

WHEEL FLANGE LUBRICATION – LINKING UP SAFETY & SAVINGS

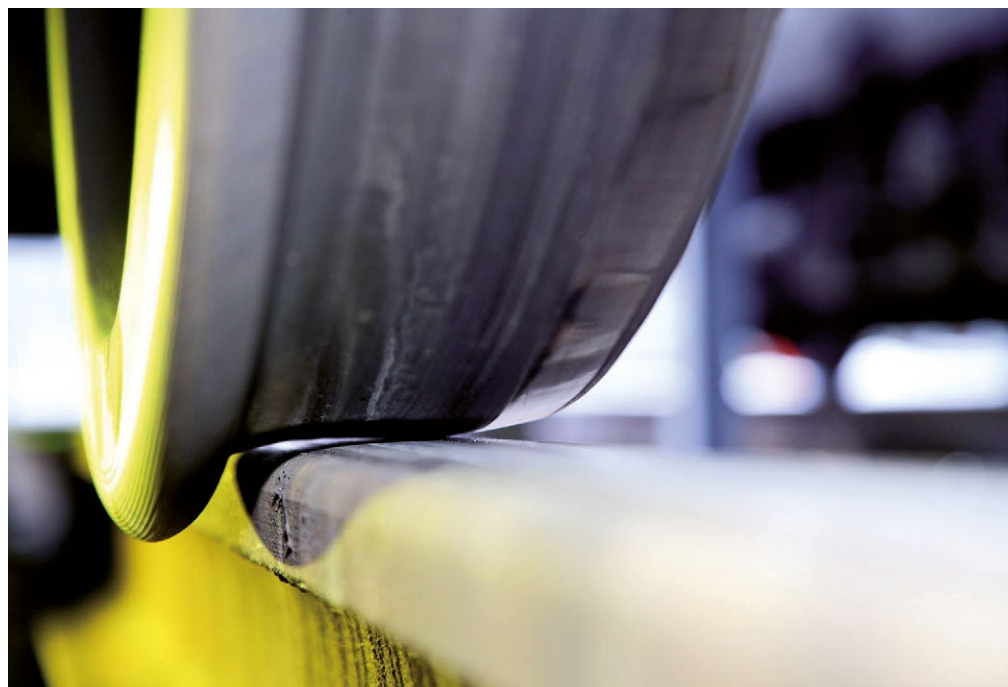
MUCH RIDES ON THE RAIL-WHEEL CONTACT. YET IT IS IMPORTANT TO DISTINGUISH BETWEEN CONTACT ON THE TREAD, WHICH TRANSMITS THE POWER AND ASSURES STABILITY, AND THAT ON THE FLANGE, WHICH GUIDES ROLLING STOCK OVER SHORT RADIUS CURVES AND POINTS.

The contact exerted on the wheel tread is permanent, and its surface less than one square centimetre, i.e. around that of a 10 euro centime coin; the contact on the flange is infrequent, and its surface area less than that of a one euro cent coin. Yet every day, on this tiny zone, depend the lives of millions of passengers across the globe. It is essential that the wheel flange does not ride up the rail head; nor must the wheel exert stress to such an extent that it causes the rail to skid.

In theory, the flange does not intervene when the axle takes curves. But in the case of short radius curves, or a significant centrifugal force, the flange may enter into contact with the inner side of the exterior/outer rail to generate, on the one hand, significant lateral stress, and, on the other, rapid wear of the flange. The main factors influencing this contact stress are as follows:

- the curve radius
- the suitability for running the trains, e.g. centres of the pivotal points, wheel base of the bogie, and rotation couple
- insufficient incline
- contact geometry, which depends on the rail and wheel profiles
- lubrication conditions of the wheel-rail contact

Taking into account the limited applicable sides/dimensions of wheels during reprofiling and



operating[1], and given that almost three millimetres of tread needs to be machined (i.e. removing the equivalent in kilometres of nearly six millimetres from the wheel diameter) to correct one millimetre of flange during wheel reprofiling, explains why too rapid wear of the flange represents a loss for train operating companies.

Yet the only, easy preventive measure is to lubricate the wheel-rail contact.

THE STAKES AT PLAY

When a train takes a curve, significant lateral stress is exerted on the wheel-rail contact of the front axle of the bogie.

In terms of safety, this lateral stress is one of the causes of derailments at low speeds on narrow curves, due to the wheel riding up the rail (derailment to the left of the track).

In economic terms, this stress is considered the main cause of the following symptoms:

- rolling stock: wheel flange wear (one millimetre of flange is equal to around three millimetres of tread, i.e. nearly six millimetres of the wheel diameter)
- infrastructure: lateral wear of the outer rail, and undular wear of the inner

Many studies have revealed that a rail on a curve that is not lubricated can cope with

200 million tonnes of traffic before being withdrawn from service; and that the same rail, if lubricated, could handle up to 800 million tonnes.

In terms of energy, lateral stress plays a part in environmental performance by reducing the carbon footprint (CO₂ emissions) of locomotives. This is because the dynamic friction coefficient at the top of the inner rail is closely linked to lateral stress. Consequently it influences the traction effort required to move bogies, and *a fortiori* a train, and so has a direct impact on energy consumption.

Lateral stress also impacts squeal generated by the track.

Possible problems linked to ground pollution can be limited by using eco-compatible lubricants, i.e. which are biodegradable and non-toxic.

Pricing matters

For each of the four points above, an economic study (carried out summarily by SNCF Centre d'Ingénierie du Matériel, CIM) reveals the potential benefits to be gained from lubricating the wheel-rail contact. Over time, it is likely that European infrastructure managers (IM) will transpose these points into their requirements issued to train operators.

For the IM, this will probably take the form of a multiplying coefficient factor, to be used when calculating the track charges, which will include aggression or wear of the rolling stock *vis-à-vis* the infrastructure, energy consumed, and so forth.

In October 2011, German IM Deutsche Bahn (DB) introduced a coefficient for noise pollution to its calculation table. Meanwhile in France, IM Réseau Ferré de France (RFF) is currently drawing up a table that takes aggressive parameters into account.

Taking this approach one step further, one could envisage a price scale that considers the level of aggression exerted by each locomotive and its trucks/coaches, based on their distinctive features (anti-slip and -slide equipment, torque of the bogie, etc.); the self sufficiency of

the convoy; and type of lubricant (eco-compatible, or not). All these parameters could be taken into account in the calculation table for track slot pricing.

For train operators, the stakes differ depending on whether they are transporting passengers or goods. In western Europe, the majority of passenger rail operators have acquired modern rolling stock capable of running at speeds of between 160 to 200km/hr, or even higher. These trains are generally delivered from the factory already equipped with a lubricating system for the wheel-rail contact.

For freight operators, the situation is different. Their rolling stock is ageing (according to estimates, around 60% of Europe's wagon fleet is over 30 years old), and incapable of running at speeds in excess of 100 to 120km/hr. This factor complicates the sharing of tracks with faster running passenger trains. As a consequence, both the journey and path occupancy times increase, while the possibilities of reusing equipment are greatly reduced.

A freight convoy crossing Europe spends around one third of its time in shunting yards, waiting for the necessary authorisation to circulate. Given this situation, the next generation of goods trains will undoubtedly be the object of radical changes to enable them to operate at speeds of 160 to

200km/hr, to lessen their levels of aggression *vis-à-vis* the infrastructure, and reduce the traction power required by lowering the friction coefficient.

Since the first railway line entered into commercial service up to the present day, experts have explored many avenues in the search to alleviate, or limit wear on the wheel flange.

SOME BACKGROUND

Following trials carried out by Richard Trevithick and Andrew Vivian, in February 1804, the world's first commercial railway line, between Liverpool and

Manchester (U.K.), was inaugurated on September 15, 1830. In 1845, to limit rail wear, curves were lubricated with a brush. But it was impossible to put an agent at every curve.

In 1857, Virginian Railways (North America) appear to have been the first network to try and reduce wheel wear by means of an on-board system: a sponge soaked in oil. Derisory and archaic though it may seem, this method was the first on-board lubrication system for the wheel-rail contact. At the end of the 19th century, several solutions were put to the test, of which:

- lubrication with an apparatus con-

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trolled by the train driver, used in 1890 by the French Compagnie d'Orléans (principle derived from the Jacmin method)

- a graphite paste developed by the German firm Halberstadt-Blankenburg in 1899
- injected water, first employed in 1898 by the French Compagnie d'Anjou[2]

In 1927, the Compagnie d'Orléans tested a rail lubricating system (the Lubrovia) with two defining features – it only functioned on track curves, and only lubricated the outer rail[3].

Use of this system extended to all the locomotives in the Réseau Midi (railway network in the south of France); and subsequently grew due to the widescale electrification of railway lines after World War II, coupled with the introduction of the new generation of so-called 'total adherence' locomotives, which required re-profiling every 15,000 to 20,00 kilometres. Thanks to their pendulum control, rail lubricating equipment, it was now possible to permit to space interventions on the wheel to an average of 180,000km[4]. Moreover, according to estimates, the traction effort needed was reduced by some 20%[5], while the life cycle of the rail doubled.

There were few further developments until the 1960s. This period of great change saw the development of high-speed rail, and the first commercial traffic at 250km/hr – first in Japan with the Shinkansen, followed

by France with the TGV SE, and then by Germany with the ICE. At these higher speeds, the rail lubricating system is overexposed to turbulence, rendering it totally inefficient. All the lubricant is projected onto the bogies and under the coach/wagon bodies. Indeed, at speeds exceeding 120km/hr, almost 60% of the lubricant ejected by the rail lubricating system fails to reach the rail.

The advent of higher commercial speeds, marked the demise of the rail lubricating system. It was replaced by the wheel flange lubricating system, commonly known as the 'flange lubricator'.

SOME TECHNICAL DETAILS

Trials carried out by Japan Railways (JR) and SNCF CIM demonstrate that due to the conicity of the wheel profiles and the track incline at curves, only the steering axle of a bogie needs to be lubricated.

In this section of the article we will focus on systems installed on rolling stock in service, namely the rail, flange, and stick lubricators.

Rail lubricator

The system only functions when the rolling speed is travelling at speeds equal or higher than four to five kilometres/hour. It comprises a tank that supplies (by gravity) two spray nozzles located on either side of the bogie.



Position of the spray guns

When the train takes a curve, a control, either mechanical (rods) or electric, activates the spray nozzle installed on the outer rail. The spray guns work by sucking up oil by passing compressed air in a tailpipe. A buse directs the jet onto the rail. The throughput is 15 or 25 grammes/minute, depending on the calibration of the adjustment valve. The significant consumption of such a system necessitates, on the one hand, the use of cheap lubricant, and on the other, a large capacity tank (around 100 litres).

For the system to be more efficient and guarantee the same level of lubrication in the two directions of traffic/travel, the spray guns need to be located as close as possible to the rail, and positioned in the middle of the wheel base of the bogies, at an equal distance from the two wheels. Due to this extremely low and central position, the spray nozzles are unfortunately exposed to impacts such as flying ballast.

Moreover, due to their position in the middle of the bogie spar, the spray nozzles have to be adjusted for an average curve radius. In these conditions, the greater the wheel base of the bogie and smaller the curve radius, the greater the likelihood of lubricating the inner side of the rail. *A contrario*, if the wheel tread of the bogie is small and the curve radius large, the rail tread can be lubricated.

According to our estimates, the rail lubricator ensures lubrication for the passage of around 300 axles, depending on the following two conditions:

- that the operating speed does not exceed 60km/hr (above this, air movement interferes with the spraying action, rendering it pretty much inoperable at 140km/hr)
- that the oil, which generally has low adhesivity, is not washed away by rain

Flange lubricating system

Similar to the rail lubricator, the flange lubricating system

functions only when operating speeds are equal to or faster than four to five kilometres/hour. It comprises a tank (with a capacity of around 15 to 20 litres), a distributing pump, between two to four ejectors, plus, in some cases, a distributor-diffuser (depending on the technology employed). The throughput ranges from 0.04 to 0.1cm³ of lubricant per ejector, per impulsion. The system is controlled by an electronic device installed on the train, which activates electrovalves for five seconds, at regular intervals. This piece of equipment is controlled either depending on the distance travelled, e.g. one impulsion every X metres, or on time, e.g. one impulsion every X seconds.

The operation of this equipment can be adapted according to the line profile and/or the direction of travel of the rolling stock.

Following tests carried out in 1975, on the Maurienne line (between Culoz and Modane, Rhône-Alpes region of France). SNCF estimated that a flange lubricating system guarantees lubrication for the passage of around 8 to 10 bogies, up to operating speeds of 270km/hr. In order to ensure the system performs efficiently, and to avoid the lubricant deposited on the wheel by centrifugation being projected on the bogie and under the coach/wagon body, the ejectors must be positioned as close as possible to the wheel-rail contact. However, given the cluttered environment around the wheel, installing the ejector is sometimes difficult, which hinders its maintenance and adjustment.

Up to 1980-1990, most locomotives were equipped with



▼ The ejectors must be positioned as close as possible to the wheel-rail contact



a 'bi-tube' system, with one tube canalisation for air and another for the lubricant. Since then, and for economic reasons, all new trains have been progressively delivered with a mono-tube system, whereby the air and lubricant pass through the same tube. The lubricant forms a film on the wall of the tube, and progresses in successive waves, propelled by air at each spray action.

Lubricating stick

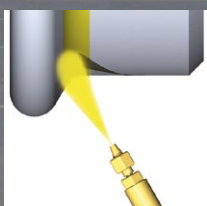
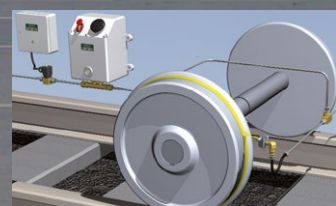
Comprising just a tappet spring and a charger. The lubricant, usually rectangular, comes either in the form of a stick, or hollow 'tips' that slot into each other.

The advantages of this system are that it is autonomous, and requires no source of external energy. But on the downside, there are two inconveniences:

Wear free throughout the curves!

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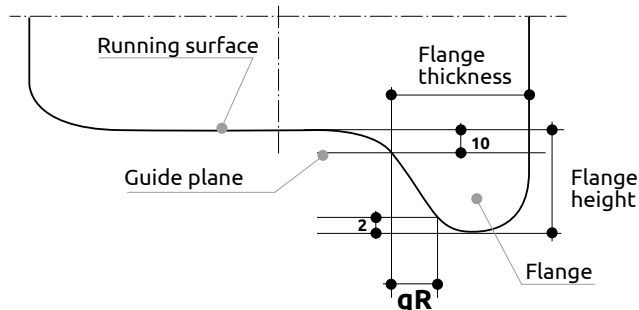


REBS Zentralschmiertechnik GmbH
Duisburger Strasse 115 • 40885 Ratingen, Germany
Telephone +49 (0) 2102 9306-0 • Telefax +49 (0) 2102 9306-40
www.rebs.de • info@rebs.de

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Stick (left), or hollow 'tips'



The study involved comparing qR developments

the stick remains in permanent contact, which means that large quantities are used, plus it is impossible (or difficult) to adjust the lubricating parameters to meet traffic conditions.

This system is widely used on freight trains in North America, as well as on tram and metro cars – rolling stock for which pneumatic energy is reserved exclusively for the braking system.

Note that lubricating sticks were used on the Eurostar trains (originally baptised the Transmanche Speed Train, TMST) since 1999 because the British railway network was only lubricated at the entry/exit points of main

stations by fixed systems installed on the platform edges. And this resulted in considerable wheel wear when operating on the rest of the national network. Although these trains are equipped with a flange lubricating system, alone it cannot compensate this wear due to its minimal setting. The latter is necessary to reduce the amount of lubricant projected onto the sides of white passenger coaches travelling at high speeds.

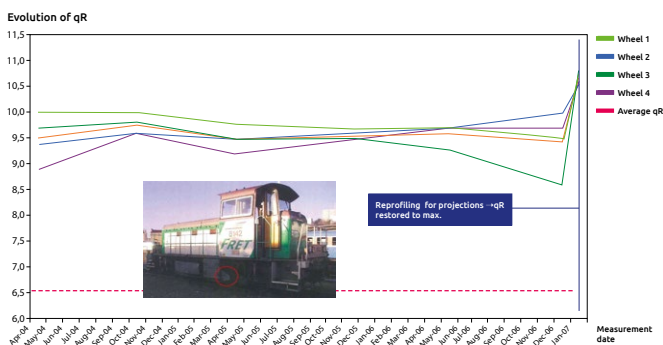
Now High Speed 1 (HS1) is in service (since 2007, running between the Channel Tunnel and London St Pancras) the Eurostar fleet operates mainly on this line.

RESULTS OF COMPARATIVE TRIALS & NUMERICAL DATA

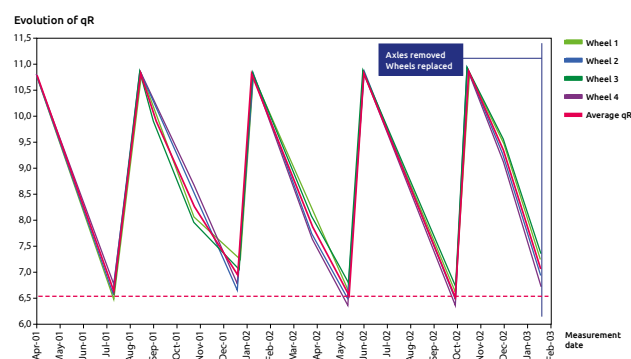
Many trials performed at high speeds have demonstrated that the wheel flange almost never touches the inner side of the rail when operating on HSLs (track more or less aligned, or with extremely large radius curves). Consequently, lubrication is not essential. This explains why the TGV *Sud Est* (the first generation TGV platform, in service since 1981) was not originally equipped with this type of system. For other traffic, especially those operating at low speeds and on sinuous lines, lubrication of the wheel flange is vital

– to avoid excessive reprofiling of the wheels and protect the infrastructure.

Besides, it is possible to pinpoint the benefits of one system compared to another, or the difference in efficiency between two lubricants. So as not to confuse the results of such studies, it is imperative that only rolling stock with the equipment under scrutiny is operated. Respecting this crucial criterion, SNCF has performed two test runs, in order to establish the economic interest of lubricating the wheel-rail contact (Y8000 shunter), and to compare the efficiency of two systems (X74500 railcar).



Y 8000 spray gun



Y 8000 without spray gun