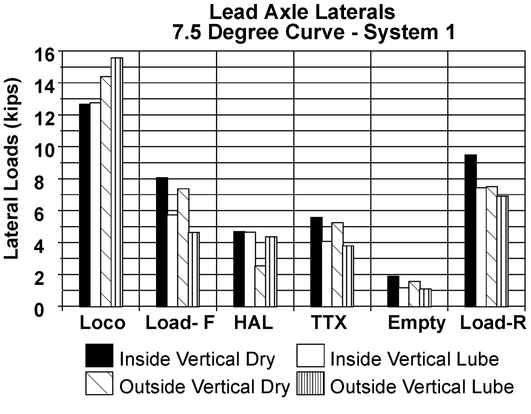

Exhibit 2. Lateral Load Performance by Car Type, 7.5-Degree Curve, System 1, Dry and Lubricated

During system 2 testing, the low rail was drier than the high rail (refer to friction section below) and lateral loads for the end-of-train loaded cars increased from 3 to 5 kips (average) and from 10 to 12.2 kips (peak).

Angle of Attack (AOA): AOA was measured at the 3- and 7.5-degree curves. During dry and lubricated conditions all systems indicated the largest changes in AOA were on the empty cars, with the HAL cars showing the least change. For example, on the 7.5-degree curve during system 2 tests, average lead and trail-axle AOA for the entire train indicated an increase from an average of 2.6 milliradians (dry rail) to 4.9 milliradians (lubricated) on this curve. Certain empty cars exhibited peak AOA dry-to-lubricated changes of 8.3 to 26.8 milliradians.

Noise: Noise data was collected during operations on both the FAST and WRM loops. A full train-frequency spectra for the entire train between dry and lubricated rails indicates an overall reduction in noise; however, evaluation of this data shows that some cars exhibited a slight increase in noise under lubricated conditions.

Friction: A hand-operated tribometer was utilized to obtain top-of-rail and gage-face friction during the entire test series of all systems. Top-of-rail friction during dry periods ranged from 0.55 to 0.6, while under steady-state TOR lubrication friction ranged from 0.26 to 0.52 after the last car. Friction data exhibited a wide variation in left-to-right rail performance and overall end-of-train carryover. The left-to-right application rate (which was adjusted by curve sensors) and consumption balance was affected due to the WRM loop having more curves in one direction, which may have resulted in some system bias. Lateral curving-force performance was affected detrimentally primarily during system 2 performance when the low rail was drier than the high rail.

Braking: A limited number of braking tests were conducted using system 1 on the TTC's high-speed railroad test track. Full-service stopping tests conducted on dry and lubricated rail indicated no wheel slip or significant change in stopping distance. The brake application rate for these tests was reduced from that used on the WRM loop due to the larger amount of tangent track. Full-service braking under the higher application rates required for WRM tests were not conducted due to the concern of contaminating test tracks that needed to be kept dry for other testing purposes.

DISCUSSION/RECOMMENDATIONS

These tests indicate the TOR concept for lubrication can be applied on a continuous basis and not lead to a detrimental amount of lubricant buildup. Under these conditions, energy savings were approximately 13 percent for all systems evaluated. Curving performance was affected by TOR lubrication, with lateral loads generally decreasing and angle of attack almost always increasing. Cars with premium trucks exhibited no improvement in performance (lateral loads) with TOR lubrication.

All systems required significant monitoring and adjustment prior to testing and are considered prototypes at this time. Small differences in application or adjustment of nozzles resulted in significant differences in performance and variations in left-to-right rail-friction values, thus additional development and increased reliability of equipment is suggested.

Periodic monitoring of top-of-rail friction is recommended to ensure that a detrimental amount of lubricant is not being built up. A malfunctioning lubricator will not affect the train that is being operated, but can result in excessive lubricant remaining on the rail after the train pass, or insufficient lubricant to properly reduce friction. Thus, inspection and adjustment methods should be developed to ensure proper operation during locomotive servicing and fueling.

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