Inconclusive theory of rail lubrication

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Synopsis: *Rail lubrication on world railways has been an age old practice. Some railways has tried it out to effect economy in fuel while others have attempted it to reduce the rate of rail withdrawals. Some railways have applied scientific method of loco mounted lubrication whereas IR has gone for crude method of manual lubrication without supported by any sort of studies. The paper underscores the need for review of manual method and design alternate practice which stands to reason.*

1. From the advent of railway systems world over, noticeable wear of rail head has been observed on sharp curves. At some places the rate of wear is so aggressive that rails are withdrawn from track much before these could carry the estimated tonnage of traffic. The life span of rails is cut down drastically by railhead wear. Unbalanced rail head is also the prominent cause of derailments since angle of worn out head facilitates sliding up of wheel flange.

2. Rail wears out by loss of material due to abrasion by the passing wheels and atmospheric corrosion. The limits of loss of section are generally specified for i) vertical plane to ensure adequate support to wheel loads, ii) horizontal plane for ensuring proper track gauge and guidance to wheels and iii) shape to counter derailment risk. We are here mainly concerned with horizontal wear which is in the shape of side cutting of rails in curves. The side cutting of rail is the result of many wheel flanges hitting and grazing the gauge face. For a certain range of curve radii, the flange hitting is marginal. On Indian Railway (IR) when the 'N' series of rolling stock (BOX'N') was introduced, the side cutting was visible and significant all over. Both the straight and curved tracks were affected in equal measure. Rail withdrawal was abnormally high. Derailments were relatively more and severe in nature involving heavy damages.

3. In order to improve the economic life of rails, lubrication of gauge face has been considered to be easy and economical solution. Mostly, on IR it is practiced through manual means. Mechanical grease applicators too were installed but did not prove successful because of vandalism and poor design. Grease is applied to rail gauge face through stick or hands. Quantity applied is uncontrolled. There is no study which prescribes maximum thickness of the lubricant film and the frequency at which it should be applied. The dusty conditions and profuse amount of grease applied together creates a thick cake at gauge face which makes one wonder if the coefficient of friction is indeed lowered or increased. The methodology and frequency has however been prescribed by management and not by field staff.

4. The article on '*Management of friction on rail – wheel contact*'[@] records that lubrication is an established means of reducing friction between moving parts. However, despite its proven effectiveness IR has not succeeded in deriving the much needed and desired benefits. The article observes that the aim of lubrication should be to maintain the coefficient of friction (f) in a range appropriate to the contact area.

Under normal conditions, that is without lubrication, the '*f*' at wheel flange/rail interface is between 0.3-0.6. It should be maintained around 0.2 or so which may affect economy of fuel and reduction in rate of wear. The important factor is the interfacial layer which comprises residual lubricant, rail and brake shoe debris, environmental contaminants like coal dust, leaves, clay and moisture etc. This layer changes its composition due to wheel loading, crushing, mixing, oxidation and burning. The burning process is due to asperity flash temperatures which may reach as high as 600 ^{o}C.

5. Increasing life of rail has become one of the major concerns for track engineers. Low service life can alter the balance of scales and the balance sheet of organization. Mostly rails are taken out of track on account of crack defects. Cracks occur naturally in steel as a result of rolling/sliding contact between surfaces under high loads. Crack initiation and its growth largely depend upon axle load, speed, cant, vehicle suspension and quality of longitudinal profile of rails. Pressure and shear forces in the contact patch are very high during traction and braking. The stresses resulting from forces in the rail are severe and damage the material by deforming it plastically. Over many contact cycles the rail surface is heavily degraded and cracks initiate. Following their initiation, cracks propagate by contact stresses at the rolling surface.

6. Each time a loaded wheel passes over crack, its tip is advanced by a small amount. During its early life, the crack remains dormant in plastically deformed layer. Thereafter it enters elastic zone. Rain water or lubricant applied to reduce wear can enter the crack and become pressurized by the passing wheel contacts causing excessive stress at the tip of crack leading to opening of the crack further.

7. An International symposium on 'Wheel rail lubrications' was held in 1987 in USA where it was reported that: The main purpose of lubrication of rails all along the studies was to reduce the rail wear and to protect side wear of rails on curved track. However, while doing the research on reduction in rail wear, an unexpected result of less consumption of fuel was experienced and from here onwards, the thrust of rail lubrication studies got shifted from reduction in rail wear to fuel efficiency in train operations. Rail wear rate during dry conditions were found to be varying by about 20% from one dry period to another whereas under lubricated conditions, the rate of wear of the same rail was noted to vary in magnitude up to 100 times. These results therefore seem to indicate that wear rate largely depend upon the level of lubrication applied. Mindless application do not result expected results.

8. The test results also indicated about 30% less fuel consumption than during dry tests. Thus the significant reduction in train resistance due to lubrication of rails became a prominent issue for discussion. It was also noted that it was the consistency of lubrication control which is essential for achieving significant reduction in wear rate. The presentations highlighted that the reduction in wear rate when the level of lubrication is high than the dry rail condition is about 80 times. However, lubrication must in a methodical and predetermined manner. Similarly, the improvement in wheel flange life has also been established.

9. The reduction in power consumption was also established on FAST by conducting tests on curved track. The saving to the extent of 34% was conclusively established. The saving from lubrication of rail is more at lower speed when aerodynamic drag forces were not significant enough to nullify the effects of lubrication. Theoretically, the resistance between the rail and wheel on straight line is on account of axle misalignment. Lubrication between rail and wheel reduces this resistance to about 60% of the original value.

10. The deliberations further highlighted that there are four basic methods of rail lubrication out of which only loco-mounted system is preferred. In this system, there are two types namely (i) pressurized spray type that uses a nozzle aimed at to apply lubricant periodically to the locomotive wheel and (ii) a mechanical roller system that stays in continuous rolling contact with the wheel flange. In the FAST study, the loco-mounted lubricators were designed to apply sufficient lubrication for an entire train to pass and therefore it was necessary to equip at least 80% locomotive fleet with lubricators. Equipping a few of locomotive in the fleet with high output lubricators was considered undesirable because of over lubrication leading to wheel slip problem. The **"little often"** concept was advanced for lubrication.

11. The report further brings out the requirements of various lubricants. The general requirement of lubricants is (1) Higher dropping point- this determines the maximum usable temperature; (2) Water resistance; (3) Pumpability; (4) Spreadability; (5) Retentivity; (6) Cost. Studies have shown that the flange temperature may go well above 150^0C on curves and therefore the lubricant has to be such that it does not evaporate under high temperature.

12. These considerations have resulted in the use of solid materials such as graphite which maintains an adequate film thickness at a wheel rail interface. The retentivity of grease is also an important factor which is defined as the number of train passes before the effect of lubricant is diminished. Experiments have established that addition of graphite to the grease increases the retentivity. The report brings out that oil based lubricating system is inherently more simple as compared to grease based system. Because of less operative pressure requirement in the system, maintenance is almost trouble free. Oil being cheaper than grease, the operating cost is low. Therefore in case of rolling stock with light axle load and with smaller length of train, it is advisable to use oil based lubrication system.

13. An article *'Effect of lubrication on rails'* brings out that the most damaging consequence of rail lubrication is contact fatigue failure of rail and wheel surfaces which cause them to be flaked, corrugated or shelled. The corrugations develop due to contact fatigue accompanied by flaking, spalling and shelling of the rail surface. It is easy to stop further growth of these corrugations by lubrication. This damage is caused by growth of surface cracks brought about by reduced wear in lubricated area. Thus, the lubrication reduces friction and helps in propagation of these cracks and thereafter these cracks grow rapidly under lubrication. The lubrication should

therefore be such that the rate of wear of rails is able to counter the contact fatigue failure of rails. The rate of wear should not be cut down drastically because then self grinding of rails to take away fatigue cracks will cease to exist. Lubrication has to be controlled to balance the wear as well as contact fatigue. To some extent rails must wear off.

14. Studies conducted on Chinese railway have shown that heavy haul freight trains and increase in traffic volume has led to alternating rail side wear even on straight line which reduced the service life of rails by big margin. Tracks with many small radius curves, rail side wear continues to be controlling factor on rail service life. Rail side wear creates a vicious cycle whereby it disturbs the track parameters like gauge. Irregularly wide gauge leads to heightened oscillations impacting more lateral force on gauge face.

15. The rail side wear occurs in three distinct stages, the study reveals. These are: rapid occurrence stage, stable development and severe wear development stage. The reason for initial rapid occurrence is that the wheel and rail profiles are not in conformity, and with excessive contacting stress, metal in rail head under goes plastic flow. After a period of rail head wear, the contact of wheel and rail approaches conformity, the contact area is enlarged to reduce stress and reduce the rate of wear. After this phase is over, with certain volume of traffic, rails are seriously weakened with constant wear, massive metal plastic flow appears on railhead and gauge wear will increase severely. The study shows that on small radius curves the initial wear rate is at 0.2mm/GMT while at stable stage it is 0.1mm/GMT. On medium range curves the wear rate in three stages is respectively 0.1, 0.05 and 0.2mm/GMT. Continuous change of the track geometry, bad versine and complex movement of bogie also accentuate deterioration.

16. The study also records that cant deficiency can reduce side wear on rails. Properly reduced track gauge also helps reducing side wear under general condition. The report concludes that dynamic response of wheel/rail is decreased by two methods that include adjusting track parameters to improve rail wheel contact and by changing physical characteristics of contact body between wheel and rail by lubrication. Lubrication is shown to have obvious influence on rail gauge wear by decreasing friction coefficient.

17. Observations made elsewhere point out that improper greasing will hasten the wear of rails. Water also act as lubricating medium and reduces wear significantly. Therefore the ambient conditions will influence the requirement of lubrication. The uncontrolled way of lubrication can lead to flow of grease on rail head. If there is liquid or lubricant on the surface, it will penetrate into cracks. When a wheel runs on, it will first seal the crack and ‘lock’ the liquid inside. When the following wheels run on, in the contact area the high pressure of the lubricant or liquid further develops the crack.

18. Studies do not reflect any consistency in their findings except that *'f'* will be reduced by application of lubricant at rail/wheel interfaces. However there are several other parameters at play which suggest that lubrication might do more harm than good. At any rate, lubrication should be in controlled manner and the thickness of film should be pre-designed. Despite this fact being prominently clear, on IR lubrication is still done manually and in an unscientific manner. Besides, cost of labour is so high that comparative study may suggest doing away with lubrication altogether.

19. On IR, it has been observed that the wear of rail on curves of radius varying from 875m to 700m is insignificant. Primarily, this may be due to the fact that axles are able to assume radial position. For radius less than 700m the biting action of wheel becomes noticeable. Considering this delineating point the curves of radius from 580m to 875m are lubricated once a week. Curves flatter than 875m radius are lubricated once in a fortnight. And curves of radius less than 580m are lubricated every day. It is a matter to be pondered if the film of lubricant can stay at gauge face in the dusty conditions, apart from magnitude of traffic, for 15 days. The decision seems to be based purely on conjecture. However, in the field never the lubricant film has been seen staying at gauge face of rails for so long a period (Readers may disagree with this observation). Field results also indicate that on curves having radius less than 580m the wear to the extent of 10mm to 15mm has been measured in a time span of 3-5 years when gauge face is lubricated every day. Further startling observation is that even when lubrication is applied daily, after passage of 4-5 trains the rail face becomes silvery shining and iron powder begins to fall. This phenomenon suggests that when angle of attack becomes excessive, heat is generated due to which the lubrication evaporates; partly it is squeezed out and some quantity may be swept away by wheel flange. Besides, when curvature is sharp the axles are unable to assume radial position. Thus expecting the lubrication to last for 24 hours is again not based on scientific study. The frequency is not correlated with traffic density, curvature of curves and environmental conditions.

20. Survey conducted over 1000 km track on IR covering straight and varying degree of curvatures brings to the fore the severity of defects generation on straight track followed by track having flat curvature. In a period of about one year there were 49 rail withdrawals from straight as against 11 rails from curves of flatter radius. No case of rail withdrawal from curves having sharp curvatures was reported. All withdrawal on sharp curves were on account of excessive wear resulting into wide gauge. This further validates the fact that faster wear rate on sharper curves scrapes cracks before they penetrate and propagate into rail metal.

21. In case IR continues with its existing practice, in that situation at least it should be established as to what degree of curvature the axles are able to assume near radial position. Else, data may be collected from field and curves up to certain radii be exempted from lubrication since saving in fuel is does not appear to be the motto. On sharper curves a study may be commissioned to suggest scientific ways of doing lubrication. It may be noted that in Indian conditions, there is profuse amount of dust

and organic matter in the track. With passage of every train, the dust gets deposited on the lubricant film. In couple of days it develops into a sort of cake which starts falling off the gauge face. The efficacy and economy of manual lubrication therefore remains shrouded in mystery. Neither the method adopted appears to help increasing life of rail in track nor does it save fuel consumption. The only practical and scientific solution seems to be loco mounted lubrication system which can lubricate rails both on straight and tangent alignment where up to a certain curvature it would reduce fuel consumption and on sharper curves apart from achieving savings in fuel consumption rail life would also be enhanced.

22. Indian railways, it appears is yet to capture the real benefits of controlled rail lubrication i.e. energy saving, longevity of rail life, rail climbing tendency of wheel on curves, reduction in noise level, better traction capacity with existing fleet of locomotives. IR is far behind in exploring feasibility of rail top lubrication under Indian conditions. It is perhaps the right time when IR has started heavy haul with higher axle loads to adopt the appropriate practice of rail lubrication for reducing damage to rails and consequent premature withdrawal from track.

23. The another interesting phenomenon is that on relatively flat curves the wagons loaded with CC weight are not causing any wear, whereas CC+8+2 loads are inflicting severe damage at such places. This indicates that the suspension of heavier load stock needs redesign to permit flexibility to bogie rotation. Else the withdrawal rate of rails will shoot up.

Conclusion: Lubrication should be based upon the scientific studies. It should be established if the benefits flowing from lubrication are more for saving energy or prolong the service life of rails. Heavier axle load bogies need a re-look at their design. Manual method yields no benefits and should be done away with immediately and save the scarce human resource.

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