Freight Car-Based Top of Rail Friction Modifier Application System

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SUMMARY

This paper outlines a new application technology for top of rail (TOR) train mounted friction control, particularly suited for captive freight fleets. The spray application system is mounted on a revenue-generating freight car located immediately behind the trailing locomotive. Compared with locomotive mounted systems [1, 2, 3], the new approach provides higher capital utilization, no impact on locomotive maintenance scheduling, and a simple but robust system. A prototype system has been successfully designed, installed, & field-tested on a revenue-generating ore car at QCM's facility in Port Cartier, Quebec. As well as equipment performance, results are also described on lateral force reduction.

Index Terms: Top of Rail Friction Control, car mounted dispensing system, lubrication, friction management, TOR

1.0 INTRODUCTION

1.1 The Railroad

Cartier Railway Company (QCM), owned and operated by the Quebec Cartier Mining Company, was constructed in the late 1950`s to transport iron ore concentrate between the Lake Jeannine mine and a deep sea terminal located on the St-Lawrence river, over a distance of 305.7 km (190 miles). In the early 1970`s the railroad was extended to the Mount Wright mine located close to the Labrador border and 418.4 km (260 miles) from the shipping facilities in Port Cartier. The iron ore products are sold in North America, Europe and Asia.

Cartier Railway is a short heavy haul captive railroad that runs through a rugged topography with 50% of its main line in curves up to 7 degrees and a maximum grade of 1.35%. It has 20 bridges, 5 tunnels and over 120 rock cuts. Although iron ore is the primary product transported, wood is also brought down by rail to a local sawmill and pulp mill in Port Cartier. The total volume transported generates approximately 24 MGTs on the railroad yearly.

Throughout the years, Cartier Railway has been involved in continuous improvement in order to reduce its operating cost. Since the 1980's, it has increased the rail life through a series of actions including preventive grinding. With rigorous predictive and preventive maintenance practices applied to the track and the rolling stock, it was possible to improve the overall quality of the railroad and maximize its efficiency.

1.2 The Challenge

One of the major issues addressed at Cartier Railway in the last decade has been the elimination of derailment possibilities. A lot of human energy and capital investment has been directed towards detection equipments. Wayside detectors such as hot box detectors, wheel impact load detectors, dragging equipment detectors, lateral force and angle of attack measurement, surveillance cameras, have all contributed to the reduction of derailments, along of course, with a thorough preventive wheel maintenance program, ultrasonic testing of rail and axles, etc.

But, even with all these efforts, the risk of derailment, although largely minimized, was still present mainly with the low rail roll over phenomenon. Following a series of locally unexplained derailments in the mid-1990`s, experts from Rail Sciences Inc. and the Canadian National Research Council suggested that the low rail in high degree curves be slightly contaminated with grease or other lubricant in order to reduce the friction and therefore reduce excessive lateral forces and high L/V ratios. Although this recommendation would have reduced considerably the risk of low rail roll over, it was never put in place because of adhesion problems with the locomotives. Most of the high degree curves are located in areas where good traction is required.

Following the introduction of a preventive maintenance program on the ore car fleet, aimed at the rehabilitation of the car bogies, hollow worn wheels, side bearings and center plate lubrication, along with the addition of spikes

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to improve the holding power in high degree curves, Cartier Railway was derailment free for 7 years.

In June 2003, a derailment involving 28 loaded ore cars occurred in a 6.5 degree curve at km 261.5 (mile 162.5). The cause was found to be associated to a stiff truck and dry rail following a preventive grinding intervention with the rail grinder. Cartier Railway had just begun monitoring the angle of attack of wheels with a WID system and unfortunately the bad acting car had been spotted on its previous trip but had not yet been removed from service.
Further remedial actions had to be introduced in order to eliminate the possibility of repeating this scenario. In the fall of 2003, Kelsan Technologies Corp. from Vancouver, met with representatives of Cartier Railway to introduce their friction modification product. Interested by the other side benefits, such as locomotive fuel consumption and greenhouse gas reduction [4, 5] and seeing the results attained at BC Rail and other railroads [6, 7, 8,9] Cartier Railway immediately realized that they had just found what they had been looking for, a means of reducing lateral forces and high L/V ratios while maintaining adequate adhesion for the locomotives.

1.3 The Solution

During a visit with Kelsan Technologies and BC Rail in February 2003, the three conventional application methods of the product were presented to Cartier Railway followed by a field trip where each could be observed. After a brainstorming session with a group of technical, operation and maintenance personnel, where all the pros and cons associated to each application method were identified, Cartier Railway suggested a new approach to Kelsan which consisted of applying the TOR friction modifier product, KELTRACK®, from the first ore car behind locomotives. This method would be simpler and more flexible while keeping the cost down, whereas the whole fleet of locomotives would not have to be equipped.

Although this paper outlines a novel method of dispensing a TOR friction modifier to the railhead, it should be noted that the benefits of the applied friction modifier, KELTRACK®, have been well documented.

2.0 TOR ORE CAR EQUIPMENT DESIGN

2.1 Revenue vs. Non-Revenue Car Mounted System?

In the initial design discussion, a basic question was raised as to whether this car should be used to generate revenue (i.e. carry ore). The primary argument for a ballasted non revenue car was a simplified design as the equipment would not have to meet the rigorous requirements associated with ore dumping; a process in which the entire car is rotated through an angle of 160°. On the other hand, loss of a revenue generating car would impact on productivity and increase logistical requirements (more car switching). On an annualized basis, QCM would have to run at least one additional 160 car train to make up for the lost productivity associated with a ballasted TOR non-revenue car.

As a result, the decision was made to design the TOR equipment to meet the requirements for a revenue generating car. The final design would use only 15 % of the revenue carrying capacity for the TOR equipment (figure 1).

Figure 1: Outfitted Car: 85% Revenue Carrying Capacity

2.2 Selecting an Ore Car

QCM car #4114, a standard 9.1 m (30 foot), 90.7 metric tons (100 ton) ore car manufactured by Canadian Car was selected to be outfitted with a friction modifier TOR delivery system. A general layout viewed from the left side of the car is shown in figure 2.

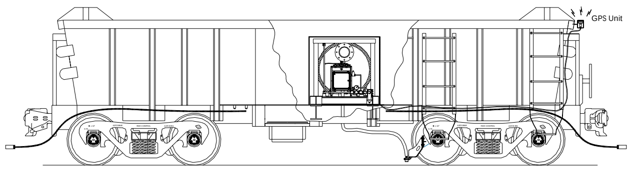

Figure 2: QCM TOR Ore Car General layout

This particular car style was chosen over other car types operated at QCM as it's under body structural steel provided more bolting opportunities to restrain the TOR system. This was an important factor considering that the 1000L product tank (approximately 1650 kg fully loaded) would be rotated through a severe angle during the ore dumping process. The subsequent design specified bolting the system directly through the ore car floor into the underlying structural steel "I" beams as seen in figure 2. Although mounted centrally across the car, the TOR system was offset slightly to the car brake end.

2.3 TOR Dispensing Equipment- An Overview

The prototype TOR dispensing equipment consists of the following components:

- 1000 L Stainless Steel product tank

- Left/Right Dispensing Pumps
- Left/Right Dispensing Nozzles
- Head Pump
- Stainless steel material for all wetted parts
- GPS- PLC control
- Touch screen interface
- Heat tracing cabling /Heating Elements for low temperature operation
- External system indicator lights
- External product filling ports
- External hook-ups for 74VDC & air.

Figure 3, taken during system installation, shows the system installed in a compartment 127 cm (50 inches) long by 122 cm (48 inches) high running across the width of the ore car. Although not incorporated into the prototype, the design easily lends itself to be mounted on a single skid. *The primary benefit of such an approach is significantly reduced onsite installation time as the system can be preassembled, pre-wired, pre-tested etc at the vendor.*

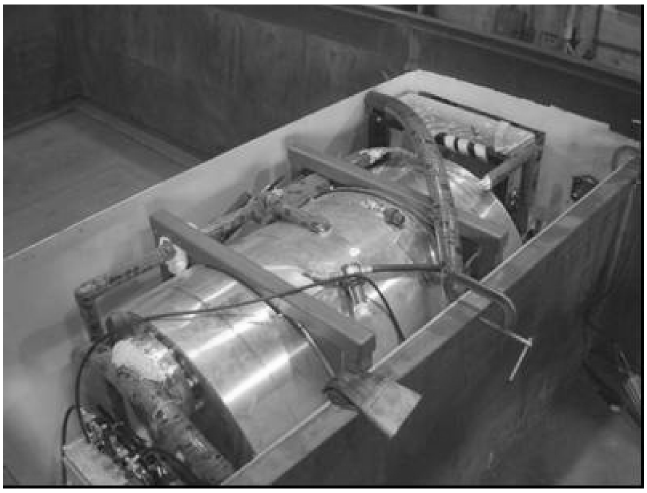

Figure 3: TOR equipment in Ore car Compartment

Left & right entry panels were cut into the car to allow access to the system as shown in figure 4. The main control panel located on the right side of the Ore car is not shown.

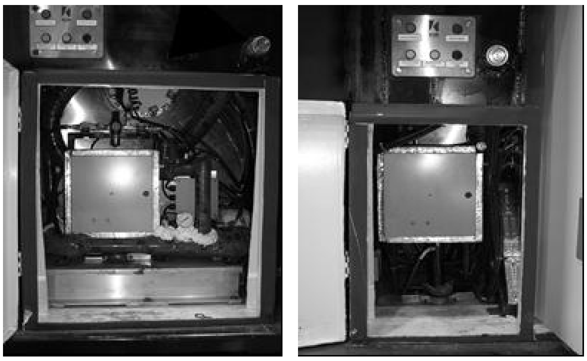

Figure 4: Ore Car left and right side components

TOR nozzle mounting brackets were designed to be attached to existing Ore car side frames (figure 5). Adequate vertical and lateral adjustment is provided to ensure proper nozzle alignment. Typically, the TOR spray nozzles are positioned 5.1-7.6 cm (2-3 inches) above the rail center. Take-off plates welded onto the ends of each car side frame provide a bolting surface for the nozzle brackets.

Figure 5: Ore Car TOR Nozzle Mounting Details

2.4 The GPS-PLC System

An externally mounted GPS unit provides all the required navigational information for the PLC control system including car speed, curve sensing, heading and location. Based on this input, the PLC can be programmed to apply a constant application rate (on a per distance basis) for both tangent and curved track. Use of GPS for this application eliminated the need for having individual curve & speed sensors as well as increasing the system's flexibility by including heading & latitude/longitude data.

Field testing performed during the commissioning of the prototype car indicated that the processed GPS signal (figure 6) was able to successfully:

- Distinguish between tangent and curved track.
- Distinguish between left and right handed curves.

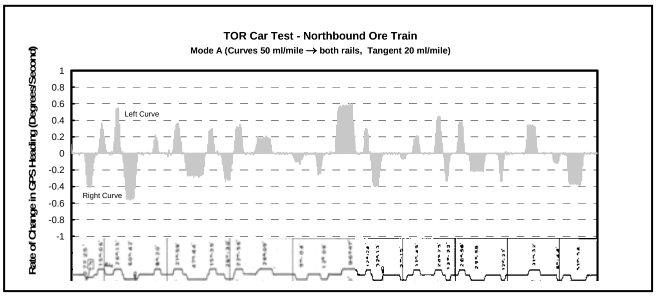

Figure 6: Field Testing the GPS as a Curve Sensor

Unless prohibited by the application mode, spray operation is enabled whenever train speed is above 8 kph (5 mph) and disabled only when the air brake pressure switch is activated.

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2.5 Tunnels

Within the territory QCM operates, multiple tunnels are found in which GPS reception is not possible because satellite line of sight is lost. In these cases, the control system is programmed to recognize each tunnel using its known GPS coordinates. If the TOR spray is activated entering a tunnel, it is maintained through the tunnel using the present train speed. By default if GPS communications are not re-established after a pre-set time, spray activation is stopped.

2.6 Accounting for Car Orientation

Sensors in the electrical panel detect which car end cable is connected to the locomotive automatically allowing the car running orientation to be determined. Car orientation is required when applying product on low rail only in curves.

2.7 External Hook-ups

Compressed air required for atomizing product at the TOR nozzles is supplied to the TOR system using standard railcar air hose fittings located on each end of the Ore car. In a similar way, electrical supply (74 vdc) for operating the TOR system is also provided through standard electrical connectors located on each end of the ore car. Figure 7 shows the car brake end details including the electrical and air locomotive connections and GPS unit.

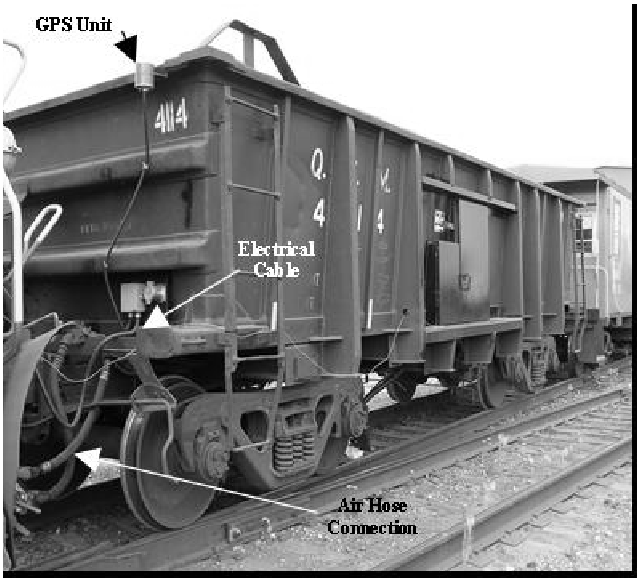

Figure 7: Ore Car Brake End Details

Figure 8 shows the TOR car power connection on the short hood end of QCM locomotive unit #21.

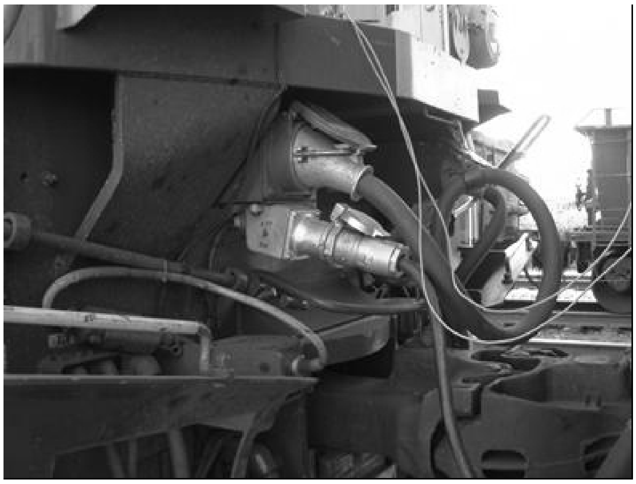

Figure 8: QCM Locomotive Power Connections

DC power is supplied from the locomotive battery through a circuit breaker to the TOR car plug receptacle seen in figure 8. QCM added a secondary on/off control switch at the plug to provide local power activation for train crews and maintenance staff.

Initially, the design scope was to investigate the use of the locomotive MU line to provide power to the car mounted system. However, the inclusion of a robust ancillary heating system to allow for effective low temperature operation resulted in a potential amp draw that exceeded the capability of the MU line. If no heating system is required, or the amp draw requirements are reduced, use of the MU cable becomes feasible.

2.8 Winter Operation

For cold weather operation, the product tank was outfitted with electric heating pads and insulated with mineral wool with aluminum cladding. Tank product temperature is automatically maintained by the TOR control system and is designed for operating to -30°C

For cold weather operation, all the piping and hoses carrying product are heat traced with self-regulating cable and fully insulated to provide freeze protection to -30°C. Each dispensing box is also heated and insulated to prevent product inside from freezing. In addition to heat trace cable wrapped around each TOR nozzle, direct heating is supplied in each nozzle to provide extra heating when heat losses exceed heat trace capability. An ambient temperature sensor located on the Ore car undercarriage is used to automatically activate the ancillary heating equipment when temperatures drop below 5°C.

3.0 TOR ORE CAR OPERATION

3.1 Activating/Deactivating the system

The system is design to activate once the TOR Car plug is inserted into the (live) locomotive socket. Conversely, when the cable is removed from the locomotive socket the system will power down. No other action is required by the user to start/stop the system.

3.2 Programmable Features

One of the key features developed in this prototype is the ability to program a specific application strategy for the TOR friction modifier. This includes:

- Setting an application rate for tangent track
- Setting an application rate for curved track
- Option of applying on both rails or low-rail only in curved track.
- Programming of up to three "Modes" (a mode being a set of curve/tangent application rates) based on selected latitude/longitude co-ordinates. This allows the user to differentiate between empty & loaded train sets as well as change the application rate in areas of dynamic/air braking.

It should be noted that once programmed, the instructions are stored in memory and are not lost when power to the system is turned off. Changing the settings is performed easily through the touch screen interface.

3.3 Tank Filling

Filling valves are located on both sides of the car.; no spill fittings are used to minimize any potential mess. Overfilling the tank is prevented by using a shut-off float valve located inside the tank along with specialized venting to eliminate product leakage during the car dumping process.

3.4 Diagnostics & Alarms

Located on the each side of the car near the filling valve are a set of external indicator lights:

- Green – system functioning
- Red – System non-functioning (Alarm)
- Product Tank Level (Full, 1/4 Full, & Empty)

Accessing the touch screen can provide further details if an alarm (red light) is indicated on the external panel. Future plans include a remote download feature to monitor the onboard system diagnostics.

4.0 OPTIMIZATION OF TOR APPLICATION RATE

The TOR outfitted car was placed in one of QCM's standard 160 wagon train sets which traveled back & forth between the port and the mine. Typical tonnage for these trains sets were 3420.1 metric tonnes (3770 tonnes) empty and 17327.2 metric tonnes (19100 tonnes) loaded.

Table 1 highlights the application strategies assessed for southbound loaded trains traveling through the lateral load site.

Condition	Curve (mL/km) Low	Curve (mL/km) High	Tangent (mL/km)
BASELINE	0	0	0
TOR 2	63	0	0
TOR 3	94	0	0

Table 1: TOR Application Rates for Loaded Southbound consists

5.0 MONITORING TOR EFFECTIVENESS

A significant challenge exists when monitoring TOR effectiveness as when properly applied to the rail, friction control materials are virtually invisible to the naked eye. A number of performance parameters can be measured to determine effectiveness TOR friction control. These include rail friction, dynamic rail head deflection, curving forces, and train energy.

As a key issue with TOR is the effect on curving forces, data produced by a truck performance detector (TPD) was selected as a primary method for monitoring system effectiveness. For this project the primary goal was to reduce curving forces and evaluate changes in system performance during prototype trials and adjustments, thus a full matrix of measurements associated with a standard TPD site (normally needed for flagging poor acting vehicles) was not required. Monitoring curving performance of a number of similar trains at a single location allows the effects of variations in TOR friction to be assessed.

A similar methodology for monitoring curving performance is in use at many other TOR evolution sites. This allows the same software packages to be utilized for all sites, with the additional benefit of permitting performance to be compared between different TOR application systems and deployment strategies. Although the load station measures and collects curving performance of all passing trains, to further reduce data analysis costs, this particularly study only compiled and evaluated data produced by standard ore trains with 160 loaded or empty ore cars.

The load station was installed on a 435 meter radius (4 degree) curve near kilometer 16.1 (milepost 10), (Figure 9) which is approximately 16 km north of Port Cartier at the southern end of the line.

Figure 9: Load station location, MP 10, looking northward.

The load station data collection system is activated when a train wheel triggers one of the vertical strain gages. The analog signal from each strain gage is sampled at 512 samples/second in the conversion process to a digital data base. Internal software examines data flow and patterns, followed by peak detection algorithms to determine a vertical and lateral load for each axle. This data is stored in a file for each train, which are transmitted by phone line for subsequent analysis by TTCI engineering staff.

5.1 Load Station Data

To determine the effectiveness of different TOR rates/patterns, average forces produced by lead or trail axles for each train can be shown in a time history format, delineated by test period. Additional analysis can be conducted to display forces generated by each axle of the train, axle-by-axle, and front to rear on a train specific basis.

The initial trial period was conducted to determine effectiveness of different application rates and patterns. Two months into the test a rail at the load station site was struck by lightning, damaging some circuits. This required partial replacement of gages, causing a shift in calibration. For this reason the time history shown in figure 10 shows forces observed during the second and third (TOR2, TOR3) evaluation periods. This data represents what is achievable for typical steady state operations.

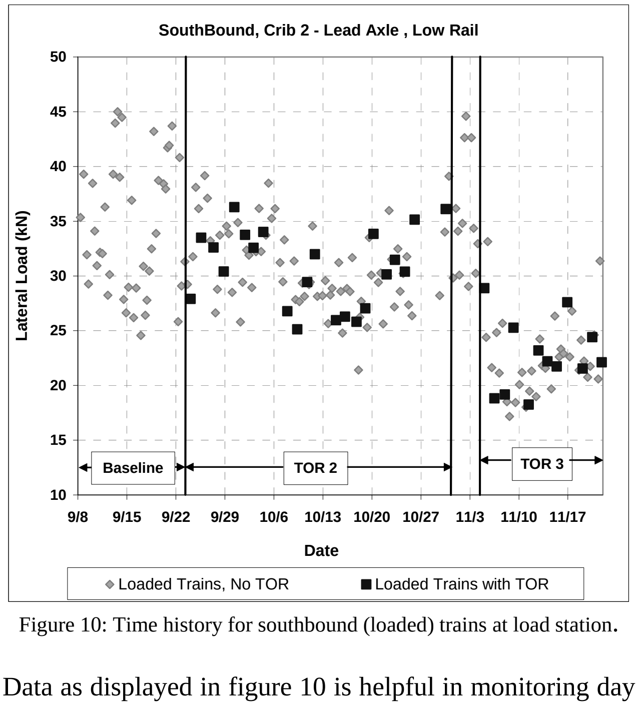

Figure 10: Time history for southbound (loaded) trains at load station.

Data as displayed in figure 10 is helpful in monitoring day to day progress and overall shift in curving performance. By averaging all trains of similar nature (in this case: loaded 160 car ore trains) with and without TOR the long term effect of a specific TOR application rate and pattern can be quantified.

Figure 11 shows average forces for three periods (baseline, TOR 2 and TOR3).

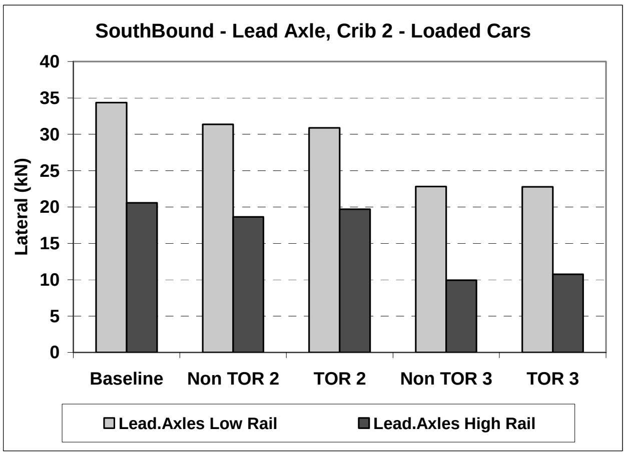

Figure 11: Average forces produced by lead axle, loaded trains for baseline, TOR2 and TOR3 periods. (Non TOR2, Non TOR3 indicates forces produced by trains not equipped with TOR systems during that same period.)

The average forces produced by passing trains show a reduction with time, indicating a gradual buildup and conditioning of wheels and rails. By examining forces produced within a specific train (front to rear) the effectiveness and degradation of the product applied for that train can be determined.

Figures 12a and 12b show front to end of train curving forces for two different, but identical in consist trains. The first figure shows results when no TOR car was operated, the second figure with the TOR car in operation.

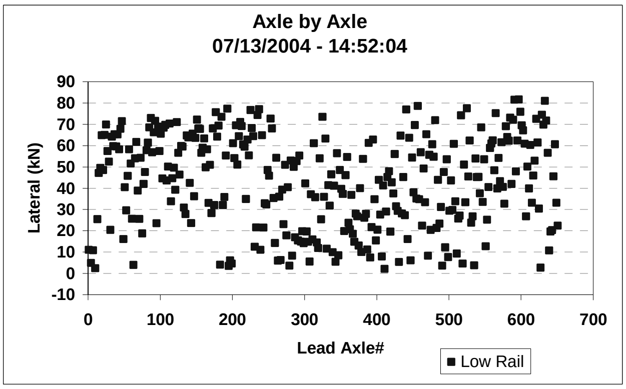

Figure12a: Front to end of train curving forces for baseline train

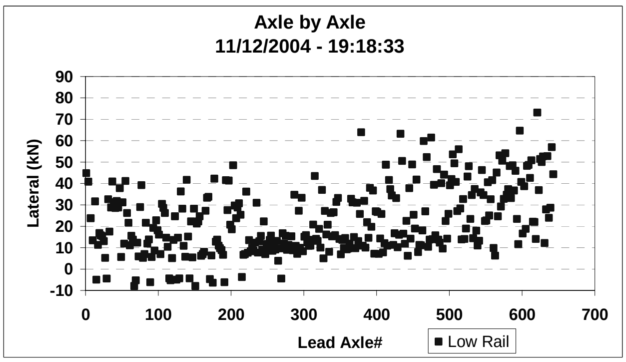

Figure 12b: Front to end of train curving forces for TOR conditioned train

Data for a typical non-equipped train (July 13th, 2004 figure 12a top) shows peak forces of about 80 kN, with little variation between front to rear of the train. Data for a typical TOR equipped train (Nov 12, 2004 figure 12b bottom) shows several features when a friction control material is applied at the head end of a train.

1. The peak forces are reduced, with only a few at the higher levels noted on a non equipped train.

2. The forces at the front of the train (staring with axle 1) are lower than the end of the train, signifying that the product is gradually loosing effectiveness towards the end of train.

3. The end of train is not producing the same high lateral loads as the end of a non-equipped train, signifying some end of train carryover.

The product remaining on the rail after the end of the train acts to reduce curving forces on one or more following trains. This explains the reduction in curving forces noted for non-TOR equipped trains as shown in figure 11.

Operating a greater number of trains equipped with a TOR car will result in more end of train carryover. In the long run this results in reduced curving forces for more of the non-equipped trains. The steady state level of curving forces achievable (as well as end of train effectiveness) will depend on a combination of the number of equipped trains and the friction control product application rate. Deployment of addition TOR units, in a captive system, would likely result in a reduction in the product application rate required to maintained a conditioned system.

6.0 CONCLUSIONS AND RECOMMENDATIONS

In conclusion, a new application technology for TOR train mounted friction control has been successfully developed and field tested for captive fleet operations. In this case, the spray application system was mounted on a revenue-generating freight car located immediately behind the trailing locomotive.

Field testing has demonstrated that the application of a friction modifier product from a modified ore car was successful in controlling lateral forces for a 160 car 19100 tonne consist. Further analysis of the data indicates that other non applying consists were also deriving benefits of reduced lateral forces due to the presence of residual friction modifier material on the rail head.

7.0 ACKNOWLEDGEMENTS

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