Researches of influence of electric current on tribounit "Wheel-rail"

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S u m m a r y In-process studies of influence of electric current passing through the contact of two interactive rollers on their wear at varying of size of strength of current and attached loading are undertaken in and experimentally theory, and also the coefficient of friction is certain at the different friction states of surface of rail.
Experimental studies are undertaken an on the machine of proof-of-concept SMC-2 on PAT "Luganskteplovoz", and also on the automated instrumentation-designing stand setting "Machine of friction" in a laboratory on the department of railway transport of the Volodymyr Dahl East Ukrainian National University. The mechanism of influence of electric current is educed on tribounit, what application of this method allows to ground for the increase of coupling in the system "wheel-rail".
K e y w o r d s : electric current, coupling, heat, electric wear, mechanical wear, coefficient of friction.

INTRODUCTION

From processes what be going on in the contact of interactive inter wheels and rail, efficiency of hauling rolling stock depends on the whole [1-5]. The size of coefficient of friction renders large influence on the terms of co-operation in the system "wheel-rail" and, in the end, on the running expenses of railways [6, 7, 14].

For the improvement of coupling internals of locomotives on a railway transport apply a method that consists in the serve of sand in the zone of contact of wheels with rails. Depending on the state of contacting surfaces of wheels and rails, such method can provide 30% increase of coefficient of rolling friction [2, 8, 12]. In spite of obvious dignities, application over of sand his use brings and to the negative consequences: contamination sand of ballast prism, to 20% to the increase of resistance of motion [9, 10, 11, 13], in addition, sand is the strongest abrasive and considerably influences on the wear of wheel and rail increasing an adhesion and abrasive wear, that in turn effects on safety of motion of rolling stock. In accordance with the programs of Ukrzaliznytsia introduction of high-speed motion requires the search of energy effective methods and methods of increase of coupling with the least affecting environment.

Analyzing the existent methods of improvement of friction co-operation of wheel it is set with a rail (Fig. 1), that providing stably of high coefficient of rolling friction in the zone of contact of wheel with a rail can be attained by two methods - cleaning of contacting surfaces from contaminations or introduction to the zone of contact of different substances (activators).

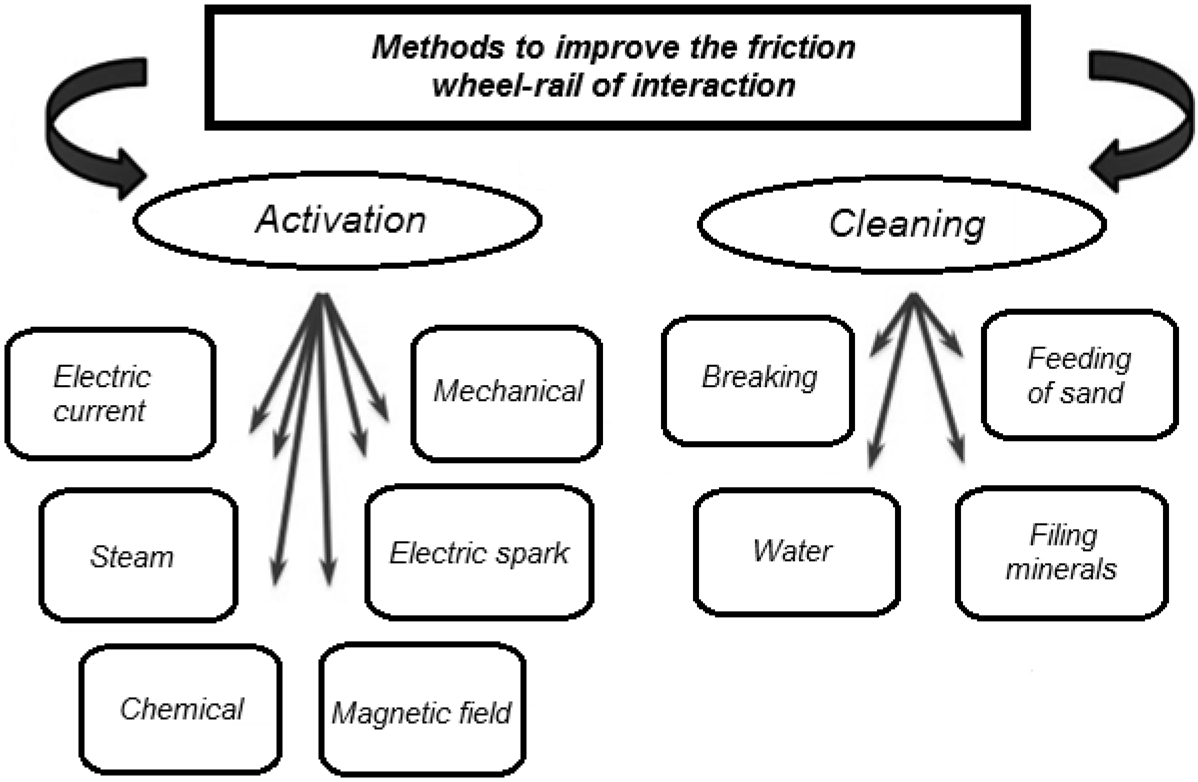

Fig. 1. Methods of improvement of friction cooperation of wheel with a rail

Researches are known sent to the search and development alternative to sand of methods of increase of coefficient of rolling friction is the use of modifiers of friction [15, 16, 17, 18], surfactants substances [19, 20], activators of friction [21, 22].

In-process [23], influence of electric current passing through a contact is investigational, on his tribology properties. The prospect of this method by implication is confirmed by the data got during exploitation of electric locomotives. It is set that their maximum coefficient of rolling friction higher on 8% at diesel engines that is probably related to the key-in of electric current through the contact of wheel with a rail [14]. However, conducted analysis of literary sources as in our country so showed abroad, that research on determination of influence of electric current on worn down of pin pair "wheel-rail" not conducted.

Aim of the article: Determination of influence of electric current on friction properties of contact "wheel-rail".

Materials and research results.

For research of processes a leak in a contact "wheel-rail" at flowing of electric current it is necessary to conduct their detailed analysis. One of parameters, characterizing the process of contact of wheel with a rail is warm, distinguished here.

In ground of tribounit, warm, distinguished at a friction is the result of friction of skidding that results in a mechanical wear. At a key-in through the pin pair of electric current additionally distinguished warm, that heats tribounit also. It is related to that the real contact of wheel with a rail will be realized not on all surface of interface, and only in a few points total area of that, and is the real surface, because of what at the key-in of electric current, there is transitional resistance or resistance of narrowing. Flowing of electric current through a contact, possessing transitional resistance, causes his heating. As a result of heating of pin zone there are current bridges appearing between contiguous rollers are melted, material evaporates or burns down. As a result there is an electric wear.

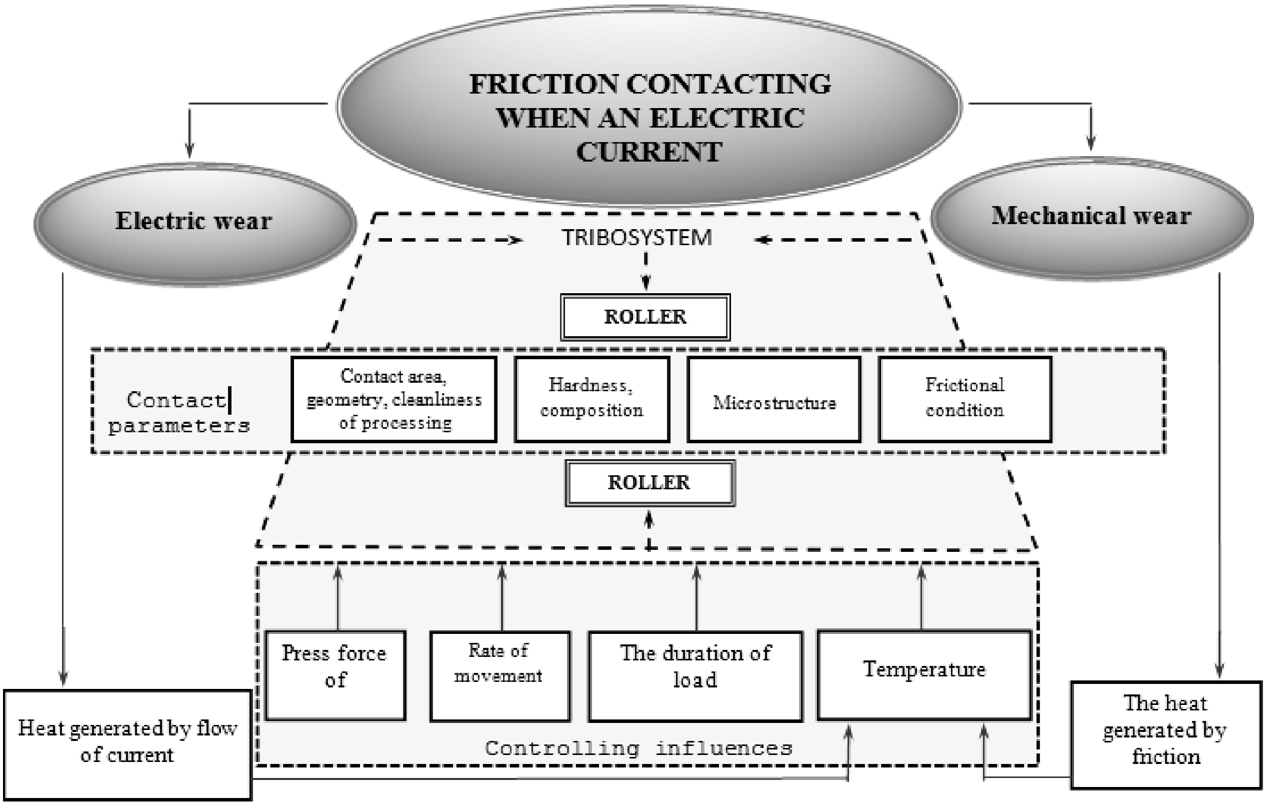

Fig. 2. Block diagram of processes in the contact under the influence of electric current

Thus, at the key-in of electric current in tribounit except a mechanical wear observed electric wear (Fig. 2), size and character of that is in a great deal determined by efficiency and perspective of this method of increase of coupling.

Theoretical pre-conditions of influence of electric current on the size of wear of tribounit were fixed in basis undertaken studies presented below.

Basic data at the design of mechanical wear it was been: loading on the standard of P, H; radius of spherical surface of r, m; speed of skidding of v, m/s; time of test, t, s; hardness of contacting materials of H1 and H2; heat conductivity of material of pin element λ1, W; specific heat capacity of material s, J/K [8, 9]. That allowed to define the size of mechanical wear of tribounit:

$$i_{м} = P \cdot \left[e^{\alpha} \cdot \left(\frac{P \cdot t \cdot c}{r^2 \cdot \lambda_1} \right)^{\beta} \cdot \left(\frac{v \cdot t}{r} \right)^{\gamma} \cdot \left(\frac{H1}{H2} \right)^{\varepsilon} \right],$$

where $\alpha, \beta, \gamma, \varepsilon$ – coefficients determined experimentally.

Influence of electric constituent is examined, as an additional external parameter of tribounit, that affects descriptions of contact. A general electric wear is determined by dependence [25]:

$$W = sP\left(W_0 + W_1 \sqrt{I/10} \right).$$

Taking into account higher expounded an electric wear is equal:

$$i_{Э} = \left[\gamma Q + \frac{sP}{9.81} \cdot \left(W_0 + \frac{k1}{P^{k2}} \cdot \left(\sqrt{\frac{I}{10}} + k3 \cdot \sqrt{\frac{Q}{s}} \right) \right) \right] \cdot \rho \cdot 10^{-6},$$

where: k1, k2, k3 – coefficients chosen from tables [23],

Q – amount of heat, J,

P – pin pressure, H,

ρ – density of material, kg/m3.

The results of design of mechanical and electric wear are presented on a Figure 3.

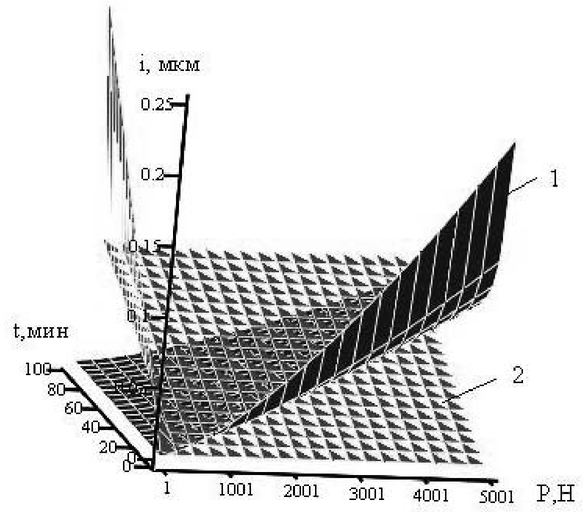

Fig. 3. Dependence of the attached loading (P, H) and wear (i, mkm) in time (t, s) at passing of electric current through a contact "roller-roller; 1 – electrical wear (ie), 2 – mechanical wear (im)

At a design influence of electric current is certain in time on the wear of the investigated standards (Fig. 3). An electric wear (surface 2) prevails at the small vertical loading that is investigation of presence in the pin pair of the undestroyed contaminations possessing high transitional resistance. With the increase of loading and destruction of contaminations transitional resistance falls, amounts of heat of distinguished in a contact diminishes, and an electric wear goes (surface 2 (Fig.3)) down.

A mechanical wear (surface 1 (Fig.3)) increases with the increase of loading, that confirmed by researches [26, 27].

For confirmation of basic conformities to law of influence of electric current on a wear tribounit "roller-roller" experimental studies are undertaken on the proof-of-concept machine of SMC-2 (Fig. 4).

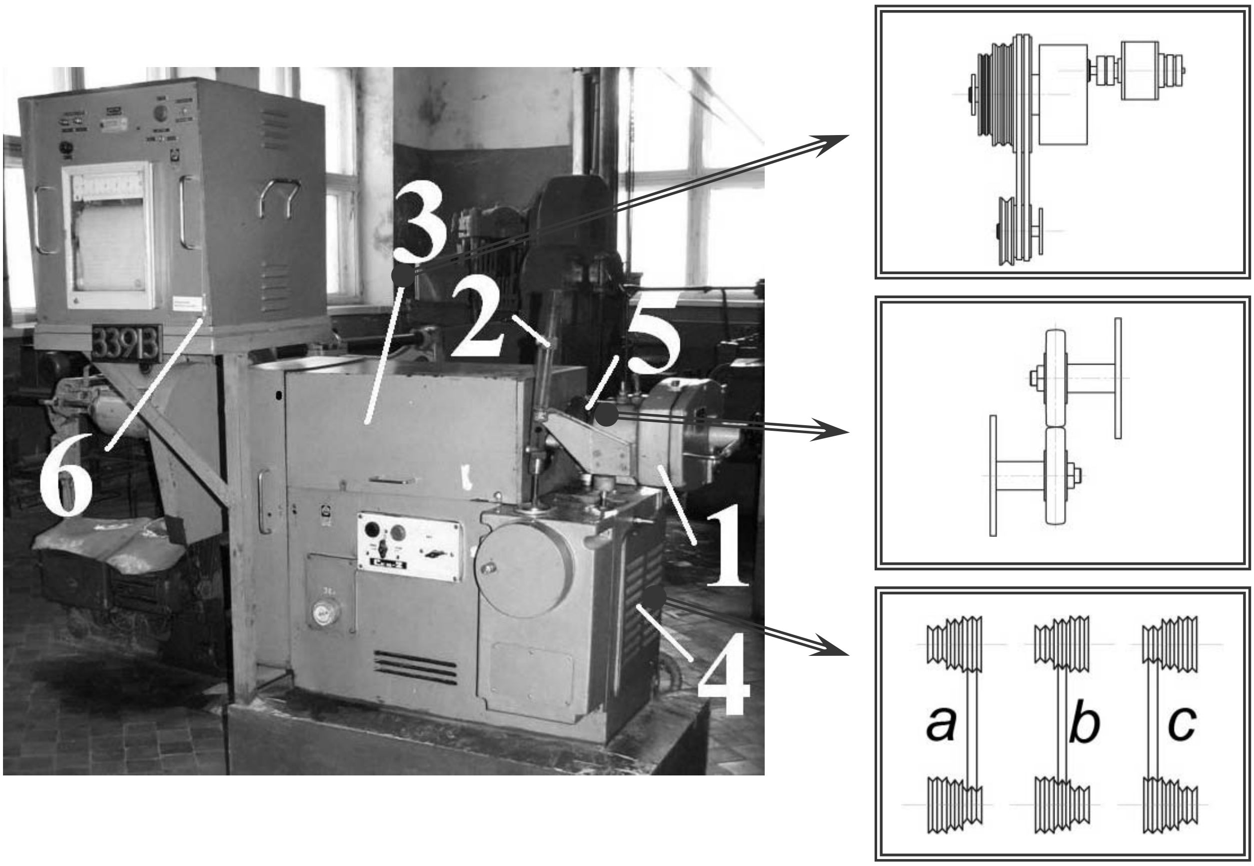

Fig. 4. test machine SMC-2
1 – carriage 2 – loading mechanism 3 – wheel drive, 4 – belt transmission (a – 300, b – 500, c – 1000 rev/min), 5 – system "movie-movie"; 6 – electronic unit

The machine of model of SMC-2 (Fig. 4) is intended for the tests of materials on a wear and determinations of their friction properties at a friction skidding and wobbling in the conditions of normal temperature in the pair of friction "roller-roller" and additionally equipped by the system of serve of electric current (Fig. 5), that includes:

- a transformer TDM–500,
- a transformer of current,
- an ammeter.

Turn-downs of parameters of work of SMC-2 here were in next limits:

- frequency of rotation - 300, 500, 1000 turn/mines,
- a coefficient of slipping of round standards with identical diameters – 0, 5, 10, 20%,
- a range of measuring of loading – 0...5 кН.

As experimental standards the rollers made from collotype bracer steel were used. Overhead and lower rollers have an outward diameter a $40 \cdot 10^{-3}$ m, internal diameter a $16 \cdot 10^{3}$ m and breadthways a $10 \cdot 10^{-3}$ m, hardness of surfaces makes according to 269 HB and 350 HB, the cleanness of treatment corresponds 7 to the class concordantly GOST 2785-75.

The aim of experimental researches was determination of work of forces of friction in a contact "roller-roller" at a leak through him electric current on conditions of close to the real contact "wheel-rail".

The way of friction was determined on dependence:

$$S = 2b \cdot \frac{V_1 - V_2}{V_1} \cdot n \cdot t \,,$$

where: b – semi width of plane of contact:

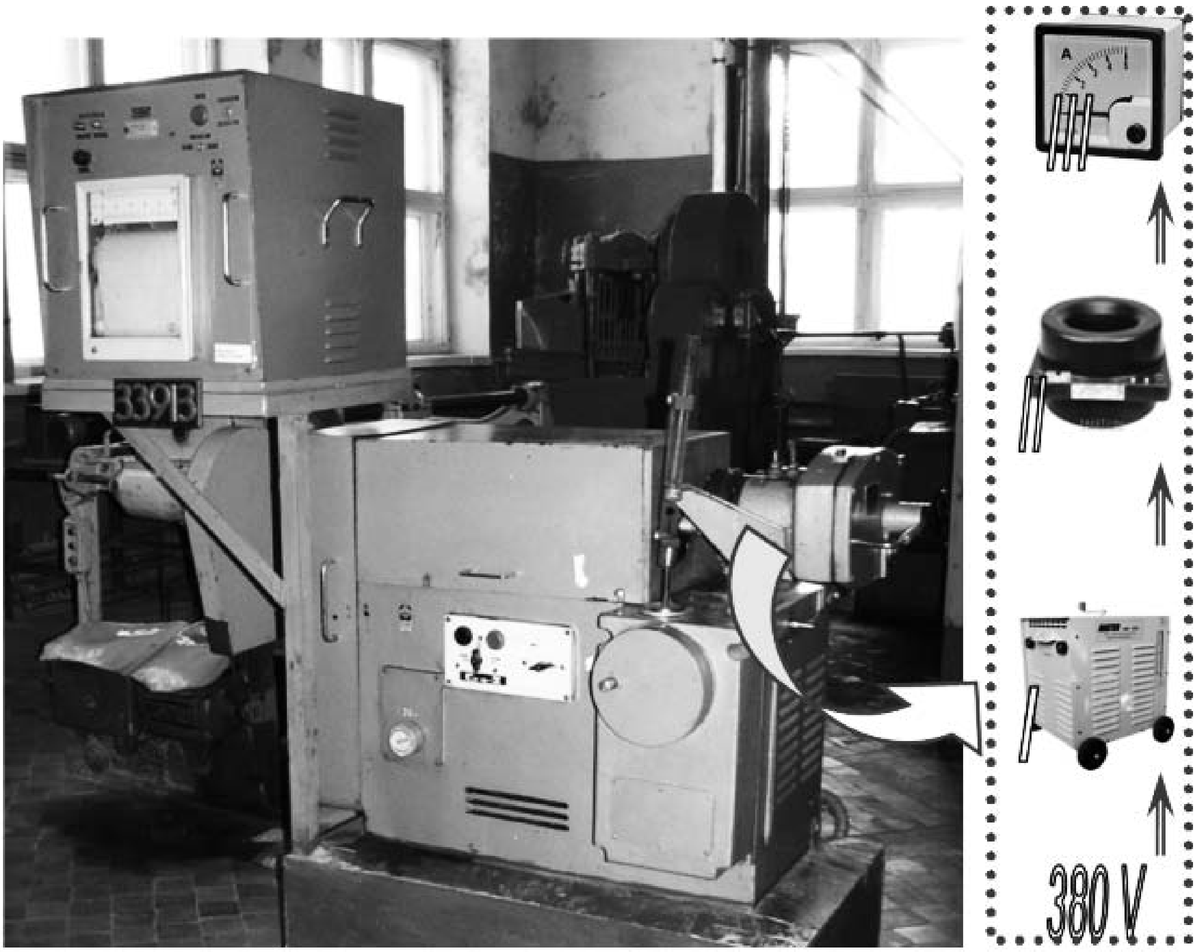

Fig. 5. Machine proof-of-concept SMC – 2 with the system of serve of electric current : 1 – transformer TMD-500, 2 – transformer of current, 3 – ammeter

$$b = 1{,}522 \cdot \sqrt{\frac{k_d \cdot F \cdot R_{np}}{l \cdot E_{np}}},$$

where: Kd = 1 – dynamic coefficient, for an unstressed cyclic laddering,

R_{np} – brought radius over, m:

$$R_{np} = \frac{r_1 \cdot r_2}{r_1 \pm r_2},$$

here: r1 and r2 – radiuses of examinee standards, m,

E_{np} – brought module over, MPa:

$$E_{np} = \frac{2 \cdot E_1 \cdot E_2}{E_1 + E_2},$$

here: E1 and E2 – modules of normal resiliency of examinee materials, MPa.

V1 and V2 – linear speeds of standards, m/s :

$$V_1 = \frac{p \cdot n}{30} \cdot \frac{D_1}{2},$$

$$V_2 = V_1 \cdot s,$$

here: s – coefficient of slipping.

Work of friction:

$$W = F_{mp} \cdot S,$$

where: $F_{mp} = P \cdot f$,

P – normal force, H,

f – coefficient of friction.

Time of wear of standards:

$$t = \frac{N}{n},$$

where: N – number of cycles of laddering,

n – frequency of rotation of standard.

Results of series of experiments on determination of influence of the skipped electric current through a contact "roller-roller" on friction properties presented on a Fig. 6.

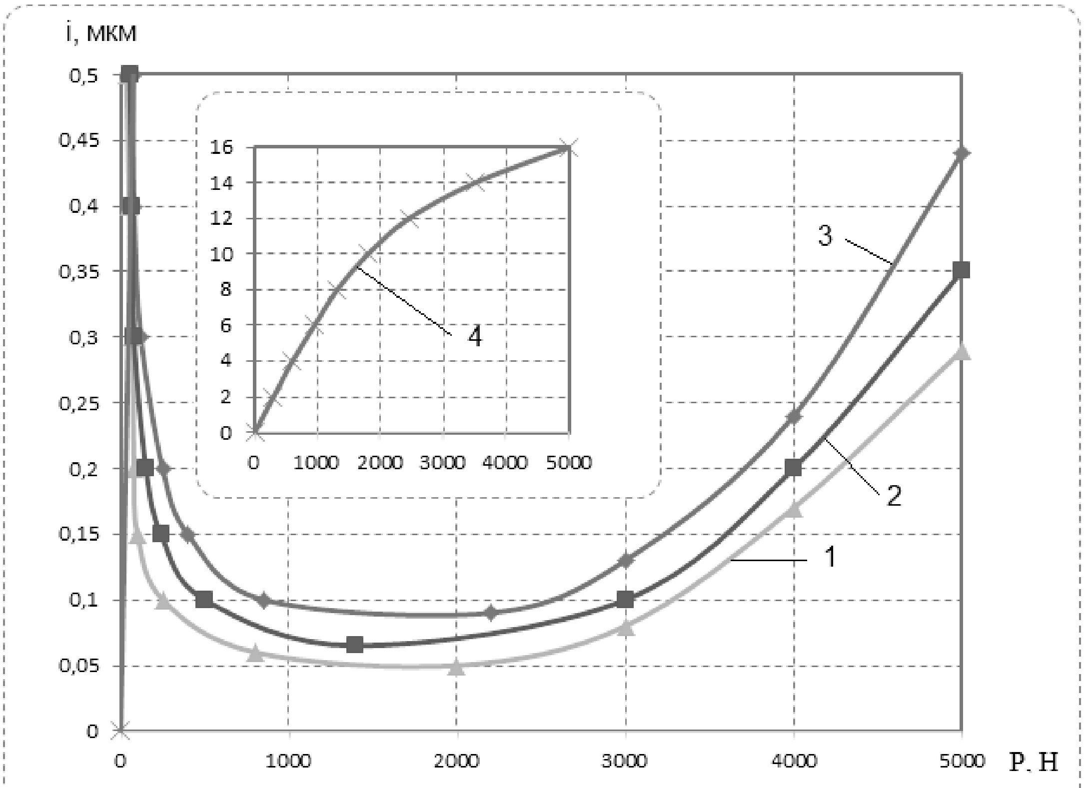

Fig. 6. Dependence of wear of rollers on loading at presence of electric current: 1 – strength of current of 100A, 2 – strength of current 200A, 3 – strength of current of 300A, 4 – wear under act of sand [12]

The experimental researches presented on a Fig. 5 confirm the results of the design given above. On graphic arts a curve is presented 4, that characterizes the wear of surface of detail under act of sand with different speed of his serve, according to researches [28]. At comparison of curves 1-3 and 4 evidently, that a wear from influence of sand in several times exceeds a wear from influence of electric current.

Actuality of problem of wear of railway wheels and rails stands especially sharply in connection with the running expenses related to the regrind of wheel pairs and influence of him on hauling-economic descriptions of rolling stock. The model of wear of tribounit supposes proportional dependence between the worn down volume V_B and work of friction of Ar :

$$V_B = kAr,$$

where: k – index of wear that is determined experimentally.

And the size of wear at the contact of surfaces is straight proportional to work of forces of friction. A friction determines a coupling size, as taking into account the resiliency of wheel and rail their co-operation takes place on some pin surface (spot of contact), where and tangent force of friction, that, is formed, as well as, coefficient of friction, depend on the great number of system and casual factors, basic from that are normal pressure, speed and temperature [13].

Consequently, except determination of influence of electric current on a wear a tribounit "wheel-rail" it is expedient to define degree of his affecting coefficient of friction.

For determination of influence of electric current on the coefficient of friction on the department of railway transport of Volodymyr Dahl East Ukrainian University experimental studies are undertaken on the automated instrumentation-designing stand setting "Machine of friction" [2, 8, 29]. Stand setting "Machine of friction" is equipped by the device of serve of electric current in a contact "roller-rail" chart of that, presented on a picture 1.

Measureable parameters on the stand setting it are: vertical effort on a working roller, force of friction of roller at a rail, frequency of rotation of engines. The signals, taken off from the sensors set on the stand setting of I (Fig. 7), are given through the block of processing of data of II (Fig. 7) on computer - III (Fig. 7), that allows jointly with a control stand to manage the hauling roller of V (Fig. 7) by a working roller and to destroy these experimental sizes of coefficient of friction from a temperature in real time. The smooth set of speed of rotation of working roller is provided by the worked out - IV (Fig. 7) on a microcontroller ATMEGA8, that is managed computer of III (Fig. 7) also.

Power is tricked into to setting of I (Fig. 6) regulated by means of transformer TDM-500 – VI (Fig. 7).

Results of experimental researches on determination of influence of electric current on a friction pair "roller-rail" of the stand setting "Machine of friction" presented on a Fig. 8.

On results experimental researches the increase of maximal coefficient of friction is set in a contact "wheel-rail" at the serve of electric current :

- to 23% rails covered by a blight at influence of current 375 A, here meaningful influence on the coefficient of friction renders the current of 100A and higher (1 Fig. 8),
- to 30% clean rails at influence of current of 375A, meaningful influence on the coefficient of friction renders the current of 100A and higher (2 Fig. 8),
- to 28% rails covered by water at influence of current of 375A (3 Fig. 8).
- to 27% rails covered by exhaust oil (4 Fig. 8).

The got results can be interpreted taking into account the theoretical pre-conditions described in [30],it mean supposition about the flowage of superficial layer explains increase of spot of contact in tribounit and, as a result, results in the increase of coefficient of rolling friction, what was observed during realization of experimental researches.

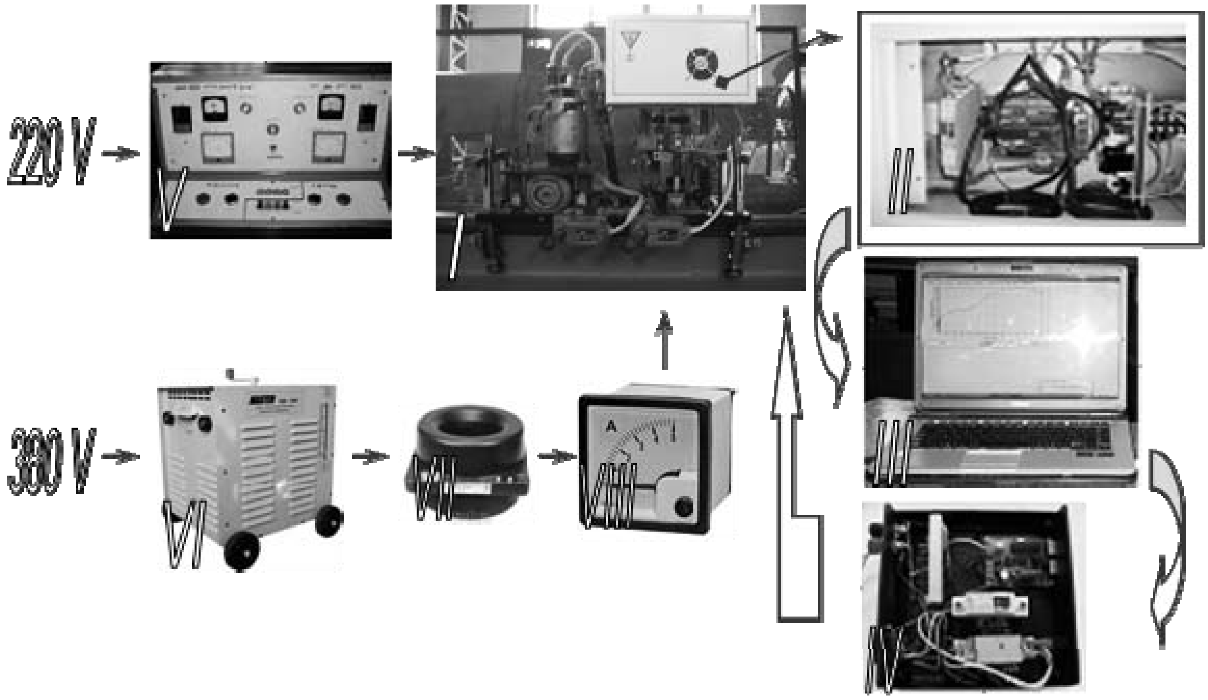

Fig.7. Chart of the automated instrumentation-designing stand setting "Machine of friction" with a device for the serve of electric current in a tribounit "roller-rail"
I – general view of the automated instrumentation-designing stand setting "Machine of friction"; II – block of processing of the obtained data, III – computer; IV – regulator of smooth tension; V – control stand by a hauling roller; VI – transformer TDM-500; VII – transformer of current, VII – ammeter

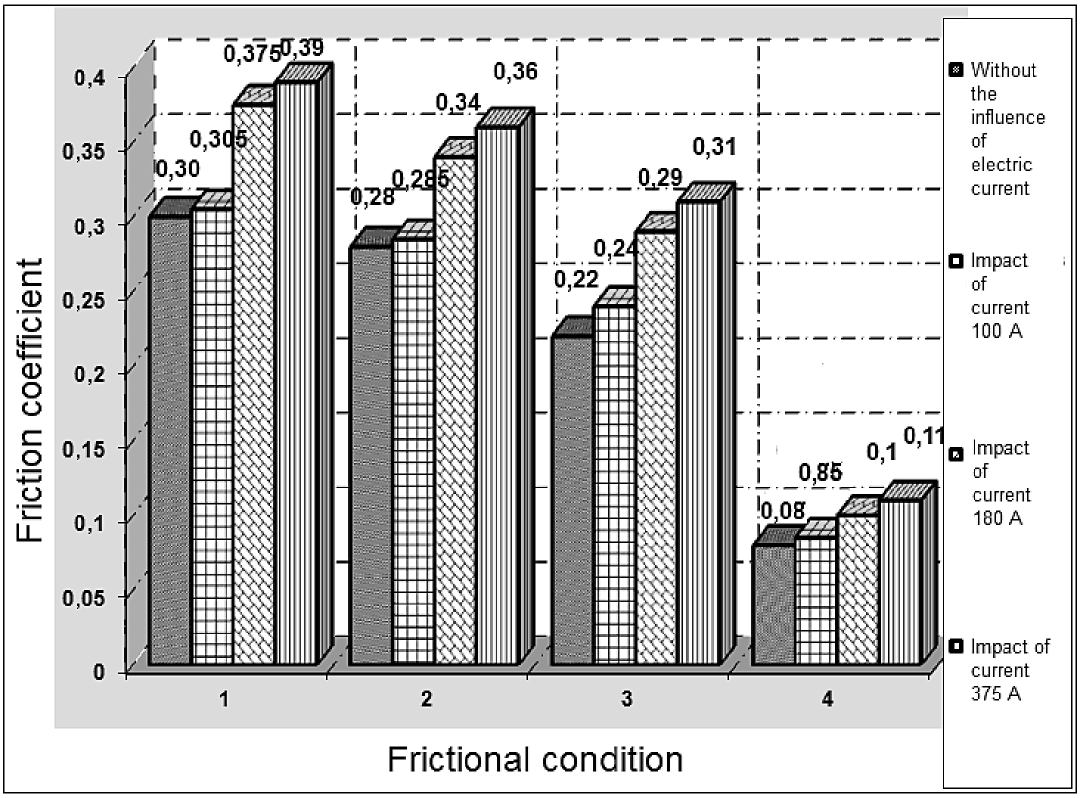

Fig. 8. Dependence of coefficient of friction on influence of electric current at presence of superficial contaminations and to different strength of current, coefficient of friction at:
1 – rail is covered by a blight, 2 – clean rail, 3 – rail is covered by water, 4 – rail is covered by exhaust oil

In addition, experiments are conducted on research of influence of electric current of high-density on a friction contact at presence of in him sand. Quartz sand, as is generally known, is a dielectric and, consequently, a dielectric barrier appears in a contact. At the key-in of electric current there is a hasp in a contact, bridges that heat and melt lances of roughness's of superficial layer appear, that results in an erosive wear [31], evidently presented on a Fig.9, where a roller is represented after undertaken experimental studies with a presence in the contact of sand.

Fig. 9. Erosive wear of roller at affecting of electric current of high-density tribounit of "roller-rail" at presence of sand

CONCLUSION

1. Applied in exploitation of rolling stock the method of increase of coupling by the serve of sand in the zone of contact of wheel with a rail considerably wears down the ground surfaces, and his basic defects (resistance to motion is an obstruction of rail grate and pointer translations, that results in the decline of safety of motion) require the search of new ways of decision.

2. The method of increase of coupling by the serve of electric current in the contact of wheel with a rail is able partly to replace the serve of sand in the pair of friction "wheel-rail".

3. The mechanism of influence of electric current on tribounit is based on that an additional heat is introduced in the system, there are flowages, increasing the spot of contact of wheel with a rail that assists the increase of coupling [32]. The size of wear depends on the attached loading and temperature in tribounit.

4. It is set that the increase of coefficient of friction on clean rails makes a to 30% dependence on the closeness of the skipped current, on rails covered by water to 28% rails covered by exhaust oil to 27% on rails covered by a blight on 23%.

5. Influence of electric current does not cause the wear of raceway unlike the wheel given in a contact with the rail of sand.

6. Undertaken studies showed that influence of electric current is parallel with sand on tribounit of interactive surfaces of wheel with a rail results in the erosive wear of contacting to the solid.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ЭЛЕКТРИЧЕСКОГО ТОКА НА ТРИБОСОПРЯЖЕНИЕ «КОЛЕСО-РЕЛЬС»

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Аннотация: В работе теоретически и экспериментально проведены исследования влияния электрического тока, проходящего через контакт двух взаимодействующих роликов на их износ при варьировании величины силы тока и приложенной нагрузки, а также определен коэффициент трения при различных фрикционных состояниях поверхности рельса. Экспериментальные исследования проведены на машине испытательной СМЦ-2 на ПАТ «Лугансктепловоз», а также на автоматизированной измерительно-моделирующей стендовой установке «Машина трения» в лаборатории на кафедре железнодорожного транспорта Восточноукраинского национального университета им. В. Даля. Выявлен механизм воздействия электрического тока на трибосопряжение, что позволяет обосновать применение данного способа для повышения сцепления в системе «колесо-рельс».

Ключевые слова: электрический ток, сцепление, температура, электрический износ, механический износ, коэффициент трения.