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POSSIBILITY OF APPLICATION OF BIODEGRADABLE LUBRICANT GREASES ON RAILWAYS IN REPUBLIC OF SRPSKA

Authors:Marica-Maja Dugic,Pero Dugic,Valentina Petkovic,from Oil Refinery Modrica
Jasminka Jankovic, from Railways Republic of Srpska

Summary

Manufacturers of lubricants and users in the last years are more and more working on replacing conventional lubricants based on mineral oils with alternative biodegradable lubricants.

This is especially present at the critical points of lubrication, i.e. points from which the lubricant directly goes into the environment. These lubricants should be adequate replacement for conventional lubricants and must fully perform the function of lubrication.

Subject of research in this paper are biodegradable lubricating greases for lubrication of critical points on the railway (wheel rim, rails in curves, railway switches).

In principle biodegradable greases have structural form like the greases based on mineral oils. When choosing a raw material earlier the biodegradability was the only important criterion, and today these are also: bioaccumulation, toxicity on people, eco-toxicity…

To check properties of biodegradable greases in application, there was an application research on the railways of Republic of Srpska.

Research was done in the time interval that comprised low temperatures from –25^oC with snow, long rainy periods, high summer temperatures of up to 40^oC with many sunny days.

Results of the application research show that these greases have good lubricating properties, high level of corrosion protection, reduced wear and reduced number of additional lubrications.

Key words: *biodegradability, lubricants for railway, wheel rim of the locomotive, railway switch.*

1.INTRODUCTION

Even though a lot has already been written about lubricants which are less toxic to environment, and which have already found their application in different points of lubrication, this is still a frequent subject of researches.

Great attention is paid to losses of lubricants into the environment. This is especially present at critical points of lubrication such as: chainsaws, agricultural machinery, mobile hydraulic equipment, station for preparation of water, transportation machines (ski-lifts and ropes), open gears, mining equipment, windmills, hydro-electric stations, railway (2).

That is why manufacturers of lubricants and users must increase efforts to replace conventional lubricants based on mineral oils and other toxic components, with alternative

lubricants which are more neutral to the environment, i.e. biodegradable lubricants.
Trend of producing biodegradable lubricants started with production of liquid lubricants in the 70ies of the 20th century. Biodegradable lubricating greases have come to the front in the last 6-7 years.
In Republic of Srpska is produced and consumed annually more than 500 tons of lubricating greases, which are all with low level of biodegradability. Most of them are used on critical points of lubrication from which grease gets directly onto the ground. This is especially present as a consequence of lubrication on the railway (wheel rim, tracks in curves, railway switches). In RS is used about ten tons of lubricants for those points of lubrication.
That is why for the a/m points of lubrication were developed biodegradable lubricating greases, which is the subject in this paper.
Biodegradable greases should be adequate replacement to the conventional lubricating grease and must completely fulfil the function of lubrication.
After leakage from the point of application, and in contact with natural micro-organisms (which happens depending on the weather condition in several weeks to several months), biodegradable grease degrade to biodegradation products, CO_2 and water.

2. COMPOSITION OF BIODEGRADABLE GREASES

In principle biodegradable greases have the same structural form as the greases based on mineral oils. They consist of base fluid in which are dispersed thickeners agents, with addition of additives and as needed filling agent.(1)
When selecting raw materials earlier biodegradability was the only important criterion. Today other aspects are also as important, such as: bioaccumulation, toxicity to people, ecotoxicity (to fish, bacteria and plants), emission into the environment, performances...
Number of raw materials which can be considered has grown compared to the period before and this in itself gives more possibilities for selection when creating formulations of biodegradable lubricating greases.

2.1 BASE FLUIDS

Base fluids which are used in formulations of biodegradable lubricating greases can be divided into two groups:

1. natural oils (vegetable oils)
2. biodegradable synthetic esters

Vegetable oils and synthetic esters basically have the same chemical structure, so their characteristics are similar. Synthetic esters have still advantage over herbal oils when choosing in formulations, but these advantages have also higher price. If we wish to achieve better stability of greases at high and low temperatures, we will give advantage to selection of synthetic esters.

2.2. ADDITIVES

For achieving expected performances in the biodegradable greases, too, it is necessary to use additives which must meet several criteria, such as:
- highest possible percentage of biodegradability
- that they do not have mineral oils and heavy metals
- that with minimum dosage are achieved desired performances

The most frequently used additives are:

- antioxidants: amines, phenols, vitamin E, phosphites
- corrosion inhibitors (for steel and dyed metals):derivatives of fatty acids,amines
- EP/AW additives: dithiophosphates, dithiocarbamates, phosphites, S-P compound
- additives for adhesiveness: polymetacrylates, poly-isobutylene, natural resins.

2.3 THICKENER AGENTS

Thickener agents used in biodegradable greases must be neutral for the environment, and their selection depends on the point of application of the grease. The most often used thickener agents are: lithium 12-OH-stearat, calcium 12-OH-stearat, mixture of Li/Ca 12-OH-stearat, inorganic non-soap thickener agents such as: bentonite, silicagel, poly urea.

3. BIODEGRADABILITY

Term **biodegradability** can be defined as the ability of a compound or a mixture to be degraded by biological influence of live organisms.
Testing biodegradability is a complex procedure on whose results influences series of factors. Even though the number of methods which have been developed until now is big, none fully is satisfactory, because it is about a complex of natural processes which cannot be simply interpreted. Most of the methods cannot be applied for lubricating greases and give only approximate.
The most frequently used methods for determining degree of biodegradability are:

1. CEC-L-33-A-93
2. Modified Sturm method (OEC D 301 B)
3. ASTM D 5864
4. OEC D 301 F

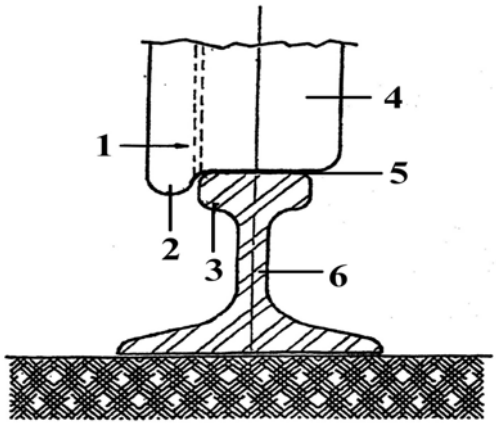
Considering the big range of tests of biodegradability, tests performed according to only one method are not reliable.
Greases which after the test of biodegradability have a degree of biodegradability according to Sturm methods of at least 60%, a according to CEC-L-33-A-93 at least 80%, are considered biodegradable.

4.CRITICAL POINTS OF LUBRICATION ON THE RAILWAY

Points from which the lubricant get directly into the environment we can call critical points of lubrication.
On the railway we can determine three such points from which the lubricant soon after lubrication gets into the environment. These are wheel rims of the vehicle, tracks which are lubricated in the curves and railway switches.

5.THE WHEEL/TRACK TRIBOLOGICAL SYSTEM

For a safe drive of railway vehicles had to be defined the term of mutual interaction between the track vehicle and tracks, i.e. between the wheel and the track.
This **wheel/track** system is very important for many reasons: in exploitation it causes huge costs for wear and damage in the contact area, which leads to: material losses, reduction of safety in traffic (bigger possibility of slipping off), increase of noise, and in general reduce comfortableness of the trip.
Figure 1. shows wheel/track tribological system.
In order to reduce friction and wear of the wheel rims, and of the lateral sides of the tracks, and at the same time to increase the factor of safety against slipping off, it is necessary to use lubricating devices.



1. Lubrication zone
2. Wheel rim
3. Inner edge
4. Wheel
5. Rolling surface
6. Track

Figure 1: *The wheel/track tribological system*

Figure 2 shows possible deformations and waer of the top head of the track.

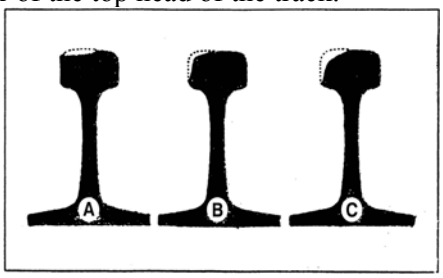


Figure 2: *Deformation and wear of the track*

These damages are caused by load of the wagons on the track, which are in the range of up 10 000 kg/cm^2.
By dotted line on the figure is shown the original shape of the track head. When there is lubrication present, or the contact between the wheel rim and the internal edge of track head is the smallest, then we get form A, i.e. result is of plastic deformation.

Forms B and C are result of wear (abrasion) of the side of the track head. In ideal conditions contact surface is only the rolling surface between the wheel and the tracks, which is shown in figure 1.
Figure 3. shown drawings of several examples of different wears of the wheel rim which appear in the exploitation and the parameters which are measured.
Prescribed profile of the wheel and circle of rolling of the wheel on the track influences the safety of moving and the intensity of tear of the wheel rim.

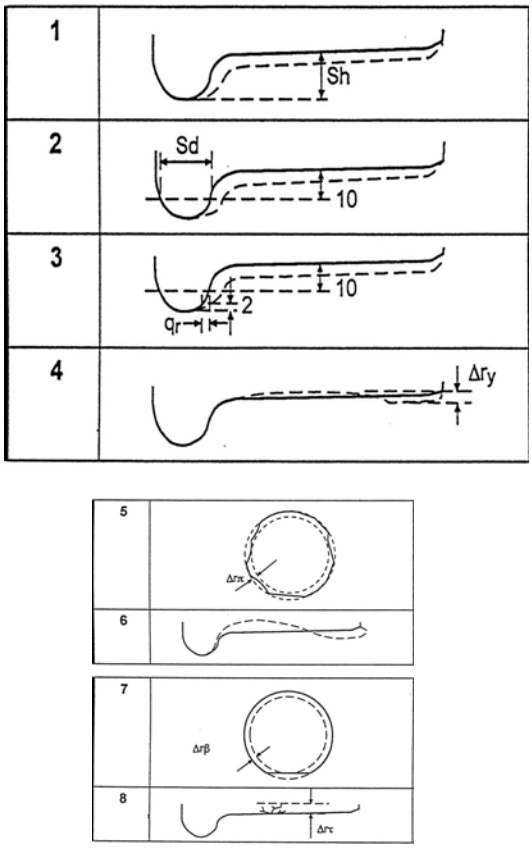
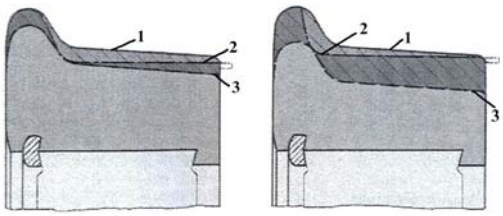


Figure 3: *Examples of wear of the wheel rim and parameters measured in exploitation*

Numbers of drawings 1-4 show appearance of the normal wear of the wheel rim, and numbers 5-8 show that there was a change in the shape of the rim and the wheel, i.e. deformation.



(a) (b)

Figure 4: *Appearance of the contact zone of the wheel rim with the track which was properly lubricated (a) and which was not lubricated (b)*

1 - profile of the new rim
2 - profile of the worn rim
3 – profile of the too worn rim

Intensity of the wear of the wheel rim depends also on the material of the wheel and of the track, load, speed, configuration of the route (hill-plane).
Certain parameters of the rim of the wheel are measured, such as: height of the rim (h), thickness of the rim (d) and sharpness of the rim (q_R). If the wear of the surface of the wheel is near maximum allowable value (h<36 mm, 22 mm<d<33 mm, q_R>6,5 mm), lathing is done, and if it is not possible, rim of the wheel or the wheel are replaced.(3,4).
Figure 4. shown appearance of the wear of the wheel rim which was properly lubricated (a) and which was not lubricated (b).

6. LUBRICATION OF THE WHEEL RIM AND THE TRACKS

Lubrication of the wheel rim and of the tracks can be separated as a very important part in the tribology.(5)
Lubricant, in this case biodegradable lubricating grease, direktno influences on several important factors in the above mentioned wheel/track tribological system, and they are:

- Increase of safety from slipping off
- Protection from wear of the wheel rim and the track
- Reduction of noise
- Saving energy through reduction of friction between wheel rim and the side of the track head

There are three main manners of lubrication:

1. lubricating devices attached to the vehicle (locomotive)
2. lubricating devices attached to the tracks
3. lubrication by a special vehicle

Figure 6. shows manner of lubrication of the wheel rim and tracks by installed lubrcating device installed tied to the locomotive. For lubrication of the tracks are used lubricating devices tied to tracks. They are activated mechanically during passing of the track vehicle. Every wheel by exercising pressure on certain contact part activates lubrication device and certain quantity of grease comes out on the inner edge of the head of external part of the track. Grease is then transferred from the track to the wheel rims during contacst of the wheel rim and the track.
Figure 5. shows the described lubricating device.

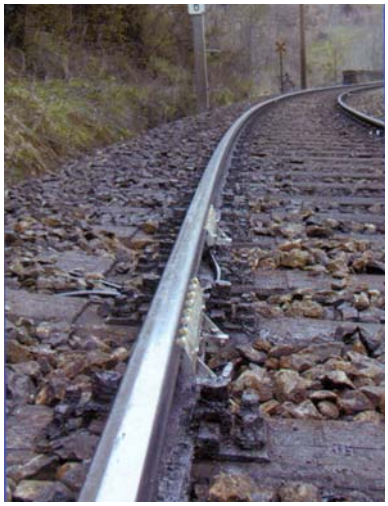
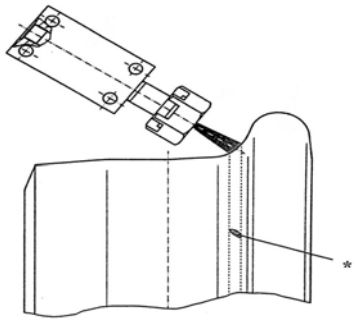


Figure 5: *Lubricating device tied to the tracks*

Figure 6: *Lubricating device tied to the locomotive*



* zone which is being lubricated

Figure 7: *Appearance and position of the nozzle for lubrication of the wheel rim.*

7. LUBRICATION OF THE SWITCHES

Lubrication of the switches also reduces costs foe parts and protects switches from damages, and influences good operation in all weather conditions. All of this influences the safety and regularity of traffic.
Unlike lubrication of wheel rim and tracks, lubrication of the switches is neither mechanical nor automatized.
Switches are still mostly lubricated manually, with a brush or specially adjusted portable devices for lubrication - grease gun.

Figures 8. and 9. show manners of lubrication of the switches, and figure 10. shows movable part of the switch which are lubricated.

Figure 8: *Lubrication of the pads of the track by grease gun*

Figure 9: *Lubrication of the pad of the track by a brush*

Figure 10: *Movable parts of the switch that are lubricated*

Biodegradable lubricating grease for lubrication of movable parts of the switch should meet several most important requirements:

- reduction of friction when switching and achieving the final position of the switches and tracks in all weather conditions
- good protection from corrosion, especially in unfavourable weather conditions
- good adhesion ability to wet and dry surfaces and good waterproof properties
- good lubricity and ability to penetrate to the places hard to approach and at low temperatures, i.e. that the consistence at –10°C should b between 000 and 00
- good stability to UV rays
- as high percentage of biodegradability as possible

8. EXPERIMENTAL PART

There are formulated and produced biodegradable lubricating greases for lubrication of critical lubricating points on the railway, such as wheel rims, tracks and movable parts of the switches. To test their application properties, they were subjected to exploitation testings on Railway of Republic of Srpska.

For testing was selected the most frequently used switch on the railway junction Doboj. For monitoring lubrication of the tracks in the curves was selected several curves on the line Modriča-Doboj. Wheel rims were lubricated by a systs tied to the vehicle, i.e. lubricating devices in a form of a sprayer were mounted on a locomotive.

Lubrication of the movable parts of the **switches** was done with biodegradable grease of semi-liquid consistence (NLGI 000) mark BG-1. testing was done in the time interval which comprised low temperatures of -25°C, long rainy periods, high summer temperatures of up to 40°C with many sunny days. Lubrication of slipping pads and the so-called "swallow tail" (switching device) was done mannually, by appropriate brush, in the intervals of 4-5 days. During testing in summer period were taken samples of the grease from the pad of the swith before the new lubrication and analyzed in the laboratory.

Change of acid number was not significant compared to the initial value. This shows us that the grease tested is resistant to influence of UV rays. During the longer rainy period was observed by visual inspection that the grease adhere well to the lubricated and that it was not washed off. On the pads were not observed traces of corrosion. During winter period it maintained lubricity and low consistency which can be seen from the data shown in graph 1. the penetration at low temperatures was measured and can be seen that it slightly reduces with the reduction of the temperature.

Lubrication of the **wheel rim** was done with grease of the same consistency with addition of colloid graphite, mark BG-2. An electric locomotive was chosen with central lubrication system, which consists of: command device, electro-pneumatic valve, grease tank and nozzle by which under air pressure the grease is spread on the wheel rim (figures 6. and 7.). Before the beginning of the testing an overhaul was performed on the locomotive. On the wheel were put new wrappings

(bandages). Testing in application is still in progress, and in the time to come will have to be adjusted interval in which the nozzle will release the grease. In the beginning the lubricating system was set so that the grease was released after every 400 m passed. Such way of lubrication did not satisfy on the parts of the tracks which are in the stations.
During this period of testing were periodically monitored parameters of the wheel rims which are controlled. By a special instrument are measured thickness of the rim, height of the rim and sharpness of the wheel rim.
Even now can be concluded that the tested grease has given good results, because there was not recorded increased wear of the wheel rims after periodical measurement of the above mentioned parameters. In winter period the grease had good pumpability and satisfactory lubricity. This can be seen also from the laboratory testing of penetration at low temperatures, whose value slightly declines with reduction of the temperature (Graph 1.).
Lubrication of the **tracks in the curves** was tested with biodegradable grease with consistency NLGI 2, mark BG-3. In the curve was placed lubricating device tied to the track. In the tank was periodically poured tested grease.
During the test period by visual inspections was checked situation of the lubricating device, lubrication of the tracks in the curves and behaviour of the grease.
It was concluded that lubrication of the tracks is good, therefore the grease was by wheel rime transferred over the length of tracks in the curve and far from the point of lubrication, about 150 m. During rainy days the grease had good adhesion and it was not washed off. Operation of the lubricating device was goods, there was not plugging and the grease was automatically released when the trains passed, regardless of the weather conditions.

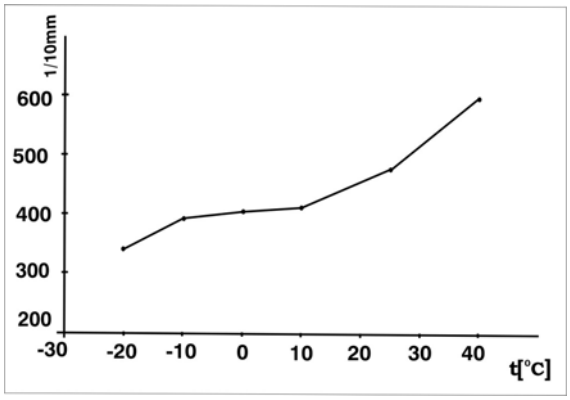
All three tested greases were produced from:

- mixture of lithium and calcium 12-OH stearate, as the densification agent
- mixture of rape oil and synthetic biodegradable ester, as the base fluid
- environmentally acceptable additives

Physical-chemical characteristics of all three tested greases are given in table 1.

Table 1. Physical-chemical characteristics of the greases

MARK OF THE GREASE	BG-1	BG-2	BG-3
NLGI-NUMBER	000	000	2
PENETRATION AFTER 60 STROKES,mm/10	475	470	287
PENETRATION AT -10^{O}C	395	395	242
PENETRATION AT -20^{O}C	345	335	226
Cu CORROSION, 3 h/100^{o}C	1a	1a	1a
DROPPING POINT, ^{0}C	176	177	180,6
CORROSION PROTECTION , EMCOR TEST	0/0	0/0	0/0
DIAMETER OF WEAR, test 4-balls,mm	0,47	0,45	0,50
WELDING POINT, test 4-ballS, N	2800	3000	2500
OKSIDATION STABILITY,100h/100^{o}C pressure drop, kPa	50	50	50



Graph 1: *Effect of temperature on penetration*

9. CONCLUSIONS

Production and application testing of biode-gradable lube greases intended for lubricating critical lubrication points on the railway, such as wheel rime, tracks in curves and switches have shown the following:
1.All three greases fully satisfy on the lubrication points for which they are intended, i.e.:

- they have good lubricity properties at all temperatures

- they provide high levels of protection of lubricated surfaces from corrosion

- the wear on the wheel rims and tracks is reduced

- by all above characteristics was influenced on a more comfortable drive because the noise was reduced and the safety of passengers was increased

2. In lubrication of switches was reduced number of additional lubrications compared to the lubricating oil used before which was on the mineral basis, i.e. savings were achieved in lubricant and spent working time.

3. By this application testing was increased awareness of responsible people in charge of purchase of lubricants, end users and others, by gaining knowledge about environmental protection and shown interest for application of biodegradable lubricants which are used in this area of lubricants application.