WHEEL / RAIL FRICTION MANAGEMENT SOLUTIONS

NÁZOV PRÍSPEVKU

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1 INTRODUCTION

Grease or oil has traditionally been used to reduce friction in the gage face / flange area. There are some well defined problems with the use of these hydrocarbon products: in particular, grease and oil migrate to the railhead causing low friction, which generates wheel flats, rail burns and poor adhesion. Other problems involve cleanliness, safety, and environmental issues.

Wheels and rails are often contaminated with water, grease, coal, grain, sand, dust, wear debris etc. These contaminants invariably change the friction between wheel and rail. Some contaminants (e.g. iron oxide and sand) will increase friction, whereas others decrease friction (e.g. grease, coal and water). Inadequate friction can result in disasters. For example, low friction can cause poor braking. High friction on the gauge face / flange can cause low speed wheel climb derailments. Friction also causes numerous damaging effects. Abrasive wear, plastic flow, corrugation, shelling and spalling are obvious forms to wheel and rail rolling contacts. High friction, in particular, causes severe wear plastic flow and fatigue.

Optimising friction at the wheel/rail interface may require either higher or lower friction, depending on the specific situation. For example, locomotives need high friction to increase draw bar forces and provide greater tractive effort. Low friction is required in tangent track areas and at the rail flange to reduce wears and save energy. It is clear that friction in the wheel/rail interface should be controlled for optimal results.

To increase adhesion, sand is often used to override grease and contaminants, and to increase low friction on the railhead. Sand against steel has negative friction, which causes problems we shall review later. As a result of these constraints, dispatch adhesion is often limited because of varying frictional conditions. In combination, grease and sand form a paste which has detrimental grinding characteristics, increasing the wear rate in the gauge face/flange area.

Kalousek **[1,2]** has reviewed the very different mechanisms of friction, adhesion and lubrication as they occur at the interfaces of the wheel tread / rail top and the wheel flange / side of the rail. The tread / top is subject to both fretting and oxidative wear. Wheel tread / rail top wear is caused by very small displacements of motion typically in the range 1 to 150 microns. The small relative motion generates wear debris consisting of fine plate-like particles (0.01 to 2 microns). Most of these particles are oxidized to various forms of iron oxide, depending on environemental conditions. The variations in iron oxide chemistry as a result of weather variability appears to play a significant role in frictional variations, although this area needs better understanding at a fundamental level. The wheel flange / rail gauge face is subject to sliding with slip between the surfaces ranging from 0.5 to 10 mm. Large plate-like particles up to 2 mm are generated in the

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absence of lubrication. This leads to high friction (0.4-0.6), rough flange and gauge side surfaces, and high wear rates.

This paper reviews new technology that offers the opportunity to control friction levels on the railhead at 0.40 or higher and 0.20 or lower at the gauge face / flange area throughout the run.

2 FRICTION MANAGEMENT CONCEPTS

Friction Management is the ability to control friction at the rail / wheel interface at levels between 0.06 and up to 0.60 and, when desirable, allows the type of friction to be changed from negative to positive. Friction modifiers are materials which can have low friction, high positive friction, very high positive friction or flat friction, depending on the requirement. Technology is available to manage the friction between 0.06 to 0.60 at whatever level within this range is desired. The wheel / rail interface is separated by a film of wear debris and contaminants. Successful friction management introduces solids into the wheel / rail interface with well defined frictional properties in appropriate quantities which modify the frictional characteristics of this layer.

2.1 Positive and negative friction

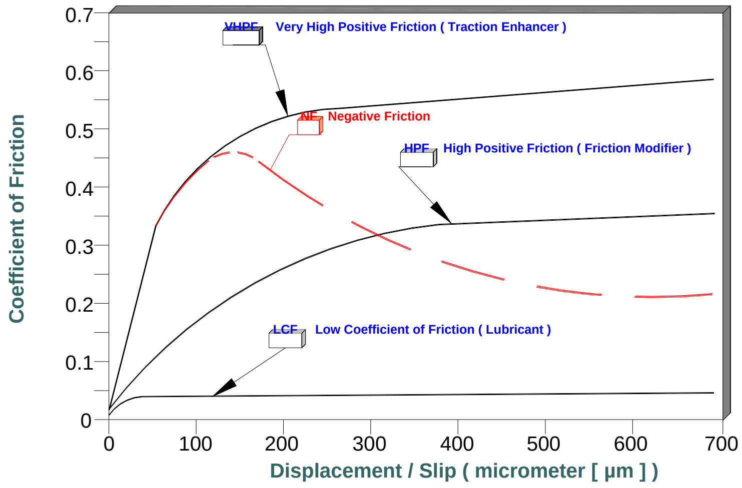
The concepts of positive and negative friction are critical to understanding the underpinning of friction management solutions. Shearing or rolling of the layer between the wheel and the rail occurs to accommodate the velocity difference between the two surfaces. When the layer reaches its critical shear strength, displacement (slip) occurs along the weakest plane.

Fundamentally, positive or negative friction results when the shear plastic modulus either increases or decreases with increasing shear rate. More simply, consider that with positive friction the coefficient of friction increases with creep; conversely for negative friction the coefficient of friction decreases with creep. Many of the material combinations commonly found in the wheel rail interface layer have negative friction. The dashed line in ***Figure 1*** shows negative friction, commonly found between the wheel and rail today. Either steel on steel or sand in the interface initially has a positive friction, but quickly change to negative friction when the creep curve is saturated. Negative friction is the fundamental requirement for the occurrence of the stick-slip phenomenon, and is a poor condition for adhesion. Introducing material with a positive friction characteristic between the wheel and the rail is a central component of an effective Friction Management program.

2.2 Friction characteristics of LCF, HPF and VHPF

Figure 1 illustrates the frictional characteristics of three different friction management products compared to steel on steel (dashed line) under different creep conditions. LCF is a dry solid stick lubricant that maintains the coefficient of friction below 0.1 over a wide range of creep conditions. It is applied to the wheel flange, and because of its dry solid nature does not migrate to the wheel tread or the top of the rail. HPF is a friction modifier with positive friction characteristics that maintains coefficient of friction from 0.17 to 0.35 depending on creep conditions, and is applied to the wheel tread. VHPF provides very high positive friction (up to 0.6) that can effectively increase traction. It is typically applied to the wheel tread on locomotives.

Fig 1 Friction characteristics of different friction management products



These materials in all cases transfer from the wheel to the appropriate part of the rail. In the case of LCF the dry material migrates from the wheel flange to the rail gauge face, but does not (unlike traditional petroleum based products) migrate to the rail head.

2.3 Application Methods

The solid lubricants and friction modifiers described are applied using a reliable bracket and applicator system tailored to the particular application. The stick is pressed against either the wheel flange (in the case of solid lubricants) or against the wheel tread in the case of solid friction modifiers. As the stick wears a constant force spring maintains an even load.

Liquid versions of the products are also used in cases where this better fits the application. On-board systems are currently under development with several major equipment vendors to apply the liquid product in a controlled and accurate manner. It is expected that this method will be particularly suitable for trains that typically have long service intervals, such as North American Class 1 Railroads. Other alternatives that are available or under development include hand held application methods, application from a “Hi Rail” vehicle, and application from modified wayside applicators.

A radically different application method currently in development involves positive friction management brake shoes. These are being developed in partnership with a major brake shoe manufacturer.

Conditioning is an important concept in optimising application of friction management solutions. A system is conditioned when both the wheel and rail are coated with lubricant or friction modifier at a film thickness of approximately 5 microns. This is achieved through film transfer from either the wheel to rail, in the case of solid sticks, or rail to wheel, in the case of liquids applied to the rail. Saturation is sufficient product in the wheel rail interface to override the effect of contaminants such as leaves, sand and rust. By saturating the system the friction levels remain constant and give the rail operator the maximum benefits of friction management. Saturation with solid sticks is generally achieved when solid sticks are applied to 25% of the wheels.

3. RESULTS WITH FRICTION MANAGEMENT SYSTEMS

Following are presented a series of examples to demonstrate the effect of friction management on various wheel rail related problems. While friction management is an effective solution to many wheel / rail problems, it is important to recognise that this approach is complementary to a proper wheel / rail profiling program. While Friction Management alone can provide the substantial benefits, the optimum solution will usually involve both technologies properly applied.

3.1 Friction levels

Table 1 shows frictional data from an AAR/TTCI test. It shows that use of HPF Friction Modifier applied to the top of the rail reduces friction from 0.60 to 0.35. The HPF Friction Modifier holds friction levels on both rails at this level and changes the friction from negative to positive which does not interfere with the locomotive adhesion or braking.

TABLE 1 AAR / TTCI Top Of Rail Friction Measurements

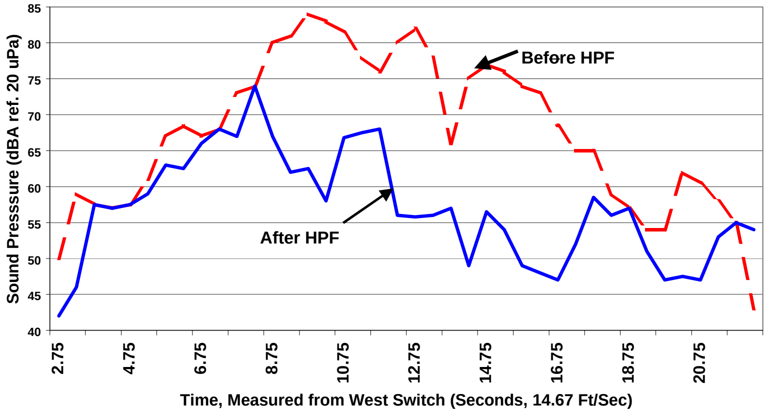
Rail Condition*	***High Rail***	***Low Rail***
Dry	0.50	0.60
Dry	0.60	0.60
HPF	0.60	0.40
HPF	0.53	0.43
HPF	0.47	0.40
HPF	0.43	0.40
HPF	0.35	0.33
HPF	0.36	0.34
HPF	0.35	0.36

*7.5 degree curve, sequential laps, AAR/TTCI WRM circuit

3.2 Effect on noise levels

Noise can be a significant problem for rail systems operating close to residential neighbouthoods. In North America railroads have faced major lawsuits by residents as a result of noise. The major cause of noise is not wheel flange / rail interaction as is commonly believed. Rather 80% of noise is typically a result of top of rail effects such as stick-slip. Application of HPF with positive friction characteristics to the wheel tread is an effective approach to mitigating this problem. One of many examples of this is shown in ***Figure 2,*** which illustrates results from an on-line noise test carried out by Navcon Engineering Network on the Sacramento Regional Transit District Light Rail System. In this case noise readings are shown before and after the application of the HPF Friction Modifier. A significant reduction in noise level is apparent.

Fig 2 Noise reduction, Sacramento trial



3.3 Effect on energy reduction

Two trial results illustrate the energy benefits achievable with different types of friction management:

A) Top of Rail friction modifier

Table 2 illustrates the energy savings achievable with the friction management system on the top of the rail. In this case liquid HPF was applied to the top of the rail using an on-board system on the locomotive. The test achieved mechanical energy savings of 13.3% and electrical energy savings of 13.5% with the friction management approach. These results were obtained at an AAR/TTCI evaluation using a 5.3 km closed loop test track. It should be noted that these results are relevant only for this specific system. Energy reduction for other cases could be higher or lower, depending on specific circumstances such as curvature and the grade of the track

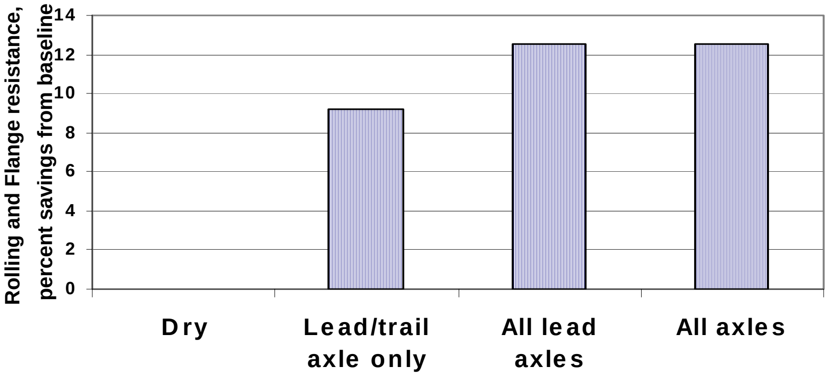
Table 2. *Energy reduction with liquid HPF, on-board application*

	Average speed, km/hr	**Coupler force, kN**	**Mechanical, kWh**	**Electrical, kWk**
Dry	48.1	185.5	324	360
Friction modifier	50.1	152.3	281	311
		Percent energy reduction:	**13.3**	**13.5**

B) Flange lubrication with solid LCF

Fig 3 shows energy savings for solid stick flange lubrication with Kelsan LCF. In this case top of rail friction modifier was not employed. These figures refer to locomotive savings only (tractive effort only), and do not show coupler savings, which include buff forces.

Fig 3 Energy reduction, flange lubrication



A trial combining the two approaches is currently at the planning stage.

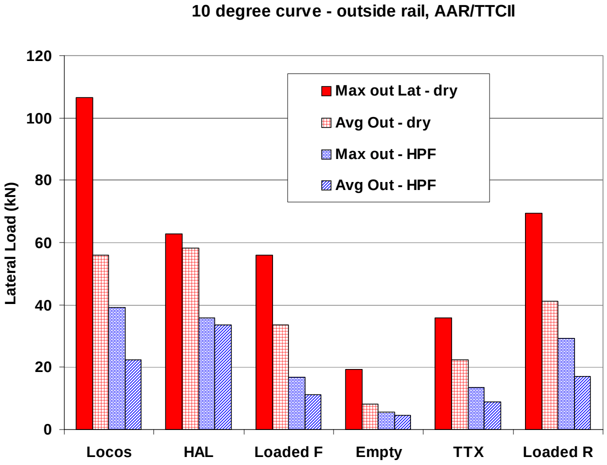
These results were obtained under similar experimental conditions to the top of rail trial, at the AAR/TTCI closed loop facility. The test used two GP30 locomotives pulling 32 loaded 90 tonne capactiy hopper cars at speeds from 40 to 64 km/hr. The test loop included curves of 3,4,5,7.5,10 and 12 degrees with short tangents between each curve.

3.4 Effect on lateral forces (L/V)

Control of friction offers the opportunity to mitigate high lateral forces, which can develop with non-steered or self-steered trucks in sharp curves. A combination of high friction and the wrong truck conditions can lead to low rail rollover derailments.

Figure 4 shows results from the AAR/TTCI WRM Loop in which lateral loads were measured. The peak lateral forces on the locomotive were as high as 102.3 kN at a friction level of 0.60 (dry rail) before the HPF friction modifier was applied. With HPF friction modifier applied, the friction level was reduced to 0.35 and the lateral forces were reduced to about 55.6 kN. Average loads were correspondingly reduced.

Fig 4 Effect of friction modifier on lateral loads



4 CONCLUSION AND OUTLOOK FOR THE FUTURE

A new approach to friction management offers the opportunity to reduce the negative effects caused by uncontrolled or inappropriate friction levels. These include noise, wheel wear, lateral forces, and vibration, among others. Key characteristics are the ability to reduce or increase coefficient of friction between the wheel and the rail, and to change the friction from negative to positive.

Our vision for the future of friction management in the railway industry includes:

- Lubrication on the locomotive flanges, rail car flanges, and gauge face / gauge corner will provide a friction level of 0.20 and below.
- Traction Enhancers on locomotive driving wheels will provide a friction of 0.40 – 0.45 or even higher, and positive, and used only when necessary.
- Friction management brake shoes for rail cars will provide a friction level of 0.17 to 0.35, with positive friction on the railhead and below 0.20 on the flange/gauge corner.
- Friction modifiers on top of the rail after the locomotive for rail car friction control will have positive friction levels in the range of 0.17 to 0.35. We envision systems with on-board high speed continuous friction measurments providing input into closed loop control system. The friction is controlled by accurate variable application rates for the friction modifiers and lubricants.

5. EXPERIMENTAL METHODS AND PROCEDURES

Top of rail and flange face friction was measured with a Salient tribometer.

Frictional characteristics of the materials described were measured with a rheometer at the Canadian National Research Council Centre for Surface Transportation. This rheometer can be used to measure the shear stress characteristic against displacement characteristic for different interfacial layers at varying loads. A compressed powder layer on an anvil is sheared between two stationary pins, loaded against the anvil when the anvil is rotating. The torque, load and rotation angles are measured and recorded by a computer and data is converted as shear stress, normal pressure and displacement.

References

[1] Kalousek, J.: Lubrication: Its various types and effects on rail/wheel forces and wear. Proceedings: Rail and Wheel Lubrication Symposium, Memphis 1981

[2] Kalousek, J.: Friction, Adhesion and Lubrication, Advanced Rail Management Seminar – Session #8, Chicago 1996

Summary

Frictional characteristics of the wheel / rail interface have a major impact on issues such as wheel wear rates, noise, energy consumption, and traction. Contaminants such as iron oxides play a significant role in variable and uncontrolled friction levels. Friction needs to be controlled for optimal system performance - a process we describe as Friction Management. Technology is described to reduce or increase friction through the use of solid, non-hydrocarbon lubricants and friction modifiers. An important feature is the ability to change friction in the wheel / rail interface from negative to positive friction. Negative friction is an underlying cause of stick-slip, which causes excessive noise and premature wheel and rail wear. Examples are reviewed of the impact of friction management on friction levels, noise, energy consumption, and lateral forces. Finally, a future vision is presented of emerging and future friction management concepts.