Implementation of Gauge Face Lubrication on Mountainous Tracks on Indian Railways

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With the increase in axle load, stresses on rails particularly in contact patch increase. A multi-pronged strategy to minimise the effects of high contact stresses and creep forces has to be adopted to mitigate the effects. Rail lubrication with or without rail grinding and Implementation of an effective Ultrasonic testing regime is one of the most effective ways to keep the damages at the minimum. Lubrication, both gauge face and Top of rail to reduce friction and minimise the damage due to high friction and creep forces in the rail wheel contact areas leads to increased rail/ wheel life due to less wear. This also results in saving in energy consumption. Indian Railways recently installed 12 Way side, Gauge Face Lubricators which have given encouraging results in reducing gauge face wear. This paper touches upon the type of lubricators, lubricant, their performance and future of rail lubrication in India.

1. Introduction:

Friction plays a major role in rail wheel interaction, particularly in adhesion, braking, wear and rolling contact fatigue damage, formation of wheel burns, steering and hunting of locomotive and wagon bogies, and wheel climb/ mount leading to derailment.

World over, railways have been applying lubrication to the wheel/rail interface for many years to control wheel and rail wear, reduce lateral forces in curves and produce substantial savings in train energy (fuel) consumption. The traditional method of applying lubricant to the rail was by means of wayside lubricators.

The importance of lubrication has increased as axle loads and train mass have increased. The increasing axle loads and productivity requirements to increase the tonnage of railways heavily influence rail and wheel wear. In recent years substantial improvements in wayside equipment technology has improved equipment reliability, reduced maintenance requirements, increased the coverage provided by each lubricator and minimized wastage of the lubricant.

2. Benefits of Effective Rail Lubrication

2.1. Effective rail lubrication leads to reduction of gauge face wear in rails and flange wear in wheels. As a result, life of wheels and rails increases. The benefits of lubrication include:

- Reduction of fuel/energy consumption associated with wheel/rail interaction.
- Reduction in noise associated with wheel/rail interaction.

2.2. Wear rate of rail gauge face as well as of wheel flange increases with increasing degree of curvature as shown below. An effective lubrication regime reduces the rate of wear substantially.

2.3. An optimal lubrication system provides reduction in rail and wheel wear along with savings in energy, without causing harmful side effects like wheel slips and train stalling. Benefits from effective wheel and rail lubrication have been reported in many recent studies carried out on wayside lubricators and top of rail friction modifiers. Some of the reported benefits from effective lubrication are:

2.3.1. Tests on SPOORNET, South Africa, have demonstrated 51% reduction in energy required to traverse a 200 metre radius curve. Energy used by trains on the Richards Bay Coal Line reduced by more than 28% accompanied with a 6 fold increase in wheel life. (J.deKoker-1)

2.3.2. Tests carried out at FAST by TTCI have demonstrated a 30% reduction in fuel consumption with generous lubrication compared to dry conditions. Also numerous lubrication tests in the field on Class 1 railroads with long tangents, sharp curves and grades have demonstrated fuel savings of 5% to 15%. Also a lubricated top of low rail and generous high rail gauge face lubrication significantly reduces curve lateral forces. (Reiff-2)

2.3.3. NUCARS analysis carried out by TTCI has demonstrated energy savings of: 15% with wayside lubricators, 39% with Top of Rail friction modifiers alone and 65.5% with top of rail and good wheel flange (gauge face) lubrication.

2.3.4. Canadian Pacific Rail have found in recent studies that improved wayside lubrication with preventive rail grinding has increased rail life on average by 80% for the high rail gauge face and 50% for the high rail top surface. Canadian Pacific is working on top of low rail lubrication strategies to improve the life of the low rail.

3. Friction Management:

Friction Management is the process of controlling the frictional properties at the rail wheel interface to values that are most appropriate for the particular operating conditions. Friction management aims at:

- Lubrication of the gauge face of the rail to minimize friction, wear and curving resistance (μ between 0.1 and 0.25).
- Provide an intermediate friction coefficient (μ between 0.30 and 0.35) at the top of the rail to control lateral forces in curves, and rolling resistance in both curved and tangent track.
- Improve traction under driven locomotive wheels (and possibly under emergency braking situations) through the application of adhesion enhancers. Sand is most commonly used to improve adhesion.

4. Rail Lubrication Scenario in India:

In India, Rail & Flange (R&F) lubricators have been in use for long. These lubricators have a small tank of 1 to 2 litre capacity with a nozzle that oozes out grease as and when a wheel flange presses its actuator. These are not maintenance free and have mostly gone out of use. Most commonly used method had been manual application of graphite grease at a weekly or any other pre-determined frequency on the gauge face of outer rail in curves.

Inspired by the benefits reported by world railway systems, IR decided to give a trial to gauge face lubrication by installing Way side lubricators from tried and tested brand. RDSO took upon the responsibility of zeroing upon the manufacturer based on Techno economic bids.

4.1. Choice about Type of Lubrication System:

4.1.1. There are generally three types of lubrication systems:

4.1.1.1. Mobile lubricators apply lubricant to the gauge corner of the rail. There are many designs of applicators, from rail based automobile units to special cars.

4.1.1.2. Locomotive flange lubricators apply grease or solid lubricant to the wheel flange, which is then transferred to the gauge side of the railhead. The lubricant application is usually controlled on a wheel revolutions basis. The lubricant may be applied to either or both wheels. Grease is applied to the wheel through a nozzle. To avoid misaligned nozzles, an automatic control system is used. Wheel flange lubricators for solid lubricants use different application systems.

4.1.1.3. Wayside lubricators are normally of three types mechanically driven, hydraulically operated, or electrically operated. They all use various types of greases. These lubricators are installed on main line curves and at the entrance of stations.

4.1.2. Indian Railways decided to use Way side lubricators of hydraulic and electrically operated type. Based on a two packet system of tendering, an order was placed on Portec Rail Systems, USA, through their Indian representatives M/s Dynagro to supply, install and maintain 10 Way Side lubricators at 3 different sites on Indian Railways.

4.2. Choice of Lubricant:

4.2.1. In addition to meeting the basic requirements of providing lubrication to the contact surfaces at the given contact stresses, there are certain other requirements for lubricating materials, depending on climates and environment. These requirements are:

- It should be easy to apply lubricant to contact surfaces under conditions of high or low humidity.
- They should not be washed off by rain.
- They should withstand the ambient as well as rail temperature prevailing in the area.
- Also, the lubricant must be capable of withstanding the temperatures that are generated by wheel/rail interaction and braking.
- They should form a film between contacting surfaces and bring down friction considerably.
- They should get carried to longer distances along with wheel.
- Sand used to increase adhesion should not adhere to the lubricating material after its application.
- It should not be flammable, hazardous, or produce a harmful effect upon environment.

4.2.2. TTCI have carried out a number of tests on environment friendly **Soybean Oil Based rail Curve Grease** and concluded that it meets most of the above requirements. It was observed that:

- The Carry distance was 18% more than the Norfolk Southern standard petroleum track grease.
- The durability of the soybean oil-based grease as a film on the rail gauge face in the test site environment was notable.
- The soybean oil-based grease was observed to maintain a protective film of lubricant on the rail gauge face in steep gradients needing use of banking engines.
- The coefficient of friction for the soy oil grease application was measured in the 0.12 – 0.15 range while the petroleum product was measured in the in the 0.15 – 0.20 range.

These observations indicate that the soybean oil-based grease film is more durable than the standard petroleum grease.

4.2.3. The TTCI study has concluded, "With superior lubricity and reduced grease use, the overall cost of these bio based greases can reach those of current petroleum prices. To date over two dozen railroads in the United States use ABIL developed soybean oil-based grease. This grease was recently approved by Norfolk Southern, which has become the first Class 1 railroad to begin using the grease. Further use by this large railroad along with other smaller railroads should help show the economic and environmental benefits of these specialty bio based greases."

4.2.4. Considering the above findings, Portec Rail Systems offered competitive all inclusive prices for supplying and installing of equipment including free maintenance during one year warranty period, supply of lubricant and follow up annual maintenance for two years. As such, Bio based Soy Grease has been chosen for use with these lubricators in India.

5. The trial Sites:

5.1. Three trial sites were selected in difficult graded sections of Central, West Central and East Coast Railways, having tight curves. Due to their difficult topography all these sites have been recording high side wear rates with low rail life. Manual lubrication with indigenous grease has been in existence in all these three sections.

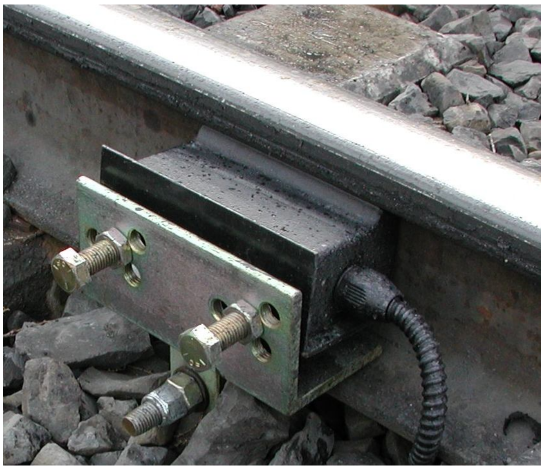
5.2. Total 12 Lubricators were procured. These were basically of 2 types; Hydraulic and Electronic. The electronic lubricator was electrically powered. These were further divided as Solar powered and electrically powered based on source of electricity. Distribution of the lubricators amongst the three sites was as under:

Sl No	Lubricator No	Lubricator type	Railway	Section	Up, Down or single line	Location
1.	SL # 3794	Hydraulic	ECOR	Borraguhalu – Karakvalsa	Single line	77/2-3
2.	SL # 3795	Hydraulic	ECOR	Boddavara – Sivalingapuram	Single line	40/28-29
3.	SL # 3795	Hydraulic	WCR	Buddni – Barkhera	Down line	773A/24
4.	SL # 3796	Hydraulic	WCR	Buddni – Barkhera	Down line	773C/36
5.	SL # 3797	Hydraulic	WCR	Buddni – Barkhera	Down line	779/20
6.	SL # 3798	Hydraulic	WCR	Buddni – Barkhera	Down line	773F/30-32
7.	SL # 5182	Electronic with Solar Power	WCR	Buddni – Barkhera	Down line	770/32
8.	SL # 5183	Electronic with Solar Power	WCR	Buddni – Barkhera	Down line	778/44-46
9.	SL # 5184	Electronic with Solar Power	WCR	Buddni – Barkhera	Down line	781/46-48
10.	SL # 5216	Electronic	CR	Karjat – Lonavala	Down Line	112/300
11.	SL # 5217	Electronic	CR	Karjat – Lonavala	Down Line	118/800
12.	SL # 5218	Electronic	CR	Karjat – Lonavala	Down Line	124/02

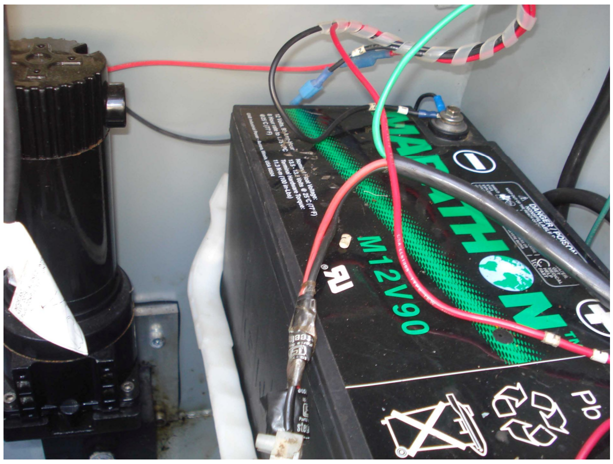
6. The Lubricators:

Total 12 lubricators were installed under the project, 6 each of hydraulic and Electronic type. Electronic type has distinct advantage over hydraulic type as they offer better control on flow of lubricant.

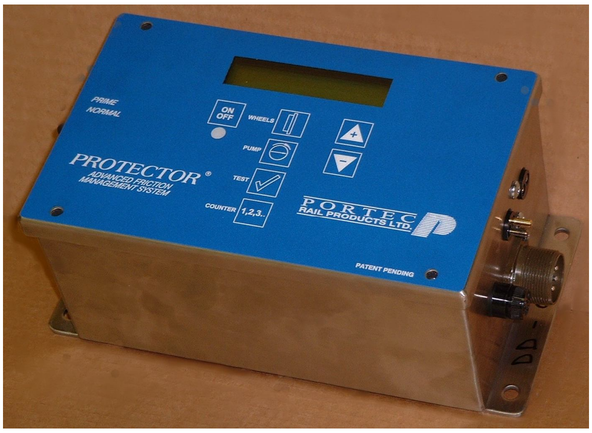
6.1. The system in Electronic Lubricator consists of a rail-mounted magnetic sensor, a control box, an AC to DC converter or solar-charged battery, a gear motor/pump, a tank with a hinged top, and a material distribution system of hoses and applicators attached to the rails.



Electromagnetic Wheel Sensor



Battery and Electric Pump



Control Box to control dispensation of lubricants in terms of fractions of sec per wheel

Box housing Battery, Electric Pump and control Box

6.2. The system operates as passing wheels enter the magnetic field of the rail-mounted sensor. The sensor transmits a signal back to the control box with every passing wheel. The control box counts the number of signals from the sensor and when the pre-selected total is reached, the control box turns on the pump for the pre-selected duration. The material is to be pumped through a main hose to a central distribution manifold where it splits into distribution hoses that connect to the multi-ported, applicators, clamped to the rail.

6.3. The product then travels to the dispensing ports of each applicator to deliver controlled amounts of product onto the rails. This product is then picked-up by passing train wheels. The applicators should be placed far enough apart to coat opposite quadrants of the passing wheels for optimum product distribution.

6.4. The applicator oozes out grease beads at the gauge face of the rail as shown in Fig below. These beads rise up towards the gauge corner on coming in contact with wheel flange. The wheel flange picks up the grease beads from rail face and carries the grease along, as shown in Fig below. The grease keeps rising between the contact surfaces of wheel flange and rail gauge face towards gauge corner. Controlled discharge of grease ensures that there is just enough grease to rise up to the gauge corner and there is no excess that may rise on to top of rail or which may fall off from bottom corner of gauge face. Grease has been noticed to be available on wheel flange even after a travel of 7 km.

Grease beads oozed out from applicator on the gauge face of rail.

Grease beads are picked up by wheel flange and carried down the track as the wheel moves on.

7. <u>Performance as Reported by Site Engineers:</u>

7.1. General observation about all the lubricators are as follows:

7.1.1. Friction measurements taken at all three sites for all 12 lubricators have shown the coefficient of friction (μ) to be in the range of 0.19 to 0.25. This is a good achievement over a μ value of 0.6 to 0.66 recorded for dry rail conditions.

7.1.2. The carry down of grease in the direction of traffic is varying from 1.5 Km to 3 Km.

7.1.3. Average grease consumption per month per lubricator is of the order of 16 to 18 kg.

7.1.4. Filling of Soy Grease is required once is three months.

7.1.5. Prior to installation of Lubricators, hand application of Grease Graphite was done, twice a day. These grease used to occasionally climb up to rail table, leading to stalling of loads. Now with the lubricator, grease is being applied on gauge corner in very small quantity. Therefore there is no grease climb on to the rail top. Accordingly, incident of wheel slip and stalling has come down considerably.

7.1.6. Uniform application of grease is being achieved, resulting in savings in the quantity of grease used.

7.1.7. Fixing arrangement of lubricator to the rails does not require any holes to be drilled in rails.

7.1.8. Considerable reduction in rail wear has been observed since installation of these lubricators. Wear of 60 Kg 90 UTS rails since their installation in 2007-08 is of the order of 2 to 3 mm in the territory covered by these lubricators. In rest of the stretches, not covered by these lubricators, lateral wear to the extent of 7 to 10 mm has been recorded.

7.2. Following performance has been reported for Lubricators provided in South East Ghat section of Central Railway in Karjat - Lonavala Section:

7.2.1. These lubricators require very little maintenance of the equipment.

7.2.2. Cleaning of applicators is required every month. This is because all the loads moving on this track are moving up the hill, requiring continuous sanding. The sand gets mixed up with Soy grease, gets hardened and blocks the nozzles of applicator.

7.2.3. For overhauling of applicator, cleaning of leads of grease and filling of grease in tank and other routine activities, railway staff was trained by the equipment supplier in a specially organised workshop and during on site servicing.

7.2.4. 1620 Kg of grease has been consumed by 3 lubricators in 30 months from April 2008 to October 2010. This gives an average monthly consumption of 18 kg per lubricator.

7.2.5. Following are some of the advantages experienced after installation of PORTEC rail lubricator:

- Saving of man power – 365 Man days per year.
- Saving of grease – since machine is applying controlled flow of grease through its nozzles, wastage of grease due to falling off of excess grease, very common in manual greasing, is avoided. There by there is considerable amount in saving in grease by machine.
- Since the time of installation of PORTEC rail lubricator in last 2 ½ years there is no stalling of down goods train booked on Permanent way department on account of grease on track. Earlier, in the manual greasing era, every alternate stalling of DN goods train was being booked on account of grease on track.

7.2.6. Cost wise, there is not much saving in grease. Rate analysis indicates that for the same length of track, PORTEC rail lubricator is consuming 54 kg per month, on 3 machines. At approximately Rs 400/- Kg, per month cost comes to Rs 21,600/-. Consumption for manual application for the same length is 63 kg per month and the cost of servo grease is Rs 350 per kg. So the cost comes to Rs 22,050/- per month.

7.2.7. Major advantage of these Lubricators has been reported by Locomotives department. This section uses captive banking engines which needed wheel turning at an interval of 14 to 15 days. Interval between turnings of wheels on account of flange wear has increased considerably to about 45 days.

7.3. Some of the issues to be addressed are:

7.3.1. It has been reported on West Central Railway that Grease is getting separated from Oil in tank, may be due to excess temperature, rail temperature on the day of inspection, 27-May-10, was 55^{o} C. **Grease shall be stirred once in 20 days**.

7.3.2. Ports of the applicators are getting clogged particularly when sanding is being done. These shall be cleaned once in 20 to 30 days.

7.3.3. Soya grease is getting thrown on to ballast, particularly in case of hydraulic lubricators, near the applicator causing wastage and soiling of ballast. Grease flow needs to be adjusted.

7.3.4. The lubricators use Soya grease which is not presently manufactured in India, thus either an alternative grease will have to be found which can be a petroleum grease or soya grease will have to be imported. In case 100 such lubricators are installed, annual requirement of Soya grease will be about 25 tons. It may then become commercially viable to manufacture Soya grease indigenously, not only to meet domestic requirements but also to export the same to neighbouring countries. India is a major producer of Soya bean seeds.

7.3.5. This is a new technology. The lubricators require periodic attention by experts, dedicated personnel will have to be developed to fill up grease, clean the applicator ports and to provide periodic maintenance. We need to develop a supervisor and a maintainer team for every such site. In his periodic visits, which may be once in 15-20 days, the maintainer should ensure that:

- At least 90% of the total ports on the gauge face bars are working.
- Minimal wastage of product on the track.
- The control box is counting the wheels accurately. Wheel counts that are significantly different from adjacent units may imply that the unit has failed since the last visit.
- The magnetic sensor is working and located properly (at the right height below passing wheel flanges).
- The battery voltage for the solar powered system is sufficient for proper operation.
- The top seal of the bar is not damaged by contact with wheel false flanges.
- The level of product in the tank is sufficient until the next filling cycle.

8. Future of Friction Management in India:

8.1. Rail life in Indian Railways has been fixed as 800 GMT for 60kg 90UTS rails. Many times rails are required to be interchanged due to gauge face wear with as low a traffic as 150 GMT, particularly in curves. Thus rail replacements are called for after passage of 250 to 300 GMT. Rail gauge face wear for dry rail conditions in different degrees of curvature is as shown in Table below:

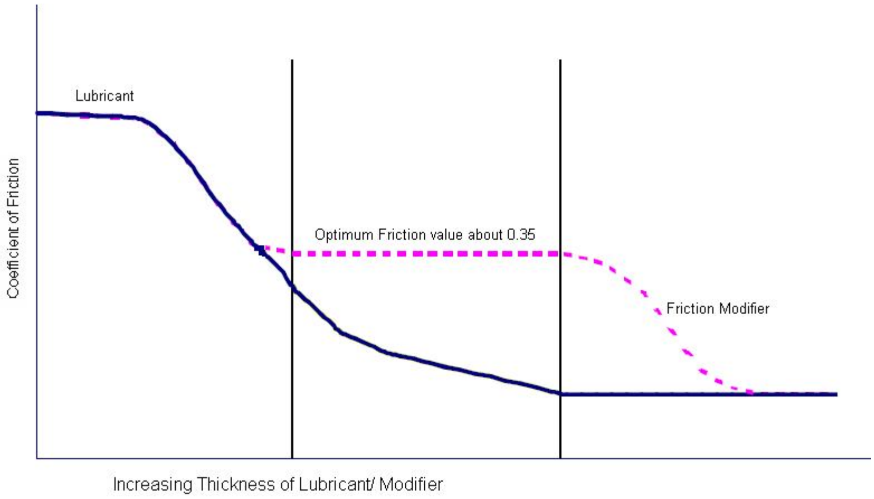
Norms for Rail Gauge face and Wheel flange wear

ASSETS	Curve Radius	WEAR RATE
Railhead gauge side wear rate, mm/GMT of traffic	Sharper than 300m radius	<0.66,
	300 to 500 m radius	<=0.05,
	Smoother than 500 m radius	<=0.04,
	Smoother than 1000 m radius	<=0.025,
Locomotive wheel flange wear rate, mm/10,000 km	Territories having 10% stretch with curves sharper than 650m radius	<=0.45,
	For mountainous regions	<=0.55

8.2. Thus, for a mountainous section having curves ranging from 300 to 500 m radius and an annual GMT of 30, the lateral wear limit of 8 mm will be reached in about 5 years i.e 150 GMT. In case the problem is compounded further due to cyclic wear, the rail may demand replacement even earlier. Effective implementation of gauge face lubrication may help increase the rail life to 800 GMT.

8.3. **Top of rail (TOR) friction control** is a recent innovation being implemented by a number of North American heavy haul freight railroads. Trials utilizing prototype equipment to apply friction control products to the TOR suggested significant benefits could be achieved by reducing curving forces and train energy consumption.

8.4. For years it has been considered to be risky to try top of rail lubrication for fear of wheel slip, leading to load stalling due to over lubrication. Now such friction modifiers have been developed which keep friction in a fixed range over a wide range of film thickness of the modifier between the contact surfaces.



Performance of Friction Modifiers for Top of rail Friction Management

8.5. Such friction modifiers along with recently developed Top of Rail Lubricators which apply a controlled quantity of friction modifier for a pre-determined number of wheel passes provide an optimal solution.

8.6. Canadian Pacific Railway (CPR) has spent the past 5 years implementing an optimised “100% effective gauge face lubrication” strategy on 3250 km of their 24,000 km network to control friction at the interface between the wheel flange / rail gauge face. Conclusive test results in 2001 demonstrated substantial savings in rail gauge face wear and in train energy (fuel) consumption. As new equipment technology became available, CPR started testing a top of rail friction management strategy to complement the gauge face systems on their high tonnage coal and mixed freight Thompson Subdivision in British Columbia, Canada. Results to date demonstrate substantial additional savings over and above “100% effective gauge face lubrication” in the areas of:

- reduced lateral curving forces,
- reduced rail wear,
- reduced train energy (fuel) consumed,
- reduced requirements for wayside gauge face lubrication units and lubricant, and
- reduced sleeper and fastener damage.

8.7. Time has now come that Indian Railways also start using Top of Rail Lubrication, in a limited way in those sections where heavy damage to track due to high lateral forces is being experienced.

9. <u>Conclusions:</u>

9.1. Knowing the benefits of effective lubrication, Indian Railways must adopt a rail gauge face lubrication regime at least at following locations, in order of priority:

- On Curves sharper than 600 m radius.
- In steep Gradients, to be highly controlled so that traction is not affected.
- In stretches with heavy traffic density, say 40 GMT and above, even in straights.
- In areas experiencing heavy rail/wheel wear due to other reasons (kinky welds, speeds, or heavy loads etc.)
- 100 percent of Track (as per latest tests)

9.2. This should be followed by introduction of Top of Rail lubrication in mountainous tracks with high traffic density so as to reduce the lateral forces on track at curves. The benefits will be visible in less gauge widening, lesser breakages of fastenings and lesser maintenance requirements at curves.

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