Implementing 100% Effective Gauge-Face Lubrication and TOR Friction Management Strategies on MRS Heavy Haul Railroad

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Summary: For several years, North American Railroads and various research institutions have been involved in implementing best-practice friction management strategies on heavy haul tracks. During 2006, MRS Railroad visited CPR and was impressed with the friction management strategy that had been developed and implemented. In 2007, MRS invited NRC-CSTT to bring this methodology to Brazil and to develop a customized strategy of 100% effective gauge-face lubrication and top-of-rail friction management. This paper discusses the processes, technologies, results and benefits based on this best-practice applied to MRS during three years (2007-2009). The business case analysis, quantifying the actual net earnings accrued to MRS as a result of the implementation of Friction Management on test sites, and the forecasted earnings that will occur through the expansion of this strategy to the entire MRS system, will be included in the IHHA presentation in June 2009.

Index Terms: Track Maintenance Technology; Safety, Innovation and Monitoring; Friction Management

1. INTRODUCTION

Over a five year period, NRC-CSTT (National Research Council of Canada - Centre for Surface Transportation Technology) was involved in the implementation of a best-practice friction management strategy along Canadian Pacific Railway's coal route. The strategy achieved very positive results in terms of reductions in: wheel-rail wear rate (30%), lateral forces in curves (50%), locomotive fuel consumption (5.7%) and derailments risks, totaling US$ 25 million per year in earnings. Considering the benefits attained by CPR, MRS Engineering Department engaged NRC-CSTT to develop and implement a strategy of 100% effective gauge-face (GF) lubrication and top-of-rail (TOR) friction management.

Furthermore, MRS retained another partner, Ch. Vidon (a Brazilian consultant), to maintain and adjust the friction management equipment, to undertake all data measurement required, to perform data analysis according to NRC-CSTT methodology, and to provide training to MRS employees. A day-to-day presence was needed on the ground to ensure the success of this pilot project, and the time required to do so would have reduced the time the MRS employees would have for their usual duties. This paper presents the processes and technologies adopted, the results and benefits obtained in the test sites over three years, and the forecasted benefits for the future expansion of this practice in MRS' track, all contributing to increases in operational safety and productivity.

2. OBJECTIVES OF WHEEL-RAIL FRICTION MANAGEMENT ON MRS

- Purchase and implement equipment and technology that will permit the efficient optimization of GF lubrication and TOR friction management;
- Optimize the GF lubrication practices along the track, in a manner that is safe, efficient, and effective for MRS;
- Regularly monitor the friction conditions on the track and determine the benefits from this practice;
- Establish procedures to ensure the correct application of friction management products on the rails to avoid negative impact to MRS transportation and operational safety.

3. SCOPE OF PROJECT

The end purpose of the project is to control the friction coefficients in the wheel-rail interface to values that are appropriate to MRS' track operating conditions.

First, it is necessary to prepare a pilot project implemented in test-sites that represent really the MRS track characterized by heavy haul operating conditions with high tonnage and traffic, and sharp curves. The scope of the pilot project proposed by NRC-CSTT, based on the methodology applied for CPR and customized for MRS, consists of five phases:

1. Selection of the optimum rail curve grease for GF lubrication;
2. Selection of test-sites and measurement of baseline (dry) conditions;
3. Implementation and measurement of 100% effective GF lubrication using the optimum rail curve grease;
4. Implementation and measurement of 100% effective TOR friction management using a friction modifying product;
5. Final report and presentation, including the guidelines needed expand the methodology to the other areas of MRS' track.

After the pilot project is concluded in May 2009, MRS must extend the control of the friction management along the track, based on the guidelines outlined in the final report of the pilot project.

3.1. Phase 1 – Selection of Lubricant-Grease

From August 2006 to January 2007, MRS' Track Engineering performed in-track testing of several lithium-based rail curve greases containing molybdenum disulfide, to evaluate their lubricity and retentivity on the rail. Standard laboratory grease test results (dropping point, worked penetration, four-ball EP and wear tests, and water washout) were also reviewed.

The rail curve grease chosen for the pilot project was Shell Retinax HDX 1.0, because it has offered very good performance relative to its price, and it was available locally. The in-track tests revealed that it lasted 67% longer than the previous curve grease used by MRS, which was a calcium-based product containing graphite.

Use of the new grease contributed to a 37% reduction in the operational cost of gauge face lubrication. The calcium-based grease would only last 30 hours on track (equivalent to 44 trains). After changing over to the lithium-based grease, the track would remain lubricated for 50 hours (equivalent to 73 trains). This reduced the frequency of mobile rail lubrication from 5 to 3 times per week, and the weekly diesel consumption of the hi-rail vehicles dropped accordingly.

3.2. Phase 2 – Selection of test-sites and Measurement of Baseline Condition

In 2007, two test zones – Pinheiral and Santana de Barra (Figure 1) – were selected in relatively flat territory to minimize the risk of stalling trains in the event of top-of-rail grease contamination. Both zones were selected based on a preliminary "de-Koker" analysis [1] which estimated the locations of future wayside lubricators. The locations of the TOR applicator systems and lateral/vertical (L/V) measurement system were also determined.

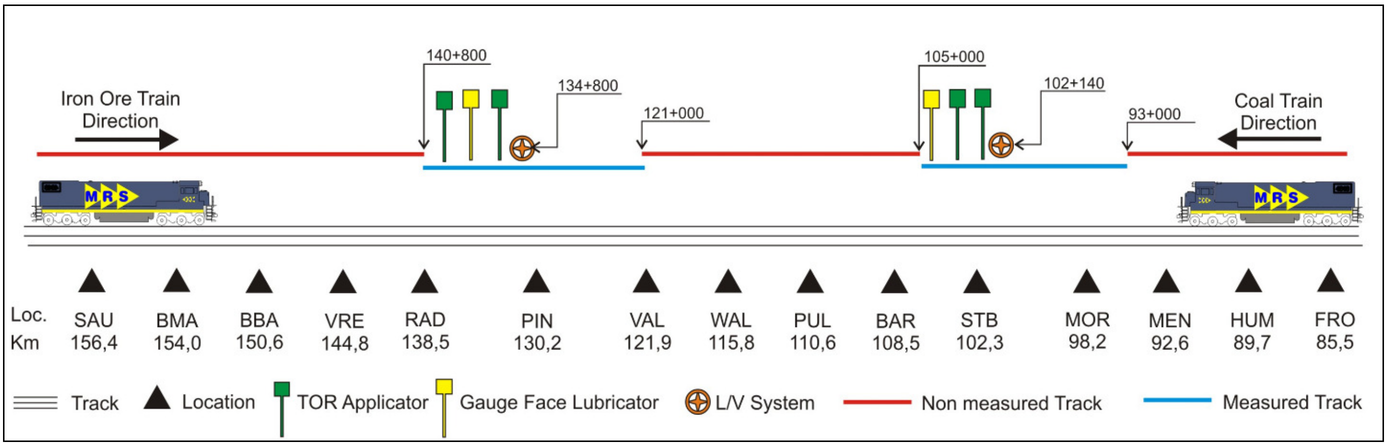

Figure 1 – Schematic of Selected Test-Sites for phases 2, 3 and 4

Table 1 – Test measurement results at three locations from km 133 (Pinheiral – RJ)

LOCATION		CURVE		RAIL		TRACK		FRICTION COEF. (μ)			SURFACE DEFECTS
Km	Post	Radius (m)	Side	High/ Low	Branding	Gauge	Cross level	TOR High	TOR Low	GF High	Dye Penetrant Test
134	13	930	R	High	JFE2006	7	21	0,42	0,58	0,28	12/12/2008
				Low	NSC 2006						
	18	490	R	High	JFE 2006	9	50	0,45	0,55	0,25	12/12/2008
				Low	HK 1988						
	21	490	L	High	JFE 2006	12	58	0,51	0,48	0,21	12/12/2008
				Low	CORUS 2006						

Mobile lubrication was suspended for six months, and periodic measurements of the following parameters (Table 1) were undertaken at several curves in both test zones:

- GF and TOR friction coefficients in several test curves were measured with a push tribometer (Figure 2);
- Rail profiles were recorded with a rail MiniProf (Figure 3) for use as references to document changes in rail wear rates compared to phase 3 and phase 4;
- Dye penetrant (Figure 4) was used to visually enhance the presence of rolling contact fatigue (RCF) damage;
- Rail manufacturer information, track gauge and superelevation measurements.

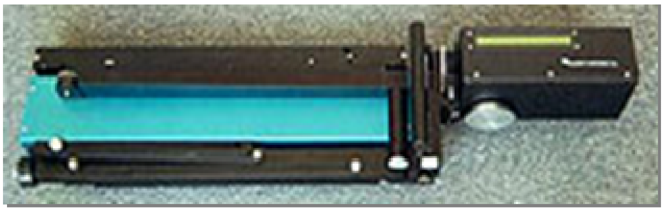

Figure 2 – Push tribometer

Figure 3 – Rail MiniProf

Figure 4 – Dye penetrant for rail surface evaluation

The push tribometer is an important tool for performance monitoring of friction management in curves, as it is used to measure, accurately, the friction coefficient (μ) on the GF and TOR surfaces (Figure 5). The ideal friction coefficients are:

GF: $\mu \leq 0.25$
TOR: $0.30 \leq \mu \leq 0.40$
$\mu > 0.50$ – means the rail is effectively dry.

Figure 5 – Friction coefficient measurement on track using the push tribometer

Data was collected periodically at 58 locations in the curves of both test zones, to be used as the baseline in a comparative analysis with the results from phases 3 and 4, to show the benefits obtained from friction management in terms of reduced wear rates and reduced lateral forces.

L/V systems have been used in several lubrication studies to directly show the effectiveness wheel-rail friction management. The lateral and vertical force data are calculated by a remote data system (RDS) (Figure 6), the core of the L/V system, which captures data from strain gauges installed in two cribs on the test curve rails whenever a train passes over the L/V site.

Figure 6 – Remote Data System (RDS)

Once installed, the L/V system measured the forces in the Pinheiral test zone in a sharp curve at km 134+800 for two months. Then the RDS was moved to a sharp curve (at km 102+140) in the Santana de Barra test zone (Figure 7), for measurements during the next two months.

Figure 7 – View of L/V system

The L/V system recorded lateral and vertical force data at each crib in the test curves, and these data were collected and post-processed by Ch.Vidon to be submitted to NRC-CSTT.

3.3. Phase 3 – Measurement and Management of 100% Effective Gauge-Face Lubrication

Initiated early in 2008, this phase consisted of the installation, activation and calibration of Portec 761 Hydraulube wayside hydraulic lubricators equipped with MC-4XL wiping bars with GreaseGuide technology and Catch-All Track-mats (Figure 8). The use of these geo-textile mats prevented grease contamination of the ballast and subgrade by retaining any grease that was splashed from the wiping bars, while still allowing rain water to pass through.

Figure 8 – Wayside lubrication installed in the 2nd test zone (Santana de Barra)

The hydraulic lubricator has the advantages of not requiring an external power source which reduces the probability of vandalism, and in this project has demonstrated good performance in terms of transferring grease to passing wheels for distribution along the rails. Grease has been observed at a distance of 8 km in either direction from the wiping bars.

The same periodic monitoring of the test zones as in phase 2 was performed, in order to obtain data from the lubricated condition for comparative analysis to the dry phase. The difference in wear rates and L/V values translates into savings in terms of reduced maintenance requirements. The grease retentivity and carry distance were measured using the push tribometer, to check that grease was not migrating to the TOR from the GF. TOR contamination can result from improper adjustment of the lubricator's flow valve, or from wiping bars that are installed too high on the rail.

The number of lubricators needed and their spacing along a particular track route depend on several factors, including curve radius, track grade, train speed, braking requirements, axle load, etc. These factors influence the retentivity and carry distance of the grease. Phase 3 was concluded in November 2008.

3.4. Phase 4 – Measurement and Management of 100% Effective Friction Management

This phase was initiated in November 2008, and consisted of the installation, activation and calibration of electronically-controlled Portec Protector IV TOR applicators, equipped with two TOR-XL bars (Figure 9). These systems were applying KELTRACK to the TOR. The hydraulic GF lubricators were still active during this phase. The same parameters as in the previous two phases were monitored on a periodic basis.

Figure 9 – KELTRACK friction modifier applied by TOR-XL on MRS Track

Developed by Kelsan Technologies, KELTRACK is a water-based friction modifier which, when applied to the TOR, produces an intermediate coefficient of friction. When the water evaporates, the remaining solid materials stay on the rail as a dry thin film. In contrast with grease lubricants, KELTRACK controls the coefficient of friction to approximately $\mu = 0.35$ (Figure 0). At this level, locomotive traction and train braking are not compromised but wear, lateral force and fuel consumption in curves are greatly reduced compared to dry conditions, in a safe and reliable manner.

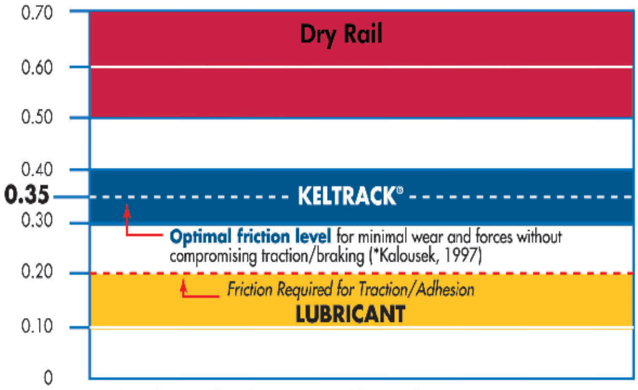

Figure 10 – Friction coefficient layers for each condition (dry, lubricated and friction modified)

3.5. Phase 5 – Final Report and Presentation

This phase was completed in May 2009. NRC-CSTT summarized the project results in a final report to MRS, with a complete description of the implementation and results from the test zones as well as guidelines for rolling out the pilot project methodology to other areas on the MRS system which can benefit from friction management. The final report included an analysis of the economic aspects of friction management, quantifying the real benefits accrued to MRS as a result of the pilot project and projecting the benefits that would occur as a result of expanding friction management to other areas of track.

4. BENEFITS FROM 100% EFFECTIVE FRICTION MANAGEMENT ON MRS

The purpose of the 100% effective friction management project is to control the wheel-rail interface coefficients of friction to values that are appropriate for heavy haul operating conditions, according to best practices from IHHA Guidelines [2].

MRS intends, through the use of gauge-face and top-of-rail friction management systems, to obtain the following benefits:

- Increased service life of wheels and rails in curves, via a 30% reduction in wear rates
- 3% reduction of fuel/energy consumption associated with wheel/rail interaction
- 50% reduction in lateral forces in curves
- Reduced risk of derailments from wheel climbing and from rail failures caused by rolling contact fatigue defects.

5. PILOT-PROJECT RESULTS

Tribometer measurements illustrate the changes in the coefficients of friction in the three test phases of the project. Figure 11 shows all COF values (at the end of Phase 2) were well above ideal levels.

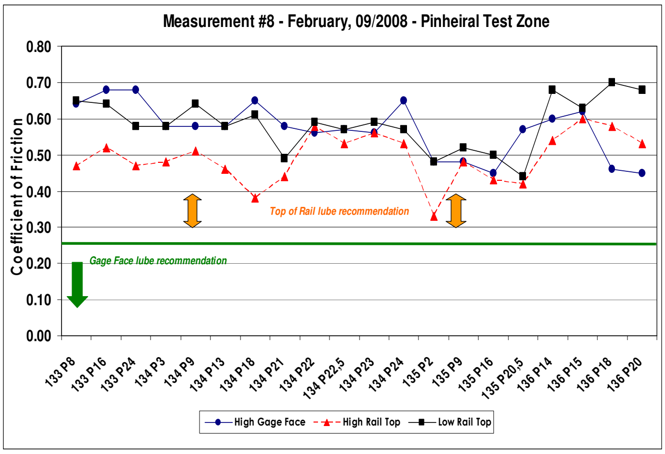

Figure 11 – COF values at the end of Phase 2 (dry)

Figure 12 reveals that the GF COF (in blue) has dropped substantially in the test zone, to below the threshold level (the green horizontal line). Some contamination of the top of the high rail is evident, as shown by the red data points near the middle of the graph. The top of the low rail remains dry.

Figure 13 (at the end of Phase 4) shows that GF COF is still below the threshold level through most of the test zone, but the tops of both rails are not suffering any contamination due to better adjustment of the grease lubricators.

Note that the presence of KELTRACK on the TOR cannot be detected with the push tribometer.

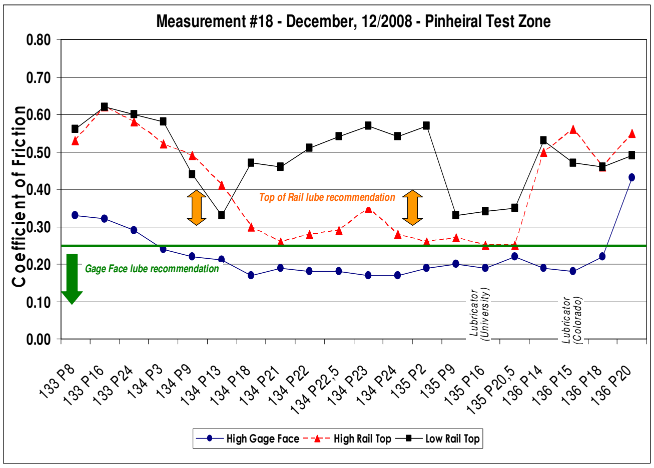

Figure 12 – COF values at end of Phase 3 (gauge face lube)

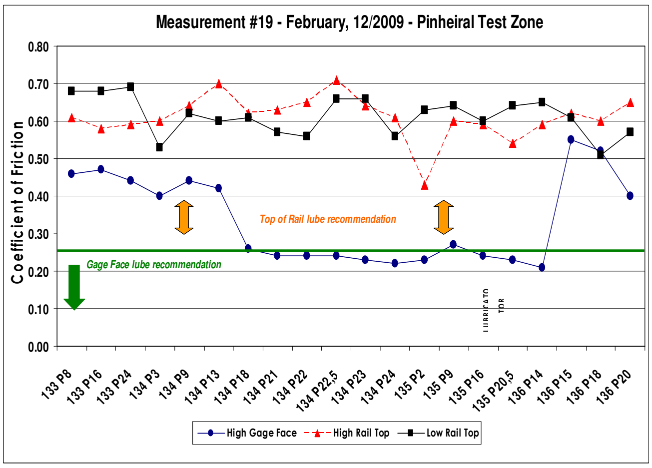

Figure 13 – COF values at end of Phase 4 (gauge-face lube and KELTRACK on top of rail)

The push tribometer is not able to develop sufficient longitudinal traction force to shear the interfacial layer of iron oxides and KELTRACK that lies on the top of rail. It rolls and slips on the magnetite particles that protrude from the interfacial layer, and these have a high coefficient of friction. Therefore, the benefits of TOR friction management must be demonstrated by other methods, namely lateral forces and rail wear rates.

The highest lateral forces witnessed in the Pinheiral L/V curve occurred on the low rail. In Figure 14, the dry condition (in blue) produced the greatest range of lateral forces, as well as the highest force magnitudes. GF lubrication (in magenta) narrowed the force range, and reduced the magnitudes of the peak forces considerably. The introduction of TOR friction management caused a further narrowing of the lateral force range.

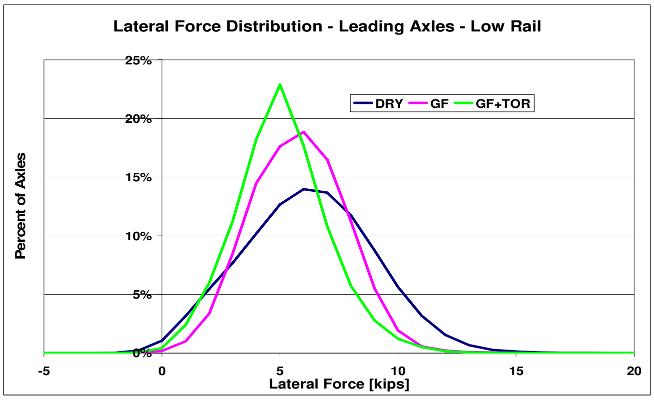

Figure 14 – Lateral forces from leading axles of loaded cars, low rail of Pinheiral test curve

The 50th percentile lateral forces on the low rail were 5.18 kips (dry), 4.75 kips (GF lubrication), and 4.01 kips (GF and TOR); these represent 8.3% and 22.5% reductions in lateral forces, respectively, compared to the dry condition. TOR friction management reduced the lateral forces an additional 15.6%, compared to the GF lubrication condition.

Figure 15 shows the lateral forces on the high rail of the Pinheiral L/V curve. It can be seen that the use of GF lubrication shifted the distribution of lateral forces towards higher magnitudes, and this was the expected result. The introduction of TOR brought the lateral forces back down.

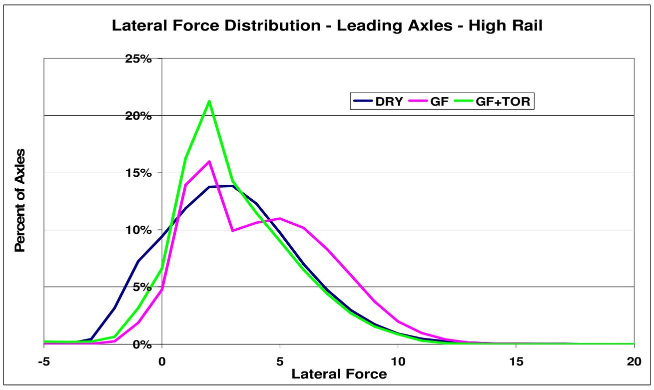

Figure 15 – Lateral forces from leading axles of loaded cars, high rail.

The 50th percentile lateral forces on the high rail were 1.79 kips (dry), 2.90 kips (GF lubrication), and 1.70 kips (GF and TOR); these represent a 62% increase and a 5.0% reduction in lateral forces, respectively, compared to the dry condition. TOR friction management reduced the lateral forces an additional 41.4%, compared to the GF lubrication condition.

Lateral forces increased on the high rail because of the reduced longitudinal force on the wheel flanges, as a result of improved lubrication. This acts to reduce the net positive longitudinal traction force on the outer wheels in the curve. In a sharp curve where creep saturation is present, reducing the longitudinal creep force will cause the lateral creep force to increase resulting in higher lateral rail forces.

Figure 16 shows the average decrease in gauge-face wear rates (between 51% and 67% in the high rail) for curves grouped in three curvature ranges, with the largest improvement occurring in the sharpest curves.

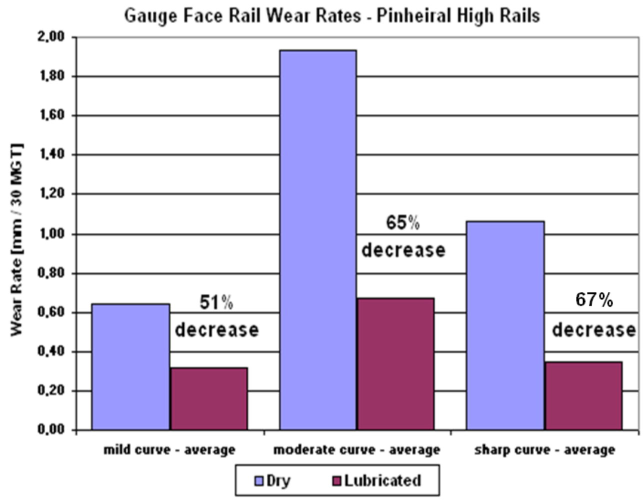

Figure 16 – Averaged gauge-face high rail wear rates, for the dry and lubricated phases (Pinheiral)

Figure 17 shows the average decrease in vertical wear rates (between 46% and 68% in the low rail) for curves grouped in three curvature ranges, with the largest improvement also occurring in the sharpest curves.

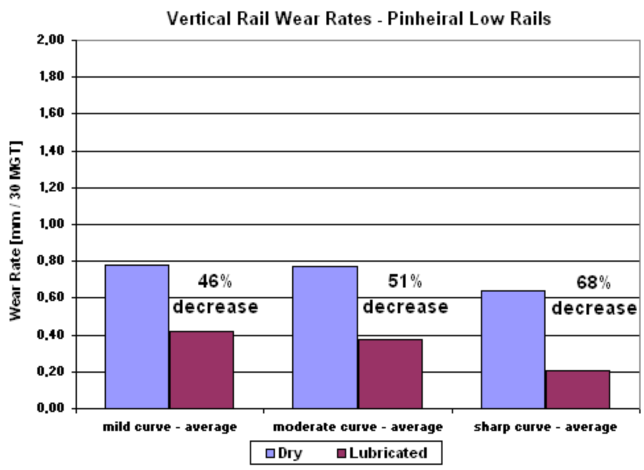

Figure 17 – Averaged vertical low rail wear rates, for the dry and lubricated phases (Pinheiral-RJ)

Further data reduction is necessary to produce wear rate results from phase 4 (TOR friction management). Based on the lateral force results (Figure 14 and Figure 15), additional reductions in TOR wear rates will occur. These results will be available during the June 2009 presentation.

Note that despite the increase in high rail lateral forces, wear has been shown to decrease for the GF lubrication phase. Wear results presented here are based on a subset of the data, and includes curves which had some TOR curve grease contamination.

6. CONCLUSION

Beginning in 2007, MRS used the knowledge developed by NRC-CSTT in their research, implementation and expansion of 100% effective friction management on the Canadian Pacific Railway to implement a customized strategy for the MRS heavy-haul iron-ore railway in Brazil. This paper demonstrates that friction management can be successful if the process is engineered to suit each railway's specific environmental, track and operating conditions.

The employment of a local partner, Ch.Vidon (Brazilian consultant) also proved to be part of the success story. They were able to take the responsibility of maintaining and adjusting the friction management equipment, to undertake all data measurement required, to perform data analysis according to NRC-CSTT methodology, and to provide training to MRS employees.

The selection of the optimum rail curve grease for GF lubrication was a key item to ensure reduced rail wear rates and produce long carry distances, thereby reducing the overall number of lubricators required in the track during roll-out to the rest of the system. This will reduce both the capital and operational costs of gauge face lubrication.

The overall benefits to MRS from the implementation 100% effective lubrication can be summarized as follows: reduction of lateral forces in curves of 22.5% on the low rail, and 5% reduction on the high rail (compared to the dry condition), and an estimated reduction in rail replacement of 27% or 6,000 metric tonnes (88 km of rails per year), based on MRS` Rail Consumption Modeling Program. In sharp curves (greater than 5 degrees) high rail life will increase by 67%.

During the past several years, 60% of MRS' rail replacement has been due to lateral wear in sharp curves. The results of this pilot project show that the implementation of 100% effective lubrication and TOR friction management strategies is the best method for MRS to obtain longer life from its curve rails and reduce the annual rail replacement.

Considering that 60% of rails have been replaced in the MRS track due to lateral wear in sharp curves, the implementation of 100% effective lubrication and TOR friction management strategies means that MRS is on right way to reduce the annual rail replacement.

NRC-CSTT has calculated the optimum spacing for GF and TOR units throughout the MRS system based on the results achieved in the test sites. MRS intends to roll-out the installation of GF and TOR equipment based on these calculations to the rest of the track in 2010. At that time MRS can report the savings achieved in locomotive fuel consumption.

7. ACKNOWLEDMENTS

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8. REFERENCES

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