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LUBRICANTS FOR RAIL TRANSPORT LIQUID (PLASTIC) FOR FRICTION PAIR "WHEEL – RAIL"

Purpose. To formulate the requirements for the basic properties of lubricants suitable for use in the systems of on-board lubricators of rail vehicles. To develop a generalized algorithm for controlling the devices of the lubrication system of rail vehicles and to propose a method for controlling the lubrication system of the wheel flanges of a rail vehicle, which makes it possible to turn on the system in advance in order to prevent an increase in the interaction forces of the wheel flanges and rails during the entry to the curved section of the rail track, as well as on the turnouts.

Methodology. Research methods include statistical analysis of the results of experimental tests of the properties of existing and proposed lubricants on the STs-2 friction machine and in the conditions of real operation of the rolling stock of JSC "Ukrzaliznytsia".

Findings. Based on the results of operational tests, it was found that Relsol-M lubricant, which is regenerated, homogenized and modified with solid lubricating impurities, even with an expired shelf life, retains and demonstrates the "transfer effect" on all wheels of the VL11m/6 locomotive, and also slows down the wear rate of the combs of the wheel rims which were not chiseled during the tests by 3.57 times and the combs of the bandages which were chiseled during the tests by 4.25 times. "Mariol NT" demonstrated the effect of reducing the intensity of wear processes of the ridges of locomotive tires in the mode of freight traffic in relatively light track conditions by 2.5 times, and in more difficult road conditions – by 5 times.

Originality. Requirements for the basic properties of lubricants, which are suitable for use in on-board lubricator systems of rail vehicles, have been formulated.

Practical value. A generalized algorithm for controlling the lubrication system of railway rolling stock is developed and a method for controlling the lubrication system of the flanges of the rail rolling stock is proposed, which makes it possible to turn on the lubrication system in advance when a rail vehicle enters a curved section of the track, as well as a turnout.

Keywords: *lubricants, lubrication, solid lubricating additives, degradation rate, railway, wheel comb*

Introduction. In order to increase safety and energy resource efficiency of transportation, to reduce the intensity of wear processes for wheel combs of rolling stock (flanks), to provide the operation of on-board systems for lubrication of combs of wheel pairs of domestic locomotives (SPP 12-5, GS-3, and others) in Ukraine, there are used such lubricants as "Relsol GS", "Relsol M" (TU U 23.2-30802090-055:2006), axial greases (GOST 610-72), mixtures of used lubricating oils /oils/gasoline/diesel fuel and finely-dispersed graphite, which either are inflammable or contain water or too coarse and tribologically unwarranted mechanical additives or have unstable (uncontrolled) chemical composition or have low indexes for ability to increase the strength of friction surfaces during catastrophic wear modes, and so on. The mentioned above and other disadvantages of lubricants result in the fact that they do not to meet modern operation conditions for rolling-stock, they do not ensure stable operation for lubrication systems. At the same time modern devices (transmitters, algorithms) for automated lubricant control system (SPP 12-5, GS-3, etc.) do not allow them to cover specialized lubricants on friction surfaces for wheel combs at certain time and duration. The mentioned above technical disadvantages do not give an opportunity for railway facilities to reduce sharply the intensity of wear processes for wheel combs (flanks), which in turn leads to reduction of safety and energy resource efficiency for freight/passenger rail transportation and sufficient financial expenses.

The purpose of the given article is to research the problems of energy resource efficiency for lubricants that are used in locomotive lubrication systems, development of rational solutions concerning their application, improvement for control system for on-board lubricant lubricating processes.

Literature review and methods. Process of interaction of wheel and rail is a physical base for rail vehicle transport. It is that mainly defines safety as well as the most important technical-economic indexes as axial load, mass and velocity movement of trains, level of maintenance costs. During movement, rail pairs function making traction force, leaning and direction of rail vehicle as well as ensure a necessary level of acceleration when starting up to speed and slowing down at breaking. All these functions are implemented in a section of combined frictional-antifrictional contact of wheel and rail and they influence considerably either all the operation of a locomotive or safety of movement at whole. Friction force emerging at the contact of wheel comb and rail results in the loss of traction force of a locomotive from 5 to 15 %, and active wear of wheel combs as well as face surface of a top of a rail.

Analysis of wear processes for friction pair "wheel-rail", defining typical kind of main and accompanying wear shows that in the section of frictional contact under the action of load-velocity, temperature, dynamic, cyclical, corrosion-atmospheric, fly ash abrasive impacts there are complex tribophysical and chemical phenomena which result in wear and degradation of contact surfaces [1, 2]. Operation in extreme conditions (high value of contact pressure from 2.5 to 3 GPa and temperature about 1000 °C at sliding velocity V_s from 0.1 to 3 m/s) is typical for tribocontact "wheel – rail" [3, 4].

During the movement of rail vehicle on a tangent, movement trajectory is of a wavelike nature. Such wavelike movement is similar to sinusoid and leads to impact of wheel flanges with rails, its value is proportional to movement velocity of a vehicle and the angle of wheel climbing on a rail.

From 18.04.2019 till 01.05.2021, by mutual initiative of PLC "MODIFIK" and JSC "Ukrzaliznytsia", under scientific supervision of PhD V.V. Protsiv (NTU "DP") and PhD A. S. Belikov (SHEI "PSACEA") there was carried out development followed by operational testing of fillers for solid TU 20.5-001-42277844-2019 (further – S) and specialized lubricants (further – SL) "MARIOL NT" TU U 23.2-31709624-

002:2009 (change 3), whose composition consists of S produced by PLC "MODIFIK" as antifrictional fillers.

Results allowed us to prove that the main kind of wearing wheel combs and face surface of a top of a rail is wear at sticking, hydrogenous, fatigue wear and wear as a result of plastic deformation while accompanying wear is impact-fatigue wear. It is typical that the intensification of wear process occurs when fatigue and hydrogenous wears at sticking causes catastrophic destruction of surfaces of wheel and rail friction as a result of dynamic load added many times at stresses significantly less than in case of non-permanent load. It should be mentioned that with a large quantity of repetitious loads for stress (causing deformations) not only strength borders of constructional materials for friction pair can be lower but earlier accepted elasticity border for the material for wheel and rail tread.

According to the results of the research, it is settled that:

- it is the index of intensity of wheel comb wear which, as the result of friction, is dominant rather than the analogous index of tread wear; thus, wear of wheel combs of rail transport limits the resource of wheel pairs on the level with indexes of quality for wheel mounting and wheel-motor blocks of locomotives;
- the most dangerous wear for friction pair is wear at sticking and fatigue wear but the most prospective direction for problem solving to reduce the intensity of wear of wheel combs of rolling stock and rails is the use of lubrication systems and SL;
- SL friction coefficient in boundary mode especially in suspensions depends not only on their viscosity but their ability to wash surfaces;
- sliding inside the layer of liquid or plastic lubricating material occurs due to viscous friction;
- high energetic amorphous friction is typical when frequency of molecules' transition under the action of friction force is getting bigger than frequency of dislocation motions in solids or bigger frequency of heat transitions in fluids; as a result, there can be the effect of reducing friction coefficient during velocity increasing;
- the presence of fillers S in SL, which realize the effect of technology of in-place engineering for friction surfaces of PLC "MODIFIK", has a decisive tribological significance for high loaded friction pairs;
- the most prospective problem solving to reduce the intensity of wheel comb wear of rolling stock and rails is the use of the systems of lubrication, rational algorithms for lubrication and SL which correspond to operation requirements and have a high index of the ability to increase the resistance of friction surfaces to transition to catastrophic modes of wear (Ud, %) [5].

Taking into consideration the mentioned above, the purpose of using lubricating material is to divide friction surfaces with the layer of material with low shear resilience which demonstrates high index of ability to increase the resistance of friction surfaces to transition to catastrophic modes of wear. At the same time, lubricating material must be held well on pair surfaces and protect them at high contact pressure; for this reason, it or its ingredients must have a good adhesive ability. Lubricating material must not only separate surfaces but fill and smooth out micro cracks on their surfaces, make surfaces smoother on an atomic level; at the same time, SL itself must have low phonon resistance.

Thus, taking into consideration the fact that peculiar operation in extreme conditions for tribocontact "wheel comb – rail" we can ascertain:

- any liquid (plastic) lubricating material of pair operates in the conditions of boundary lubrication but friction pair being lubricated has permanent tend to transition to the mode of partial metal contacting;
- lack of lubrication leads to rapid degradation of constructional materials of friction pair and then to catastrophic wear;
- use of lubricating materials, which do not modify friction surfaces in order to increase their resistance to transition to catastrophic modes of wear, is irrational and inappropriate from all points of view.

As for SL option for friction pair "wheel – rail" [6], it is known that the consistence and index of viscosity do not affect the behavior of lubricating material in the conditions of boundary and mixed lubrication [7], and thus, working efficiency in the system "wheel comb – rail", but it is correct that this lubricant must be laid on properly, locally and be held sometimes on almost vertical surface. Only consistent (plastic, not liquid) lubricating materials correspond to such conditions, that is why they should be preferred.

It is known that the main tribotechnical criterion for pair "wheel comb – rail" is durability of wheels and rails that is evaluated by runs and transported tonnage. Then the first and important property for consistent wheel-rail SL is their ability to transit along friction surfaces [8]. The second important property is life-span (operational resource), durability [9]. But as the durability of lubricants affects strongly the relief of friction surfaces, it is gradually being changed in real operation conditions for the system "wheel comb – rail" owing to cyclic recurrence of destructive factors, while choosing lubricants it is possible to neglect the criterion "durability". The third property is a complex of features named as "lubricating properties" [9] and it is evaluated by the friction coefficient, wear of friction surfaces, critical load, sliding velocity and temperature of transition to catastrophic wear. The fourth important property of SL is so called quantity of lubricating material that is not pressed out of the contact – unpressable quantity [10].

By the research carried out and experimentally, it is settled that the fifth main property for SL is the index for ability to increase the resistance of friction surfaces in friction pairs before catastrophic modes of wear [5].

It should be mentioned that the consistency of lubricants do not affect their durability in any way; liquid oils have approximately the same durability as consistent ones but as unpressable quantity is much more lower, the durability of liquid lubricants is four times higher, [10], but they have less adhesive ability and ability to transition; yet mostly they are made on the base of industrial toxic, ecological and explosive, inflammable solvents (gasoline etc.) e.g. RS-6, that is why their use is inappropriate.

Thus, there are following properties responsible for working efficiency of lubricating material in pair "wheel comb – rail" and they are key while choosing them:

- capacity for transition;
- ability to increase the resistance of friction surfaces before transition to catastrophic modes of wear.

The last index at the stage of SL option should be tested in laboratory conditions analyzing resulting factors of ability i.e. weight wear and change in geometrical dimensions of laboratory patterns using integral and differential methods and wear estimation method by initial parameters [6].

In laboratory conditions it is possible to evaluate the ability to transit lubricating material along friction surfaces. It is defined by per cent ratio on unpressable quantity of the material on an upper roll of friction machine (it models friction pair) to its quantity on a lower roll. This way allows estimating the capacity for transition of not only lubricants at whole but also its separate fractions. Various fractions have various capacity for transition. That is why during rolling with creeping there occurs separation of lubricating material into fractions. Liquid fraction stays on a slow roll and a solid one – on a lead roll [10].

It was found that all types of catastrophic wear of tribosystem "wheel comb – rail" are developed only after rather durative sliding. The research states that the longer sliding way is, the more frequently there can be micro cracks, the deeper and wider channels stay on friction surfaces. Dirty friction surface negatively affects the value of this way, especially in cavities of roughness. Positive affect is provided with the presence of protective cover on contact surfaces, presence of specific bodies – microbearings in a contact section, property of lubricating materials, characteristics of contact surfaces (atomic roughness of substances of an active layer, harness, and so on).

While choosing lubricating material, one should take into consideration the fact that when in case of any obstacles e.g. allotropic carbon in cast iron, on the way of processes of catastrophic wear are able to reduce the difficulty level of damage significantly.

It is known that if in friction pair hardness of harder surface exceeds the hardness of key on less hard surface, then catastrophic wear becomes impossible and hardening threshold is increased by several times.

From the mentioned above we can state that better lubricating materials by their tribological properties for on-board lubricants are those which follow such requirements:

- loss of the weight of movable patterns during laboratory testing of chosen lubricating material considering double increase of load is less than analogs have (compulsory);
- geometrical sizes of contact spot of laboratory patterns of chosen lubricant, considering double increase in load during laboratory testing, can be changed with the least intensity (compulsory);
- traces of chosen lubricating material can appear on corresponding friction surfaces of laboratory patterns and all wheels of a locomotive during operational testing (compulsory);
- while testing chosen lubricating material on four-ball friction machine (during an hour on loads 196 and 392 N) on friction surface there can appear servovite film flowing on friction surface to the direction of sliding (compulsory).

The research has proved that main properties of SL fit for the use in the systems of on-board lubricators of rail vehicles should be considered as the following:

- stable composition during keeping;
- homogeneity (not separated into fractions);
- easy slushing (dispersion);
- good holding on a surface (adhesive abiity;
- high moisture repellency (moisture resistance);
- high capacity for transition;
- non thickening in tanks, nipples and sprayers of lubrication systems;
- low meteorological dependence;
- absence in water composition;
- anticorrosive on metals;
- high index of the temperature of dropping point;
- capacity for bio deterioration, ecological and technogenous safety;
- compatibility with lubricating materials from other manufacturers and products made of gum and polymers;
– they satisfy the requirements for manufacturers of lubricators.

Experimental operation of lubricating composition of lubricating oil "Relsol-M", from PLC RU "NVP "Agrinol" (Ukraine), with solid lubricating additives "NT" PLC "MODIFIK" (Ukraine) was held in 2019–2020 in a regional Branch "Prydniprovska zaliznytsia" JSC "Ukrzaliznytsia", in the systems of wheel comb lubrication of a type SPP 12-5, from PLC "Yugtekhnotrans".

Earlier according to the results of development and operational testing carried out by NTU "DP" [11, 12], it was settled that modified NT lubricating material "Relsol-M" outperforms (non- modified) material by 341 % by its antiwear properties basic.

Then, according to the results of operational testing, it was stated that regenerated, homogenized and modified with solid lubricating additives even with an expired shelf life, Relsol-M lubricant retains and demonstrates the "transfer effect" on all wheels of the VL11m/6 locomotive No. 496 (JSC "Ukrzaliznytsia"), and also slows down the intensity of comb wear of bandages of wheels [13], i.e. demonstrates such advantages:

- combs of the bandages which were not chiseled during the tests by 3.57 times;
- combs of the bandages which were chiseled during the tests by 4.25 times;
- on average on all wheels of a locomotive by 2.94 times.

During observation and analysis of material testing [12, 13] it was settled that their results are correlated with accuracy sufficient to accept the methods of development and operational testing [12] by relative simplicity and the degree to renew the results.

It is stated that the mentioned above effect was achieved owing to the presence of solid lubricating additives from PLC "MODIFIK" TU 20.5-001-42277844-2019 in lubricating materials.

In 2021 in the conditions of real operation for rolling stock from JSC "Ukrzaliznytsia" there was held testing for innovative SL "Mariol NT" developed by PLC "MODIFIK" on order by PLC "Yugtekhnotrans". Half-liquid (plastic) material-bearer HT, by technical task from PLC "MODIFIK", was developed by PLC "Kompaniia Slavoil". Starting with August 2020 SL "Mariol NT" has been experimentally produced by PLC "Kompaniia Slavoil" by TU U 23.2-31709624-002:2009 (change 3, 4).

Experimental-industrial application of SL "Mariol NT" at railway facilities of metallurgical and mining industries of Ukraine has been started since April 2021.

During testing, SL "Mariol NT" demonstrated the effect of reducing the intensity of processes for locomotive bandage comb wear in the mode of freight traffic:

- in comparatively easy conditions tracks of Odeska zaliznytsia (DEPOT TP 7, Znamianka) JSC "Ukrzaliznytsia" – by 2.5 times;
- in more complicated conditions tracks of Pivdenna zaliznytsia (DEPOT Kupiansk,) JSC "Ukrzaliznytsia" – by 5 times.

This proves that the index of the SL ability to increase the resistance of friction surfaces in friction pairs before catastrophic modes of wear is determinant while choosing lubricating material. If the material is chosen properly, then the more complicated operation conditions are, the bigger the coefficient of slowing down for the comb wear processes is.

By the decision of Scientific-technical council of JSC "Ukrzaliznytsia" (of 26.05.2021) SL "Mariol NT" was recommended for usage in lubrication system like GS-3 and SPP 12-5 and others (contactless oils), with the help of which traction rolling stock of JSC "Ukrzaliznytsia" is equipped.

For the first time in Ukraine, the conducted research allowed formulating basic requirements for SL of railway facilities and rail transport enterprises, which are shown in the Table.

However, the efficiency of lubricating wheel combs for rail vehicles depends not only on SL parameters but equipment and possibilities of lubrication systems – rational lubricating mode in order to obtain maximal tribological effect from this process.

The present systems for comb lubrication operate with surplus reserve for lubrication reliability, which is achieved by much bigger consumption of lubricating materials than it is necessary for concrete conditions, i.e. always the same on sections with short (when the need in lubrication increases) and long radius of track curvature (when the need in lubrication reduces), as well as straight sections. Usually, the system gives cyclically maximum large quantity of lubricants for guaranteed wheel comb lubrication. It causes additional financial costs, pollutes the area around rail tracks to a greater extent.

In general view the control system for lubrication devices mounted on rail vehicle has to operate according to the algorithm demonstrated in Fig. 1.

The system is activated (either by the command of locomotive driver or automatically) after starting the motion of a vehicle and further works automatically. Transmitter straight-curve gradually calculates radius of curvature for rail track in a plan. If it (radius) is close to infinity, it means that motion is made along track section which can be considered as straight.

Transmitter of velocity measures this index and if the velocity is not so high, (e.g. to 10 km/h on a straight or to 5 km/h on a rounding of rail way), then it means that a vehicle starts motion or stops or is in the state of maneuver. At this time wheel comb lubrication is not necessary as their interaction forces with inner side faces of rails are not significant, but occasional getting of lubricant from lubrication system into roll-

Table

Main indexes of lubricating materials

No.	Name of index	Value	Control method
1	Penetration at +25 °C by mixing (60 double strokes), mm · 10^{-4}	380–480	GOST 5346* Method B
2	Viscosity is efficient: - at $t = 20$ °C and average deformation velocity 10 s^{-1}, Pa · s, not less - at $t = -30$ °C and average deformation velocity 10 s^{-1}, Pa · s, not more	6 200	GOST 26581* GOST 7163*
3	Creep temperature, °C, with thickness of layer of lubricating material 0.5 mm, not less	50	GOST 6037*
4	Corrosion influence on metals	Stands	GOST 9.080*
5	Temperature of drop falling, °C	180	GOST 6793*
6	Water weight part, %	Traces	GOST 2477*
7	Tribological properties on four-ball wear machine (GOST 9490-75), Welding load (P_w), N, not less	2400	GOST 9490*
8	Antiwear properties (D_{w1}) with load 196 N/392 N and at 20 ± 5 °C, mm, not more	0.55	GOST 9490*
9	Degradation rate – ability of lubricants to increase the resistance of friction surfaces before transition to catastrophic modes of wear U_d, %, not more	19	GOST 9490* SOU (STE)**
10	Degradation rate – ability of lubricants to increase the resistance of friction surfaces before transition to catastrophic modes of wear, defined by the loss of the weight of rolling pattern, by scheme disk – boot-tree, on friction machine SMTS2, %	The least among lubricants to be tested	SOU (STE)**
11	Compatibility with polymeric materials and gum	Compatible	NTD*** on SL
12	Compatibility with lubricants of other lubrication systems (movable, permanent)	Compatible	NTD*** on SL
13	Ability of lubricating material to transition, %	100	SOU (STE)**
14	Durability of axles, units, not less	260	SOU (STE)**
15	Weight part of solid lubricating additives TU 20.5-001-42277844-2019 with the size of particles ≤50 mkm (depending on origin and operation conditions of friction pair), %, within the limits	2	NTD*** on SL

Notes: 1.*GOST [69–76] – standards of the former USSR, their validity in Ukraine is gradually being stopped, but as analytical methods they have been worked out for years and they deserve to become temporarily the elements for standards of organizations in Ukraine during the period of the issue of new documents or follow domestic and European laws on standards and physical-chemical properties of SL

2.**SOU(STE) – standards for organizations (enterprises, institutions) of Ukraine.

3.***NTD on SL Normative-technical documents on producing lubricants that are being tested

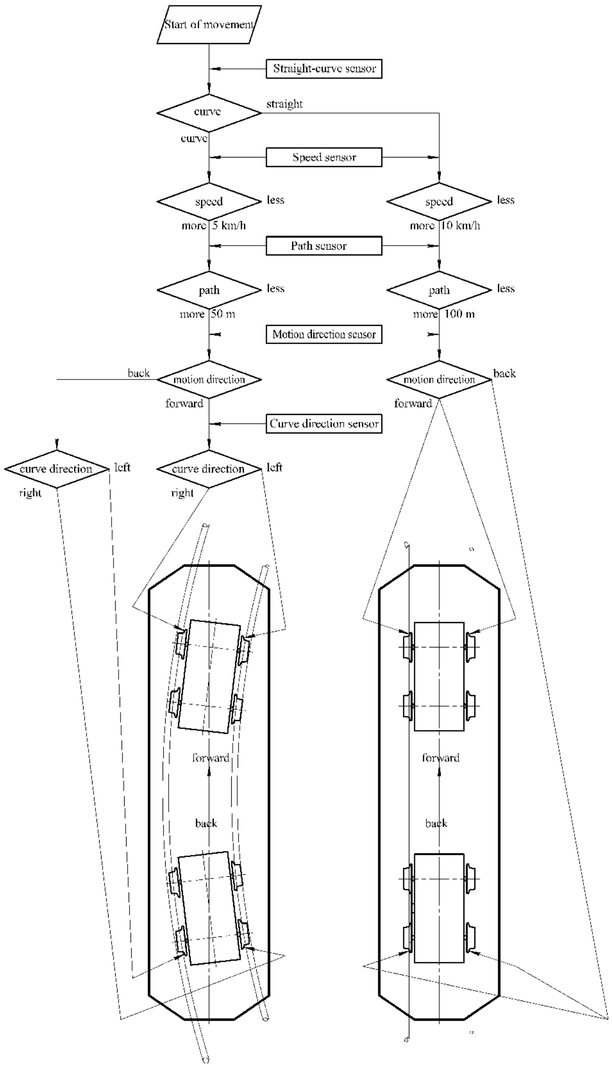

Fig. 1. Algorithm of operation of lubrication system for rail vehicle

ing tracks of wheel bandages can cause the reduction of the coefficient of wheel coupling with rails and accordingly to the loss of traction or braking effort of driving wheels of a vehicle. If the velocity gets faster than the values given above, then it can be thought that a vehicle is in the state of constant motion and it is necessary to measure the length of way which it runs.

Depending on the radius of curvature of rail track section and velocity of a vehicle e. g. each 50 meters run on the turning of rail track, it is necessary to switch lubrication system to give necessary quantity of lubricant into wheel combs. Usually, such injections are sufficient for lubrication of all perimeter of wheel comb. It is necessary to lubricate wheel combs on straight sections of rail track as through ends of wheel bandages there can be cross oscillations of wheel pairs even during the motion on straight sections (it is thought that the contact of wheel flange with inner side faces of rails happens approximately every 18 meters). That is why switching the system of comb lubrication can be made more seldom, e.g. each 100 meters for run way at the same velocity.

Usually, it is enough to lubricate combs of only running wheels of a vehicle as interaction of their combs with rails happens with the greatest efforts (and as a result they are worn faster), and the rest of lubricant on side faces of rails is sufficient to lubricate combs of other wheels of a vehicle and even set of cars in a train. So, it is necessary to turn on sprayers of lubrication system which are mounted exactly on running wheels. Transmitters of motion direction defines where a vehicle runs – forward or back. It is enough for corresponding sprayers of lubrication system to start to work on a straight section of rail track. But if the motion is on a curve section, then it is necessary to define the direction of track turning – right or left.

All transmitters necessary for stable operation of the system comb lubrication are already known. There are even several varieties of them on the principle of action and determination of necessary parameter. However, transmitters defining the radius of curvature of rail track give the result only when a vehicle has already entered curvilinear section of rail track. They are either transmitters of a truck with wheel pairs on a certain angle relatively a frame or the systems which calculate cross slope of rail track (outer rail on curvilinear section must be higher than inner one), or define an afferent acceleration. Experience of the operation for lubrication systems makes sure that it is necessary to lubricate wheel combs in advance when a vehicle is still on a straight section. So, the way of controlling the system of wheel comb lubrication for rail vehicle or/and surfaces of rails of tracks has been proposed [14]; it allows switching the lubrication system in advance to reduce explosive increase in forces of the interaction of combs and rails while entering a rail vehicle on a curvilinear section of a rail track as well as on turnouts.

Railway track (Fig. 2) in a general case has straight sections *1*, transition curved sections *2* and sections with constant radius of curvature *3*.

Enter on a straight section *4* usually is equipped as a transition curve *2*. A vehicle *5*, equipped with the system of wheel comb lubrication and/or side faces for rolling track rails can work on a straight section in an economical mode – not lubricating wheel combs at all or partially to prevent nonessential wear of wheel combs during their cross oscillations on conical wheel bandages.

In order to reduce the wear for wheel combs and flanges in a curve or reduce the moments of resistance for the turn of car trucks connected with a locomotive, before its beginning on a rail track it is proposed to mount, in advance, markers *6*, which operate as usual (e.g. with the help of magnetic, electromagnetic, optical, infrared effect on receiver *7*, mounted on a vehicle *5*). The system starts to lubricate combs of corresponding wheels and/or surfaces for trach rail rolling with intensity necessary for motion on a curved section of a track rail. The indicated markers *6* are mainly non active (they do not have power supply source and are made of cheap plastics with a slight addition of special materials). To define the beginning of a curved section with the left turning there can be two turnings but with the right turning – three. The distance between markers must be the same e.g. 1 m), the system of lubrication if necessary could calculate the velocity *V* of the motion of a vehicle and choose necessary intensity of injection of lubricating material on wheel combs and/or flanges.

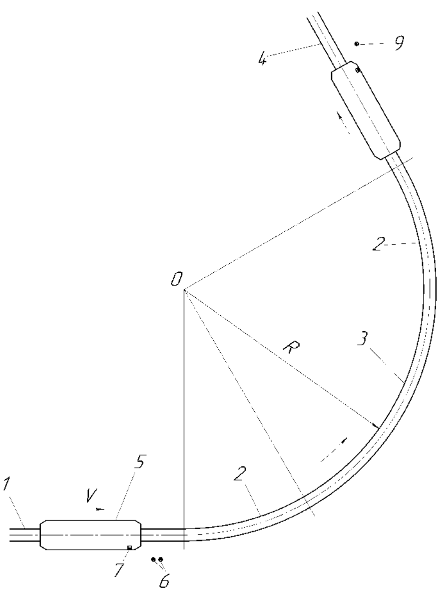

Fig. 2. Entry of a rail vehicle to the curved section of a rail track

After the end of curved section of a track e.g. one marker 9 can be set in advance so that the system can start its operation corresponding to the motion on straight sections of a track.

On a rail track there are defective sections where vehicles have to reduce the velocity of motion because of the possibility of rolling stock to run off the tracks owing to the run over of wheel combs on the top of a rail. The length of the given sections on the tracks of JSC "Ukrzaliznytsia" exceeds 20 % now. The run of such a section as well as a turnout (Fig. 3) is accompanied by increased wear of wheel combs and/or flanges. For its prevention the system of lubrication is controlled with the help of mounted markers at advance.

Before a turnout or defective section there can be mounted two (left connecting track) or three (right connecting track) markers *6*, and a receiver *7* mounted on a vehicle reads out such information and sends it to the system of lubrication. Behind a turnout or detective section there can be mounted, in advance, marker *9* which signals about the end of defective section of rail track or turnout. It is possible to mount four markers before the beginning of a turnout or defective section to switch the system of lubrication simultaneously for right and left wheels and/or flanges.

The mentioned above markers *6* and *9* can be mounted either between rails (for sections of rail track with non-reversible motion or at the side of rail track e.g. on the right by the direction of motion. Accordingly, at reversible motion on the section of rail track such markers will be mounted on both sides of a track. Moreover, marker (e.g. with the use of a barcode) can have the information about the beginning or end of section where the system of lubrication can go off or turning direction (connecting track), recommended velocity and/or the radius of curved section of the track which will be run by a rolling stock, and receiver mounted on a vehicle reads out such information and sends it to the system of lubrication.

The proposed principle of the action of lubrication system ensures the lubrication of wheel combs of rail vehicle and/or flanges, and/or surfaces for rolling rails with necessary intensity while running curved sections of a track, turnouts or defective sections, but on straight sections lubrication system is in economical mode; thereby, it ensures significant economy of lubricating materials.

The obtained results can be used in the modernization of other lubrication points for vehicles [15, 16] as well as in neighboring branches of industry [17, 18] and in manufacture of such systems [19, 20].

Conclusions.

1. For the first time in Ukraine, the requirements for basic properties of lubricants have been settled. They are suitable to be used in on-board lubricant systems for rail vehicles.

2. Generalized algorithm for controlling lubrication system devices for rail vehicles is developed.

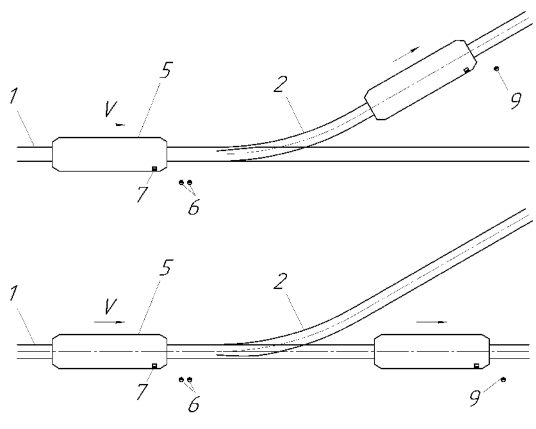

Fig. 3. Run of a vehicle on the section of a rail track with turnout

3. A technique for controlling lubrication system for wheel combs of rail vehicle and/or rail surfaces is proposed which allows switching lubrication system in advance in order to prevent an increase in the interaction forces of the wheel flanks and rails during the entry to the curved section of the rail track, as well as on the turnouts.

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Мастильні матеріали рейкового транспорту рідкі (пластичні) для пари тертя «колесо–рейка»

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Мета. Сформулювати вимоги до базових властивостей мастильних матеріалів, що є придатними для використання в системах бортових лубрикаторів рейкових транспортних засобів. Розробити узагальнений алгоритм керування приладами системи лубрикації рейкових транспортних засобів і запропонувати спосіб керування системою змащування гребенів коліс рейкового транспортного засобу, що дозволяє вмикати систему завчасно, щоб упередити зростання сил взаємодії гребенів коліс і рейок під час в'їзду рейкового транспортного засобу на криволінійну ділянку колії, а також на стрілочних переводах.

Методика. Методи досліджень – статистичний аналіз результатів експериментальних випробувань властивостей існуючих і запропонованих мастильних матеріалів на машині тертя СЦ-2 і в умовах реальної експлуатації рухомого складу АТ «Укрзалізниця».

Результати. За підсумком експлуатаційних випробувань встановлено, що регенерований, гомогенізований і модифікований твердозмащувальними домішками, навіть із вичерпаним терміном придатності, мастильний матеріал Рельсол-М зберігає й демонструє «ефект переносу» на всіх колесах локомотиву ВЛ11м/6, а також уповільнює інтенсивність зношування гребенів бандажів коліс, що не обточувалися протягом випробування, у 3,57 рази, а гребені бандажів, що обточувалися протягом випробування, – у 4,25 рази. «Mariol NT» продемонстрував ефект зниження інтенсивності процесів зношування гребенів бандажів локомотивів у режимі вантажного руху в порівняно легких умовах колії Одеської залізниці у 2,5 рази; а у більш складних умовах колії – у 5 разів.

Наукова новизна. Сформульовані вимоги до базових властивостей змащувальних матеріалів, що є придатними для використання у системах бортових лубрикаторів рейкових транспортних засобів.

Практична значимість. Розроблено узагальнений алгоритм керування приладами системи лубрикації рейкових транспортних засобів і запропоновано спосіб керування системою змащування гребенів коліс рейкового транспортного засобу, що дозволяє вмикати систему лубрикації завчасно перед в'їздом рейкового транспортного засобу на криволінійну ділянку колії, а також на стрілочних переводах.

Ключові слова: *мастильні матеріали, лубрикація, твердозмащувальні домішки, показник деградації, рейкова колія, гребінь колеса*

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