Friction Management on MRS Logística

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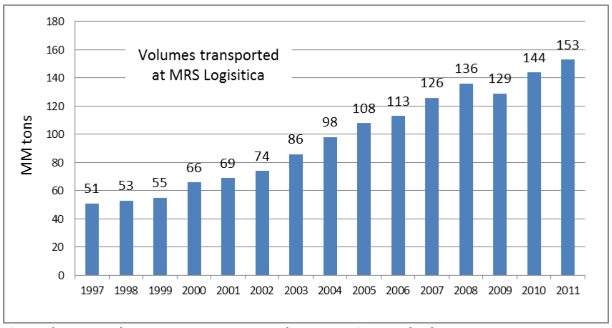
Abstract:
MRS Logística is pioneering the implementation of state of the art friction management technologies in the Brazilian rail industry. This includes both state of the art gage face lubrication and top of rail friction control using thin film friction modifiers. The primary motivation for this is the projected increase in capacity that will be required over the next 5-10 years on MRS rail network. With the prospects of heavier axle loads, longer trains, higher tractive effort and increased traffic density, there will be a corresponding increase in the stress state that is exerted on the infrastructure. Friction management is a key technology that has been identified to mitigate the impacts of increased demand by reducing wheel/rail stresses, corresponding forces and L/V ratios, rail wear, energy consumption, rolling contact fatigue, corrugations, noise and track structure degradation.
In 2007 a project began with collaboration between MRS Logistica, NRC-CSTT, LB Foster Friction Management and CH. Vidon to evaluate the benefits of optimized friction management and establish the cost/benefit impact of the technologies over a small scale test zone. In 2011, large scale installation was carried out with 75 wayside gage face lubricators and 77 top of rail friction modifier application systems installed on a territory-wide basis with approximately 629 km of track protected. This has allowed a systematic evaluation of the benefits that can be achieved in mitigating the potentially damaging impacts of higher tonnage operations under the specific environmental and operating conditions that are unique to MRS Logística and generally reflective of Brazilian heavy haul. The program has involved measurement and tracking of rail wear, friction conditions, lateral forces and L/V ratios with the use of rail profilometer, tribometer and strain gage based L/V instrumentation technologies. This paper describes how the project was developed, the methodology used, project status, data analysis and results to date.

Key-words: Permanent Way, Friction Management, Lubrication, Friction Modifiers

2. INTRODUCTION

MRS Logística S.A. Railroad started its operation in December, 1996, created from a government concession model. The MRS network crosses the most development region of Brazil, the southeast area, comprised of the states of Rio de Janeiro, Sao Paulo and Minas Gerais.

Since its inception the MRS has shown considerable growth in volumes transported. This growth implies an increasing occupation of the railway and makes the company seek to optimize resources, including permanent way, wagons and locomotives. One of the projects implemented with this goal was the "Friction Management".



Graph 1: Volumes transported at MRS Logistica.

Control of friction is a key point for railroads wishing to control costs related to the wear of wheel and rail, deterioration of permanent way superstructure due to high lateral forces and fuel consumption of locomotives. The wear rate can vary up to 20 times when friction management is used. High coefficients of friction can lead to derailments by climbing wheel and high noise when vehicles negotiate a curve. The friction management should be considered an approach to wheel-rail interface that includes grinding, profile of wheels and rails, metallurgy of wheel and rails and track geometry.

2. FRICTION MANAGEMENT

Friction Management is the process of controlling the frictional properties on all rail surfaces contacted by wheels to achieve the best balance between wear, lateral forces in curves, and fuel efficiency. (Sroba P., 2005).

Friction Management is a key to optimizing a railroad, covering three crucial areas within railway operation: costs, safety and environment.

Figure 1: Areas benefited by Friction Management.

Friction Management is the control of friction in two distinct areas of the rail through gage face lubrication and friction control on the top of rail. Gage face lubrication requires a high performance lubricant, that could be solid or liquid, it isusually grease. Control of friction on top of rail requires a friction modifiers, that also could be solid or liquid. The difference between lubricants and friction modifier is conceptual, while lubricants decreases the friction as low as possible, friction modifiers control the friction at an intermediate level, without compromise traction or braking of trains.

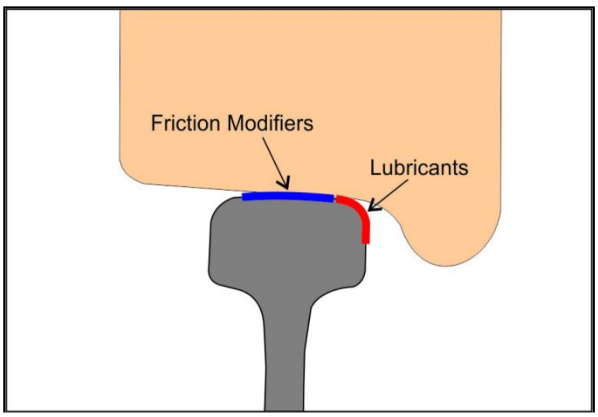


Figure 2: Different approach to two distinct areas of railhead.

High performance grease is essential to ensure that benefits would be achieved, usually with EP additives. These additives reacts with the metal surface at extreme pressure, resulting in low shear layer that minimize or mitigate the wear. In general terms, the principal characteristics of grease are:

- Drop point;
- Change in viscosity with change in temperature;
- Stability/separation;
- Film Retentivity;
- Type of thickener, the rigidity of the lubricant depends on the concentration of thickener;
- Base Oil Characteristics: viscosity, viscosity index, blend;
- Additives for adhesion, detergency, corrosion and water resistance;
- Do not interfere with the integrity of signaling systems;
- Economically viable.

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 (FM) formulated for freight applications contain no oils, greases or other liquid lubricants components. They are composed of engineered composite solids, polymers and others compounds that are mixed with water and deposited on top of rail in liquid form. When the water evaporates, the remaining dry thin film maintains an optimal intermediate coefficient of friction.

The most widely known and accepted friction modifier is KELTRACK® Trackside Freight, manufactured by Kelsan Technologies. Several papers presented at Heavy Haul Conferences before describe KELTRACK® application at North American railroads, such as Union Pacific, Norfolk Southern, Canadian Pacific, Canadian National, etc.

Top of rail (TOR) friction control technology has emerged in recent years for reducing rail wear, lateral forces, corrugations, fuel consumption and noise, . TOR friction modifiers (FM) used for this purpose have two features of particular interest for RCF control:

- Friction modifiers can be applied to the top of rail to achieve an intermediate coefficient of friction in the Third Body layer. This has the effect of reducing the

traction forces without compromising braking or adhesion.
- True friction modifiers provide a thin dry film once the carrier water has evaporated thereby alleviating concerns about accelerating crack propagation.

FM has a positive friction behavior, in which friction increases with displacement and creepage over a wide range.

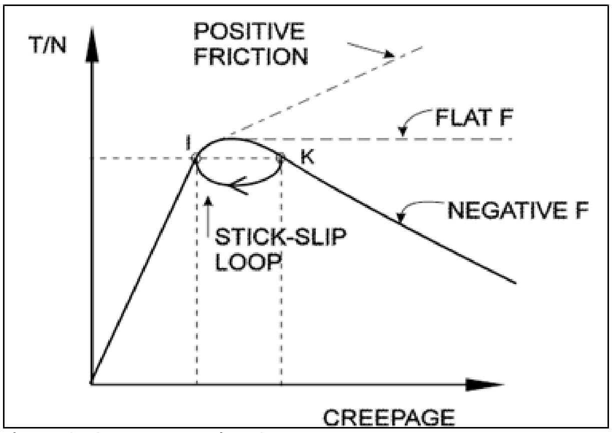


Figure 3: Creep x Traction Curve.

Table 01 shows the influence of the friction coefficient at everyday issues in the railway environment.

Issue	***Gauge face / flange friction***	***Top of Rail friction***
Flange wear	Yes	Yes (Indirect)
Tread wear	No	Yes
Fuel / Energy	Yes	Yes
Lateral (curving) forces	Yes (increase)	Yes (reduce)
Curve squeal	No	Yes
Flanging noise	Yes	Yes (indirect)
Corrugations	No	Yes
Reduce derailment potential	Yes (wheel climb)	Yes (L/V, rail rollover)
RCF	Yes	Yes

Table 01: Influence of friction coefficient.
Source: Wheel Rail Interaction Conference 2010, Don Eadie.

The use of TOR friction modifiers also can mitigate wheel and rail surface damage caused by RCF. While lubricants and friction modifiers behave similary in their ability to inhibit crack initiation associated with RCF (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, making them propagate – even at friction levels of 0,30 or less – while friction modifiers, consisting of solids, do not. As a result, FM helps to minimize crack propagation and, thereby, control fatigue-initiated wheel shelling, rail gage corner cracking, and related surface damage.

2.1. Recommended Friction Levels

Friction is measured along a distance of 15 m or more of rail length. According to AREMA 2010 Section 4.11.3.2 overall recommended (target) friction levels are:

- Gage face on curves: µ < 0,20;
- Gage corner on curves: µ < 0,20;
- Top of rail (curves and tangent): 0,30 µ - 0,40 µ;
- Differential: maximum difference between left and right top of rail: less than 0,1µ difference

Figure 4 shows recommended friction levels:

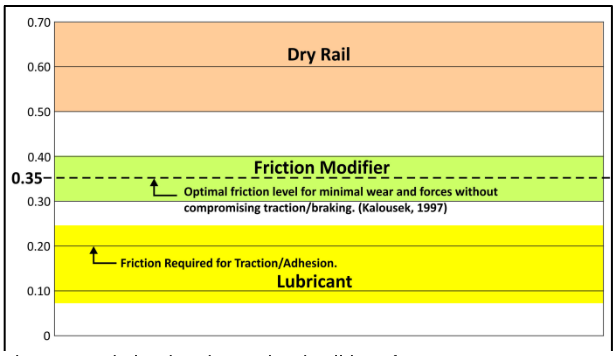


Figure 4: Friction levels at wheel-rail interface.
Source: Railway Track and Structure, "Modifying and Managing Friction", Joe Kalousek, 1997.

3. FRICTION MANAGEMENT PROGRAM AT MRS LOGISTICA

In 2007 through technical assistance from the National Research Council Canada (NRC), lead by Joe Kalousek, Peter Sroba and Rob Caldwell two test sites were chosen and the first research for the implementation of gage face lubrication and TOR application were made. In total 7 GF units and 4 TOR units were installed to evaluate the benefits. The results allowed the implementation of the friction management technology in a larger territory, in areas with a high percentage of sharp curves (over 8°) and high tonnage (over 100MGT / year).

During the Friction Management project, MRS observed an increase in rail life, a decrease in lateral forces, a decreasein the number of surface defects and less passes required for grinding.
Effective and more consistent results with regard to the benefits of friction management are expected when deploying on a large-scale equipment. The project involves the installation of

75 GF lubricators and 77 TOR units with the ultimate goal of protecting 629 km of the railway.

The Center Line has traffic consisting predominantly empty trains and will be outfitted with gage face lubrication, while the Paraopeba Branch, Northern Front of Steel Line and Serra do Mar Line (line 1) will be outfitted with gage face lubrication and friction modifiers for the top of the rail. Figure 5 shows regions of Friction Management at MRS Logistica.

Figure 5: Iron Ore Loop on MRS Logistica.

Passar a figura para o inglês ou trocar para português no parágrafo anterior

The technology applied in each part of the MRS network is from a financial expert research conducted by NRC in 2009. (Sera que precisamos deste parágrafo? Já foi falado antes…)

Region	GF Lubricators	TOR units	Route (km)
Serra do Mar	12	19	92
Paraopeba	15	46	151
Frente Norte	8	12	52
Centre Line	48	0	386

Table 02: Number of wayside units per route.

The new wayside equipments installed at MRS are electronic and use a eletro-magnetic wheel sensors installed on track. These sensor detects the passage of the wheels and sends a signal to equipment for pumping lubricant or friction modifier to the applicator bars. Electronic control boxes are used to define application parameters as a function of the number of passes by the wheel sensor and the operating time of the pump, thus optimizing the aplication of material.

NRC tests on Canadian Pacific Railway determined that the longer bars (1,48 m) dispensed 36% less than the short bars (0,66 m) to achieve the same effective distance of gage face coverage. Usually one wiping bar is installed per rail and equipments are placed in tangent track.

4. DEPLOYMENT OF EQUIPMENTS

The friction management equipments installed are Portec Protector IV for both gage face and top of rail. All units are solar powered.
Long Grease wiping bars (1,48 m) and Grease Guide® technology are use in gage face lubrication. GreaseGuide technology consist of a guide which reuses the grease wich is not carried by the wheel. One bar per rail is the typical installation and to prevent contamination of ballast is used a track mat is used. The wheels flange distribute the lubricant along the track. Figure 6 illustrates the typical installation of a lubricator.

Figure 6: Typical installation of GF lubricator.

Some considerations for placement of gage face lubricators:

- Waste of lubricant that is thrown on top of the rail;
- Quantity of lubricant that is consumed by the passage of trains;
- Length of the section of track that will be covered by each lubricator;
- the lubricating oil pumpability at different temperatures;
- Possibility of clogging of the distribution bars;
- Quantity of lubricant that is washed by the rains of the rails;
- Tendency of lubricants trickle face gage at high temperatures.

Other factors related to the conditions of the track:

- Finish the gage corner after grinding, deep facets (sharp edges) in the gage corner hinder the transfer of lubricant;
- Variations in track gage and cross level;
- Presence of level crossings in the vicinity of lubricators;
- Lubricators must be placed on tangents, and 30 meters from the entrance of the curve;
- Avoid locations with occurrence of hunting;
- Locations with available sunlight, avoid cuts and regions with high vegetation.

Figure 7: Wiping bar for lubricators, 16-port and GreaseGuide technology.

Shorter wiping bars are used for application of friction modifiers are used, Portec model TOR-ML, with a single port application. Different from the lubricant applicator bars, the TOR-ML bars are mounted on field side. The wheel tread is responsible for product distribution along the track. Figure 08 illustrates the installation of TOR unit.

Figure 8: Typical installation of TOR unit.

TOR applicators are installed in tangent track and some situations must be observed:

- Minimum distance of 30 meters from the entrance of the curve,
- The rails must not have defective surface near TOR unit;
- The width of the contact point in the area of installation must be at least 30 mm;
- Variations track gage and cross level;
- Entry Zone, the first applicator TOR should have smaller spacing;
- Regions where air brake is applied should have different application rate.

Figure 9: Wiping bar for TOR unit.

5. MAINTENANCE AND FILLING

CH.Vidon was contracted by MRS Logistica for: large scale/territory-wide assessment and equipment installation; program management, maintenance and filling service, performance verification. Dedicated maintainers were the key of success for Friction Management Program. An effective maintenance of a large number of units has been a challenge that some large railroads have not been able to fully overcome. Keeping units in operation is not a high priority activity for local maintenance staff in other maintenance activities, because the impact of the units out of service is not immediate, or may not be reflected in the goals of track maintenance team. Friction Management is a long-term investment, the result will not appear immediately. A lubricator operating continuously for months may have the results lost in just a few days if it runs out of supply of grease.

To enhance the management and availability of equipment, some units are equipped with the remote performance monitoring system, RPM™, provided by Portec / LB Foster. Through a website it is possible to know the level of the reservoir, configuration, axles counts, battery voltage, and finally the complete status of the equipment. The information is transmitted by GPRS network and stored in a database.

Inspections are conducted twice a month and filling monthly to ensure:

- At least 90% of the grease dispensing ports unobstructed;
- Minimum waste of lubricant / friction modifier;
- Operation of the sensor wheel;
- Battery is in the correct voltage;
- Friction modifier bars are not damaged;
- Equipment supplied until the next cycle of supply;
- Interference caused by vandalism.

The filling is performed with the aid of a hi-rail truck equipped with two pumps EZFill ™, one for supply lubricant and other for friction modifier.

Figure 10: Hi-rail truck for filling and installation services.

6. PERFORMANCE VERIFICATION

“You Can't Manage What You Can't Measure." (Morris A. Cohen). In parallel to the implementation of Friction Management Project, field measurements are performed periodically to record and quantify the benefits of the project. In each region the project, a number of curves were selected for monitoring the rail wear rate and COF. The curves were grouped according to the radius:

Mild Curves	R>700 m
Moderate Curves	350 m<R<700 m
Sharp Curves	R<350 m

Table 03 – Monitoring curves.

For each type of curves, ten curves are monitored by region. At each curve three measurement points on the high rail and three measurement points on the low rail were performed.

For evaluation and confirmation of the results the equipment described below were used.

6.1. Hand-Held Tribometer

It is a portable tool used for measurement of COF at specific locations on the tracks, manufactured by Salient Systems. The tribometer can obtain reading from the top or gage face or gage corner of railhead, depending on the setting of the measuring wheel. It is the instrument to verify the effectiveness of the lubrication of gage face of rails.

The biggest disadvantage of this device is the limited length of track that is evaluated, because as the readings are made by an operator pushing the equipment, not every length of track is measured, so the result is only a "snapshot". (Eadie, D.; *et al*, 2002).

Regular measurements of COF along the network are performed quarterly to verify the effectiveness of the gage face lubrication.

Figure 11: Measurement of COF using Tribometer.

6.2. Miniprof Rail

The digital rail profilometer is used to measure the wear rate of the rails. It is a device with high accuracy, manufactured by Greenwood Engineering, which consists of a reading head of the rail profile and a hand-held computer.

The wear on the gage face and the top of rail provide an indication of long-term effectiveness of the control of friction. Short periods of friction modifier application will not affect the long terms wear.

Figure 12: Rail Miniprof for rail wear monitoring.

Measurements of profiles of the rails are always performed before and after the grinding cycle, and the natural wear and artificial wear are identified. The wear rate is related with MTBT, thereby obtaining rate in mm / MTBT.

6.3. L/V Instrumentation

The instrumentation system used to monitor L/V forces in MRS Logística is manufactured by ISI. It uses strain gages installed in web and base of rails, where it measures vertical and lateral forces respectively. The system is complex and wayside based.

It is used to measure the effectiveness of the application of friction modifier, because as the product remains in greater quantity on the tread of the wheels, we cannot know the COF obtained after wayside application of friction modifier through direct measurements.

The magnitude of the lateral force is specific to each curve and is dependent on several parameters, including wheel and rail profiles, the track condition, conditions of fastening and sleepers, train speed, axle load and friction level.

Figure 13: L/V Wayside Instrumentation.

7. RESULTS

7.1. Rail Wear Rates

The graphs below show the efficiency of Friction Management Project at MRS Logística. All critical performance indicators of the project showed overwhelming savings, among them: wear rate in gage face and the vertical wear rate of high and low rails.

As expected, huge reduction of lateral wear rate (88% less) was achieved in sharp curves (R<350m). Mild and moderate curve also showed reduction.

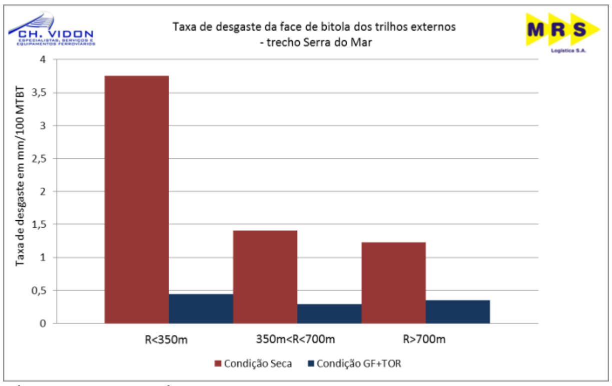


Figure 14: Lateral wear rates.

Some reduction was observed on vertical wear rates of high rail.

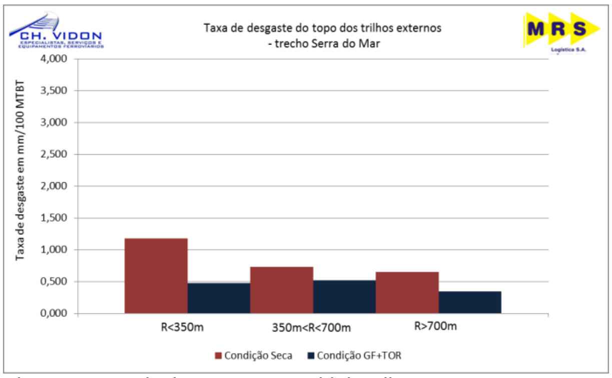


Figure 15: Vertical wear rates on high rails.

The largest reduction in vertical wear rates were on low rails of sharp curves. This result clearly demonstrates the effectiveness of using friction modifier on top of rail. Sharp curves exhibit significant savings in low rail wear as creep forces are controlled using friction modifier.

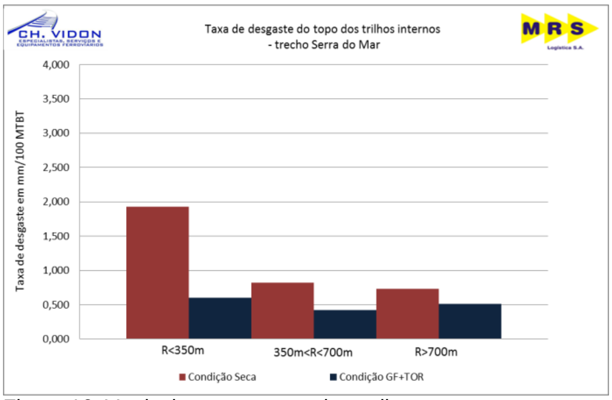


Figure 16: Vertical wear rates on low rails.

Also, according to analysis, it is possible to identify that rail curvature is a determining factor in the issue of the placement of the units.

7.2. COF

The measuring the friction coefficient during the evaluation and implementation of the project Achieving excellent results.Targets were achieved; demonstrating a balanced distribution of equipment along the MRS system. Thus, the coefficient of friction levels are achieved with minimum use of material without generating large operational impacts.

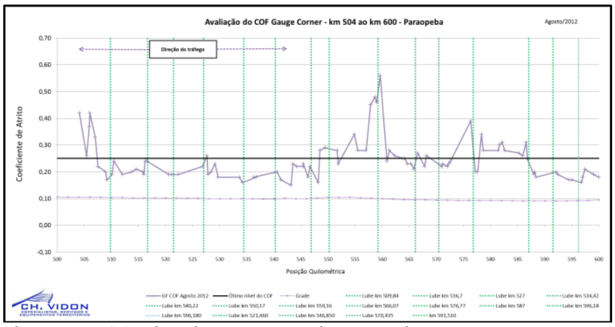


Figure 17: COF levels at Paraopeba Branch.

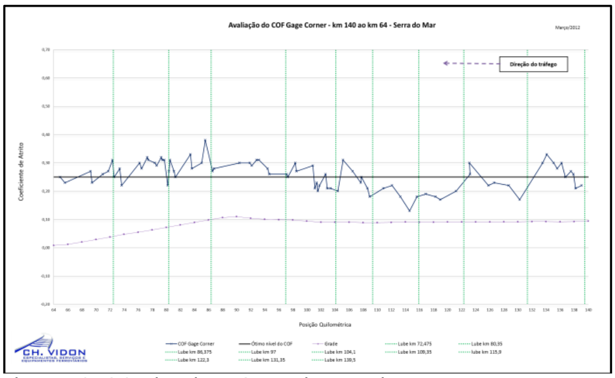


Figure 18: COF levels at Serra do Mar Line.

8. CONCLUSIONS

Friction Management has been successfully applied in major North American Class 1 railroads. In 2011 MRS Logística expanded its project with the deployment of a large-scale project, 86 gage face lubricators and 77 friction modifier applicators having the ultimate goal of protecting 629 km of the railway.

Up to this time 78 of the 163 equipments are installed. The installation of the Centre Line and North Front of Steel Line are underway. The completion of the Center Line is scheduled for early 2013.

Initial measurements using the tribometer, and readings Miniprof L / V were carried out with the purpose of establishing a baseline for comparison of benefits. The results will be presented at a later date.

Measurements for monitoring and evaluating the Friction Management program are taken periodically. Lateral force data will be evaluated as enough data is collected.

Some improvements are being added, such as upgrade units placed in sidings for both lines, re-spacement of unit in heavy down grade areas and testing new KELTRACK ER, friction modifier that has enhanced retentivity and carrydown.

The pioneering deployment of Friction Management in Brazil has achieved the expected results, so MRS is able to reduce operating costs and increase the availability of its railway network.

9. ACKNOWLEDGEMENTS

The authors thank MRS Logistica S.A. to allow engineer team to seek new technologies and techniques to apply into MRS network. They also thank the staff of Permanent Way Engineering, CH.Vidon, LB Foster who spares no efforts to solve everyday problems and seek to improve processes, contributing to the development of the MRS also occur.

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