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Impact of the type of a contaminant on electric resistance of treated track ballast

The article deals with an impact of the type of a contaminant in track ballast on the value of its electric resistance. The authors propose to treat crushed stone with organic materials before laying it down onto the track to decrease the sticking of contaminants to the ballast layer. The study has determined that electric resistance changes according to the type of coating on crushed stone grains and the type of mineral fertilizers transported by rail. Such coating can be proposed for treating clean crushed stone before laying it down onto the track during repair periods in order to extend the life cycle of a ballast layer, prevent its adhesion contamination and eliminate the erroneous occupancy of track circuit.

Keywords: track ballast, mineral fertilizers, electric resistance, track circuit, train delays.

Higher intensity and increased speeds of the train traffic require more reliable operation of all elements of the permanent way. The tracks carrying transportation and transshipment of mineral fertilizers are in a poor state and subject to track circuit failures. Deterioration in ballast is caused by its higher contamination and moisture of the contaminants. Contamination is the result of wearing sharp edges of the crushed stone granules (even in solid granite materials) under constant movement of trains. Besides, the contamination level depends on the nature of transported freight, rail track profile and other factors.

Improvements in the permanent track may be attained by cleaning and trimming the ballast, cleaning rails and rail fastenings from contaminants, replacement of drainage systems at block sections if needed, overhaul of the track in order to replace the permanent way and rails serviced the normative tonnage load [1]. Such measures, though improve track circuit isolation, do not actually influence the automatic block system operation while traffic capacity of railway hauls and stations decreases through train delays, longer wastes and higher wagon turnovers.

Analysis of recent research and publications

Publication [2] is devoted to investigation into processes and regularity of changes in track circuit isolation in time, development of methods to evaluate electrical insulating properties of ballast materials and study into efficiency of various methods to restore insulation; the author studied wooden ties rested on sand and asbestos ballast. But gradually these types of ballast were replaced by crushed stone ballast and reinforced ties with the same amount of failures in track circuits and intensive ballast contamination. The contamination includes remains of transported freight, mineral and organic additives, dissolved salts, fertilizers, leakages from tanks while filling, transporting and settling due to defects in barrels, draining facilities of tanks, etc.

Closed electric circuits may lead to delays in delivery of cargo from consigners to consignees due to contamination from transported freight and contamination of the permanent way. The best solution to avoid salinity of the track is elimination of freight spillage during transportation and transshipment [3], which is ideal for the railway industry and clients; or to develop an innovative method requiring minimum financial investments to obtain the best resistance when contaminants accumulate on the track.

It is known that a rail line is the main element of a track circuit and specifies its operational mode and properties which depend on primary parameters: electric resistance of insulation and electric resistance of rails [4].

The electric resistance of rails ZRC, i.e. the resistance of track circuit, formed by both track rails is defined by the formula:

$$Z_{RC} = Z_r + \left(Z_c + Z_s\right) \tag{1}$$

where:
Z_r is the rail resistance,
Z_c is the resistance of the connector and depends on the types of connectors used and consists of the resistance of the connector itself and transient resistance between the connector and the rail;
Z_s is the transient resistance between the shins and the rails, which depends on a contamination level of rust intensity on contacting surfaces of the plates and rail ends, tightening of bolts and weather conditions. This parameter can change in a wide range: from tenths to hundreds Ohms. Thus, the state of connectors, shins and tightening of bolts considerably determine rail resistance under direct signal current, i.e. stability and reliability of track circuits.

Electric resistance of rail line insulation is effected by the leakage current from one track rail to the other one through the tie Il.t. and ballast Il.b. The resistance is determined by the construction and state of the permanent way. Track circuits are rails located on ties close to the soil and contact it through metal elements of upper fastenings (pads, spikes, screws, anticreepers), and the ties themselves are located in the ballast layer, rested on the road bed. Due to such a structure the rail line is an electrochemical system with elements of electronic and ionic conductance with complex metal electrodes. All metal elements of upper fastenings have electronic conductance, while ballast, ties, road bed and soil – ionic conductance. Therefore, the total insulation resistance of a rail line is defined by resistances of the current running through the ties and ballast, and also the resistance of transition layers formed on the boundary between the elements of electronic and ionic conductance.

The ballast resistance depends mostly on humidity, when the temperature raises the processes in the electrodes accelerate, and the resistance of the electrolyte decreases, thus decreasing the resistance of the ballast. So, the maximum ballast resistance occurs in winder, when two factors act simultaneously: low temperature and low humidity.

The minimal resistance usually occurs in summer in hot weather, 8–10 min after a pouring rain, at high temperatures and critical humidity.

Penetration of salts with active ions (minerals fertilizers) into electrolytes rapidly decreases the ballast resistance and, as a consequence, the reliability of a track circuit as well [5]. Study [6] describes the ionic strength effect on electrical conduction.

Research [7] deals with the impact of changes in ballast resistance on the total insulation resistance by using wooden ties in dry and wet states. Special attention is given to zones of transportation of salts, mineral fertilizers, metalliferous substances, as well as the areas of total precipitation of more than 3,000 hours per year.

For bulk materials, unlike for solid ones, the value of electric resistance is greatly depends on porosity as was established in [8]. Studies [9, 10] demonstrate that electric conduction of composites depends on the concentration of filler in a material.

Earlier, the authors of [11] stated that depending on the type of coating on crushed stone grains the value of specific electric conduction can change several times and proposed treatment of clean crushed stone before its laying onto the track, not taking into account the contaminants. The similar method was described in [12], where carbon fibers were treated with epoxy resin in order to increase electric resistance of the whole composition. The difference between contaminated and clean materials was defined in [13] according to the value of electric charge, which testifies that the method can be used for studying electric properties of clean and contaminated crushed stone.

Purpose of the research

Investigation into impact of surface treatment of crushed stone on specific electric conductivity of a ballast layer to avoid erroneous occupancy of the track in mass transportation of mineral fertilizers.

Statement of the basic material

The study defines the electric conductivity of treated crushed stone by the following technique. Samples of crushed stone were poured with distilled water in proportions regulated by [14] and mix thoroughly until saturated solution has been obtained. The saturation of the solution was defined by regular measurements of its electric conductance in a measuring container, until the electric conduction of the solution gets stability. The constant electric conduction of the solution testifies that the solution is saturated.

The measuring device makes it possible to obtain values of the electric resistance R, Ohm, of the saturated solution. The electric conductivity σ was defined by the formula:

$$\sigma = \frac{56{,}25}{R} \qquad (2)$$

where R is the electric resistance of the saturated solution, Ohm; 56.25 is the coefficient which is constant for a measuring container.

Electric conductance has been defined for the clean and contaminated track ballast. In order to study the influence of coating on electric conductance, the surface of crushed stone was coated with the following materials: bitumen, colophony and colophony-glycerine mixture, lacquering coating, bitumen roof mastic, acrylic coating and silicone. The modeling of real conditions under which the track ballast work required the study of mineral fertilizers, such as potassium chloride (white), potassium chloride (grey), ammonium nitrate phosphate fertilizer ($NH_4H_2PO_4$+NH_4NO_3+KCL) and ammonium nitrate (NH_4NO_3). Values of the measured specific resistance of the samples of crushed stone with various coatings are given in Table. The sticking of a fertilizer's granules and their dissolution in film water on the surface of crushed stone decrease its electric resistance and can signal about erroneous occupancy of the track. Evaluation of stuck mineral fertilizers was conducted as follows. Crushed stone grains with coating on them were placed in certain fertilizers for 5 days. Later, in accordance with the above-described technology the electric resistance of the solution, obtained by putting the crushed stone into distilled water, was measured. The more contaminants on the surface of the crushed stone remained, the more saturated the solution was, and the less resistance it had to the running current. Thus, evaluating resistances of the obtained solutions one can choose the best coating according to the highest resistance.

Discussion of the results

The Fig. gives dependencies of electric resistance for various solutions with crushed stone of various coatings on them. The numbers of samples correspond to the ones given in the table. For all types of fertilizers the most appropriate has proved to be silicon coating. The hydrophobic behavior of the given coatings prevents sticking of salts and therefore does not reduce electric resistance of the track circuit, which is crucial for correct operation of signaling systems.

Tab. 1. Specific resistance of the samples

Numbers of the samples	Samples	Specific resistance, Ohm·м
1	Clean crushed stone	43,5
2	Contaminated crushed stone	90,9
3	Clean crushed stone with bitumen	111,1
4	Contaminated crushed stone with bitumen	100,0
5	Clean crushed stone with colophony mixture with glycerine	333,3
6	Contaminated crushed stone with colophony mixture with glycerine	125,0
7	Clean crushed stone with colophony mixture without glycerine	250,0
8	Clean crushed stone with varnish	17,9
9	Contaminated crushed stone with varnish	100,0
10	Clean crushed stone with bitumen roof mastic	43,5
11	Contaminated crushed stone with bitumen roof mastic	41,7
12	Clean crushed stone with acrylic primer	83,3
13	Clean crushed stone with silicon	166,7
14	Contaminated crushed stone with silicon	250,0

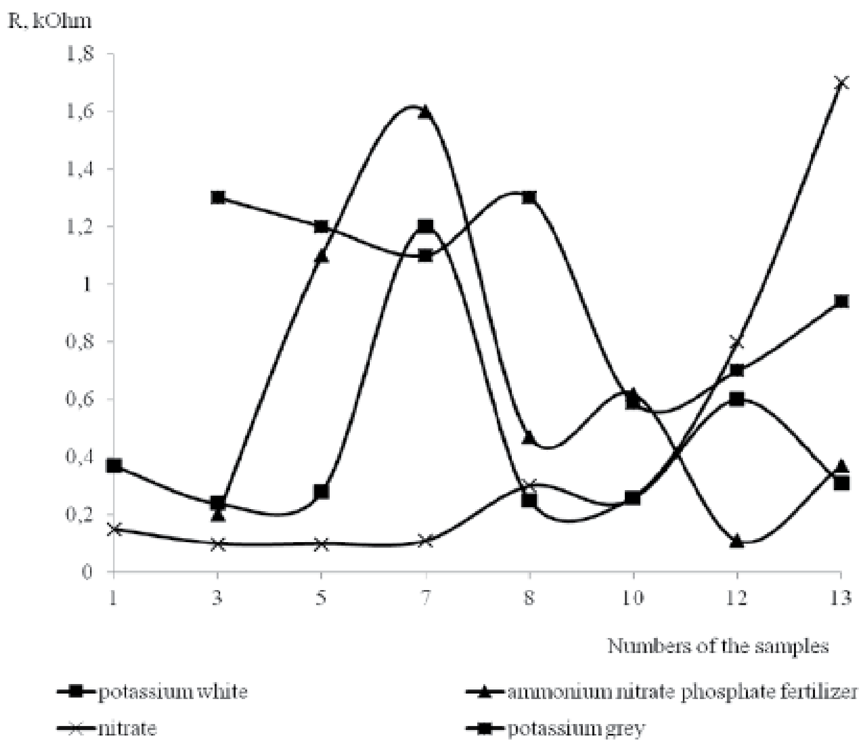

Fig. *Depencency of electric resistance on the type of a crushed stone's coating*

Conclusions of the research

It has experimentally been proved that coating of track ballast with organic substances influences its electric conductance. The maximum effect in decreasing the specific electric conduction has been observed for colophony-glycerine and silicone coating. The least sticking is peculiar to potassium chloride (grey) and ammonium nitrate which is testified by low electric conduction of these samples. Protective coating decreases electrical conduction of track ballast even when transported mineral fertilizers spill on the track; it improves reliability of track circuit.

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Wpływ rodzaju zanieczyszczenia na rezystancję obrobionego balastu żwirowego

W artykule rozpatrzono wpływ rodzaju zanieczyszczenia żwiru balastowego na wielkość jego rezystancji. Zaproponowano dla zmniejszenia przylepiania się zanieczyszczeń do warstwy balastowej obrabiać żwir przed układaniem do drogi kolejowej materiałami organicznymi. Ustalono, że rezystancja zmienia się w zależności od rodzaju pokrycia na ziarnkach żwiru i od rodzaju nawozów mineralnych, jakie są transportowane koleją. Takie pokrycie może być zaproponowano dla obróbki czystego żwiru przed jego układaniem do drogi kolejowej podczas remontów dla przedłużenia terminów eksploatacji warstwy balastowej, uprzedzenia adgezyjnego zabrudzenia i likwidacji wypadków błędnej pracy obwódu torowego.

Słowa kluczowe: *żwir, nawozy mineralne, rezystancja, obwód torowy, opóźnienia pociągów.*