***BioBlend White Paper*:**

BioGrease RC Rail Curve Grease

Abstract

Wear of railroad rolling stock and rails costs millions of dollars annually for rail systems throughout the world. Rail engineers face signifcant challenges when it comes to effective rail curve lubrication. The rail industry has attempted to address flange wear using a variety of different rail curve lubricants with limited success due to the uncertainties related to the frequency and volumetric lubricant application rates. Not only is fundamental application a challenge, but the very nature of this demanding application is such that spent lubricant will move directly into our eco-system, often having grave and debilitating impacts. This paper will explore the challenges of rail curve lubrication and offer general guidelines to aid maintenance departments in properly applying rail curve lubricant. It will also address the emergence of renewable, bio-based lubricant technologies that tackle the environmental challenge head-on.

Rail Curve Challenges

Lubrication of rails on curves is desired to minimize the rail wear and derailment propensity. From the first introduction of railways, noticeable wear of the rail head has been observed on sharp curves. At some locations the rate of wear is so fast that segments of rail are withdrawn from the track well before they could carry the estimated tonnage of traffic they are designed for. The life span of rails is cut down drastically by rail head wear. Unbalanced rail heads are also the prominent cause of derailment since the angle of worn out heads facilitates sliding up of the wheel flange. 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:

- ✓ The vertical plane to ensure adequate support to wheel loads.
- ✓ The horizontal plane for ensuring proper track gauge and guidance to wheels
- ✓ Rail shape to counter derailment risk.

Of greatest concern in rail curve lubrication is horizontal wear - which is tied to the side cutting of rails that occurs in curves. This side cutting of rail is the result of many wheel flanges hitting and grazing the rail gauge face *(the sides).* For a certain range of curve radii, flange hitting is marginal. In other cases, side cutting can be visible and significant all over the rail … with both the straight and curved track affected in equal measure. In order to improve the economic life of rails, lubrication of the gauge face has been considered to be an easy and economical solution. The problem is effective rail curve lubrication isn't as easy as it sounds and it's fraught with environmental challenges making the proper selection and application of rail curve lubricant difficult at best.

Rail Curve Lubricant Functions

For many years the environmental impact rail curve greases were having on the environment was not studied or of signifcant concern. Today's enviro-sensitive business environment has heightened the need to find efficient and cost effective ways to effectively lubricate rail curves, and to do so with minimal environmental impact.

Generally rail curve lubrication is accomplished through manual means with grease being applied to the rail head using sticks or hands. The quantity applied is typically not scientifically controlled and is a variable users will have to contend with unless an automatic grease system has been installed. There is a lack of scientific study which prescribes the maximum thickness of the lubricant film, nor the frequency at which it should be applied. Further, the dusty operating conditions common to rail applications, and the typical large volume of grease applied, combine to create a thick cake. Over time this 'cake' builds up eventually falling on the ground where over time it's dispersed via rain directly into the environment.

Lubrication is an established means of reducing friction between moving parts. The primary aim of effective lubrication should be to maintain the coefficient of friction in a range appropriate to the contact surface area. Under normal rail conditions, that is without lubrication, the coefficient of friction at the wheel flange/rail interface is between 0.3 and 0.6. In reality it should be maintained around 0.2

Another important factor is the interfacial layer which is comprised of residual lubricant, rail and brake shoe debris, environmental contaminants like coal dust, leaves, clay, moisture, etc. This layer changes its composition due to wheel loading, crushing, mixing, oxidation and burning … with the burning process being instigated due to metal asperity contact flash temperatures, which may reach as high as 600°C.

Rail Curve Service Life

Increasing the service life of rail has become one of the major concerns for track engineers since a lower than expected rail service life can alter the operator's balance sheet.

- ✓ Rails are taken 'out of track' primarily due to their crack defects. Cracks occur naturally in steel as a result of rolling/sliding contact between opposing metal surfaces subjected to high loads, which in this case is between the wheels and the rail surfaces.
- ✓ Crack initiation, and its growth, is largely dependent upon axle load, speed, cant, train engine and car suspension and the quality of the longitudinal profile of rails. The pressure and shear forces in the contact zone are very high during traction *(when the train starts out)* and braking, which further impacts rail fatigue and service life.
- ✓ The stresses resulting from forces in the rail are severe, and damage the material by plastic deformation. Over many contact cycles the rail surface becomes heavily degraded and cracks initiate. Following their initiation, cracks 'propagate' by contact stresses at the rolling surface. Each time a loaded wheel passes over the crack its tip is advanced by a small amount. The end result can be devastating if not caught in time.
- ✓ During its early life, the crack remains in a 'plastically deformed' layer. Thereafter, it enters the 'elastic zone'. Rain water or lubricant applied to reduce wear can enter the crack and become pressurized by the passing wheel contacts. This further complicates the problem causing excessive stress at the tip of crack, leading to further propagation of the crack.
- ✓ It should be noted that even the best rail curve grease is not 'fix a crack' in a can. The only way to fix a crack is to replace the rail.

Rail Curve Wear

The main purpose of lubricating rail curves is to reduce the rail wear and to protect side wear of rails on curved track. Early rail industry research on reducing rail wear brought to light an unexpected result of proper rail lubrication – reduced fuel consumption. The net impact was that from this point forward the thrust of 'most' rail lubrication studies got shifted from reduction in rail wear, to maximizing fuel efficiency in train operations.

Rail wear rates during dry conditions have been found to vary by about 20% from one dry period to another. Conversely, under lubricated conditions, the rate of wear of the same rail was noted to vary in magnitude by up to 100 times. While its logical to assume that lubrication will reduce wear, these type results supports that rail curve wear rates are largely dependent upon the level of effective rail curve lubrication. In other words – if you aren't lubricating your rail curves don't be surprised if you experience rapid wear and high rail curve replacement costs – which in many instances has now come to be expected as 'normal' when in fact it's far from normal.

Studies have suggested that there is about 30% less fuel consumption when rail curves are properly lubricated. Thus, the significant reduction in train resistance due to lubrication of rails is in fact a prominent issue for discussion, debate and action. It should also be noted that the consistency of rail curve lubrication control is considered to be essential for achieving significant reductions in wear rates. The reduction in wear rate when the level of lubrication is high, versus when the rail is dry, is about 80 times. It's signifcant.

Similarly, the improvement in wheel flange life as a result of proper rail curve lubrication has also been established. Rails haven't changed much over the years. Studies on the reduction in power consumption, especially for curved track, has been fairly signifcant. Some studies suggest that a 34% fuel economy savings can be established. Further, the savings from effective lubrication of rail is considerably more at lower speed when aerodynamic drag forces were not significant enough to nullify the effects of lubrication. Theoretically then, the resistance between the rail and wheel on a straight line is thus linked to axle misalignment. Lubrication between rail and wheel reduces this resistance to about 60% of the original value.

Methods of Rail Curve Lubrication

There are four basic methods of rail lubrication, out of which only the *'locomotive-mounted system'* for rail curve lubrication is preferred. In this system, there are two types:

1. A pressurized spray type that uses a directionally aimed nozzle to apply lubricant periodically to the locomotive wheel.
2. A mechanical roller system that stays in continuous rolling contact with the wheel flange.

The locomotive-mounted lubricators were designed to apply sufficient lubrication for an entire train to pass. Therefore, it is typically necessary to equip at least 80% of locomotive fleet with this style lubricator. Equipping just a few locomotives in the fleet with high output lubricators would typically be considered *'undesirable'* because of over lubrication leading to a wheel slip problem. The age-old philosophy of ***'apply just a little - more often'*** approach simply makes better sense.

Effective Rail Curve Lubrication Requirements

The general requirements for effective rail curve lubricants are:

- ✓ High Dropping Point - this determines the maximum usable temperature
- ✓ Water Resistance - a natural concern
- ✓ Pumpability - because cold weather is of concern, as is hot weather
- ✓ Spreadability - how easily it 'coats' metal surfaces
- ✓ Retentivity - how well it stays in place, usually a function of tackiness
- ✓ Environmental Impact – what impact does it have on the environment as it biodegrades
- ✓ Cost

Properly formulated rail curve greases must deliver on many different performance fronts. For example, studies have shown that the rail flange temperatures may go well above 1500°C on curves, and therefore the lubricant has to be formulated so it does not evaporate under high temperature. Add to all this the fundamental fact that rail curve greases need to be environmentally responsible, and a strong case can be made for bio-based, renewable and biodegradable rail curve greases that are minimally toxic.

Rail Curve Lubrication: Oil vs. Grease

Up to this point little has been said about oil lubrication of rail curves. Because of lower operative pressure requirements in oil-based rail curve application systems, maintenance of oil-based rail curve applicators is almost trouble free. Subsequently, with oil typically being lower cost than grease, the operating cost of oil-based systems is lower.

So why not just use oil for rail curve lubrication? Does an oil-based system make the most sense? Generally speaking the applicability of oil lubrication of rail curves is minimal. Trains with light axle loads and when dealing with consistently small length trains, it may be advisable to use oil based lubrication systems. Unfortunately, very few train operations fall into this category and instead are heavily-loaded *(maxed out)* and as long as possible for obvious economic reasons. In cases of oil rail curve lubrication it's important to recognize that it is the oil doing the work. In cases of grease rail curve lubrication, the oil is still doing the work, but the grease thickeners and additives help to hold the oil in place making grease lubrication of rail curves the predominant methodology in use today. The retentiveness of the grease is also an important factor which is defined as the number of train passes before the effect of the applied rail curve grease is diminished.

Rail Curve Lubrication Volume and Frequency

The most damaging consequence of insufficient rail curve lubrication is contact fatigue failure of rail and wheel surfaces which causes them to become flaked, corrugated or shelled. The corrugations develop due to contact fatigue accompanied by flaking, spalling and shelling of the rail surface. This damage is caused by growth of surface cracks brought about by reduced wear in the lubricated areas of the rail *(rail sides or flanges seemingly being the most challenging).*

The fact is that while lubrication reduces friction, it helps in propagation of these cracks, and thereafter these cracks grow rapidly under lubrication. The lubrication volume applied should therefore be such that the rate of rail wear is able to counter the contact fatigue failure of the rails. Interestingly enough 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 the contact fatigue … meaning that to some extent, rails must wear off … its part of the process. Studies have shown that heavy haul freight trains, and increased train traffic volume, has led to alternating rail side wear - even on straight rail lines, which can reduce the service life of the rails by a huge margin. For tracks with many small radius curves, rail side wear continues to be the controlling factor for rail service life. Rail side wear creates a vicious cycle whereby it disturbs track parameters - like gauge *(how far apart the rails are).* Irregularly wide track gauge leads to heightened oscillations creating more lateral force on the gauge face … the net result being more wear. Rail side wear occurs in three distinct stages:

- ✓ Rapid occurrence stage
- ✓ Stable development stage
- ✓ 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 the rail head goes into the plastic flow phenomena discussed earlier. After a period of rail head wear, the contact between the wheel and rail approaches conformity, the contact surface area is enlarged to reduce stress, and you've effectively reduced the rate of wear. After this phase is over, meaning after a certain volume of train traffic has occurred, rails can be seriously weakened by constant wear, massive metal plastic flow appears on the railhead, and gauge wear will increase severely.

Cant deficiency *(correcting the difference in height between the set of rails)* can also reduce side wear on rails. Properly reduced track gauge also helps reducing side wear under general operating conditions. The dynamic response of wheel/rail contact is decreased by two methods that include:

- ✓ Adjusting track parameters to improve rail wheel contact.
- ✓ Changing the physical characteristics of the contact between wheel and rail through effective lubrication.

Lubrication is shown to have obvious influence on rail gauge wear by decreasing the friction coefficient, which means that improper greasing will hasten the wear of rails. Water can also act as a lubricating medium and reduce wear. Therefore, the ambient conditions will influence the requirements/needs of rail curve lubrication *(frequency and amount).* An uncontrolled rate of lubrication can lead to flow of grease on to the rail head. If there is liquid or lubricant on the surface, it will penetrate into any existing cracks. When a wheel runs on, it will first seal the crack and *'lock'* the liquid inside. When the following wheels run on, the high pressure in the contact area further pressurizes the lubricant and further develops the crack *(i.e. crack propagation).* Lubrication of rail curves should be done in a controlled manner, and the thickness of the lubricating film should be *'pre-designed'*. Despite this, lubrication is still primarily done manually, and often in an unscientific manner.

One study suggested that the wear of rail on curves with a radius varying from 875m to 700m is insignificant. This may be due to the fact that axles are able to assume a radial position when going around the bend. For a curve radius less than 700m, the biting action of the wheel seems to become noticeable. Considering this, the industry standard for rail curve lubrication can generally be estimated as follows:

- ✓ Curves of radius less than 580m **grease every day**
- ✓ Curves of radius are from 580m to 875m **grease once a week**
- ✓ Curves of radius greater than 875m **grease once every two weeks**

NOTE: Rail curve lubrication frequency is not correlated with traffic density, curvature of curves and environmental conditions. These factors can increase/decrease the frequency of lubrication.

Field results seem to indicate that on curves having a radius less than 580m, wear to the extent of 10mm to 15mm has been measured in a time span of 3-5 years when the gauge face is lubricated every day. Interestingly enough, even when lubrication is applied daily, after passage of 4-5 trains, the rail face becomes a 'shiny *silver'* and iron powder begins to fall. This phenomenon suggests that when the angle of attack becomes excessive, heat is generated causing lubrication evaporation. In reality, some grease will be *'squeezed out'*, and some may be swept away by the wheel flange. Further, when rail curvature is sharp, the axles are unable to assume a complete radial position so 'squeezing out of the grease' will occur.

Summary

As you can see the challenges of rail curve lubrication are challenging. Interestingly enough, when it comes to rail curve lubrication, it all boils down to these two questions:

- ✓ How much?
- ✓ How frequently?

The amount and frequency of rail curve grease application is unique to each train system. A good place to start is to analyze whether or not train derailments have been an issue. Then physically observe the rail track for cracks, which if present suggest that the current applied grease volume is insufficient (too low) and/or too infrequent. Adjust accordingly.

The environmental implications tied to rail curve lubrication suggest that bio-based biodegradable lubricants with ultra-low toxicity be used. This type technology minimizes damage to eco-systems and supports most railroad operations green and sustainability initiatives. The rapid advancements made in performance tied to properly formulated renewable and biodegradable rail curve greases make it almost a no-brainer to take advantage of their environmental and performance efficiencies.

Some of the attributes to selecting effective bio-based biodegradable rail curve grease include:

- ✓ Designed for wayside applicators with wide temperature requirements
- ✓ Pumps and carries when using wayside application equipment and grease temperature is between 35°F and 160°F
- ✓ Recommended for heavy load applications
- ✓ Recommended for environmentally sensitive areas near waterways
- ✓ Contains advanced extreme pressure *(EP)* additives that provide excellent protection against wheel and rail wear
- ✓ Reduces friction and wear between the track and wheel flange
- ✓ Formulated to resist port plugging in wiping bars
- ✓ Longer track '*carry down'* from the lubricator

- ✓ Better gauge face coefficient of friction than petroleum-based greases
- ✓ Less migration to top of rail than conventional petroleum-based grease
- ✓ Improves fuel efficiency by providing superior lubricity
- ✓ Higher flash point than petroleum greases for increased safety
- ✓ Biodegradable formula reduces damage to the environment
- ✓ Manufactured from renewable USA-grown crop-based oils

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- ✓ How much?
- ✓ How frequently?

The amount and frequency is unique to each train system. A good place to start is to analyze whether or not they've had any derailments (BioGrease RC can help). Then physically observe the rail track for cracks … which if present suggest that the current application amount is too small and/or too infrequent. Adjust accordingly.

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BioBlend Renewable Resources, LLC made their lubricant debut in the field in 2001. Since then, we've continued our bio-lubes innovation quest expanding our product line to include not only the most advanced biobased lubricant technologies available, but also food grade and synthetic lubricants. BioBlend's goal is to provide environmentally responsible products and solutions to a wide range of industries. Our customers come to us from every corner of the earth and in every industry: drilling, mining, construction, agriculture, marine, food processing, government, and many more. The BioBlend team has a wealth of experience in lubricants, manufacturing, and distribution. The company also has the venture capital backing of Archer Daniels Midland (NYSE: ADM) and Quest Technology Ventures.

- ✓ ***Made in the United States of America***
- ✓ ***Renewable***
- ✓ ***Readily Biodegradable***
- ✓ ***Minimally Toxic***
- ✓ ***Sustainable***
- ✓ ***Performance Driven***
- ✓ ***Cost Competitive***

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