strength, ozone, contact patch, the concentration

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FRICTION INTERACTION MANAGEMENT IN TWO-POINT "WHEEL-RAIL" TRIBOCONTACT

Summary. The results of studies on the possibility of application of ozonized air to reduce the wear and tear in the tribocontact "wheel-rail" are presented. The technique of influence estimation of ozonized air, as activator surface, on the friction interaction in wheel-rail contact, is proposed, the results of experimental research results are presented.

УПРАВЛЕНИЕ ФРИКЦИОННЫМ ВЗАИМОДЕЙСТВИЕМ В ДВУХТОЧЕЧНОМ ТРИБОКОНТАКТЕ «КОЛЕСО-РЕЛЬС»

Аннотация. Проведены результаты исследования возможности применения озонированного воздуха для снижения износа в трибоконтакте «колесо-рельс». Предложена методика оценки влияния озонированного воздуха, как активатора поверхности, на фрикционное взаимодействие в контакте колесо-рельс, приведены результаты экспериментальных исследований.

1. INTRODUCTION

Among all of the friction transmissions (clutch, variators, belt drives and so on) probably the most specific operating conditions has a traction force transmission from the locomotive wheel to the rail. It must be taken into account that the wheel – rail interaction is the physical basis of the train moving on railway. Safety and the other technological – economical factors such as train mass, train moving speed and level of operational costs are mainly defined with it.

The requirements for indicators of wheel – rail interaction in different contact zones are very inconsistent [1]. On the one hand, for the required traction force realization it is necessary to provide high and stable level of wheel – rail coupling. On the other hand to predict wheel rolling on the top of the rail, wheel flange and rail lateral surface wear reduction, and reduction of train moving in curves resistance it is necessary to reduce friction between wheel flange and rail lateral surface as much as possible.

Therefore, the state-of-the-art conception of frictional interaction between wheel and the rail optimization under field conditions can be formulated as follows:

1. provide stable and high adhesion coefficient in a wheel rolling surface and rail contact zone with slip value and moving resistance minimization;
2. reduce friction coefficient in a wheel flange and rail lateral surface contact zone as much as possible;

3. while providing the necessary frictional characteristics of wheel – rail the regimes and parameters of motion should be taken into account (traction, braking, stopway, moving speed and so on).

As we know, the most popular method for adhesion activation is a supplement to the contact zone quartz sand. This method is widely used all around the world, but along with undeniable advantages (high efficiency, serviceability, relatively low cost) has obvious disadvantages (contamination of ballast, the increased wear of wheels and rails, movement resistance rise).

A group of methods of active influence on tribological properties of wheel – rail contact is developed, taking into account the disadvantages of sand usage: the mechanical [2], electrical [3], plasma, hydro- and pneumatic methods of rails' working surfaces clearance [2]. The researches directed for the search and development of friction modifiers [4], active surface materials, friction activators [2] are also known. There are studies of the electric current passing through contact influence on the tribological properties of the contact [3].

In this work a possibility of ozone usage for adhesion activation is considered. In the work [5] is shown, that the usage of ozoned air for cutting instrument cooling increases its durability in 4-5 times if compared with treatment without cooling.

2. EXPERIMENTAL INVESTIGATIONS

An experimental determination of ozoned air influence on processes which takes place in wheel rail contact was carried out using the original friction machine [6]. The friction machine consists of boogie (fig. 1) with an acceleration device placed on it (I), orienting (II) and measuring unit(III), and also a microprocessor unit (IV).

The experimental method consists of the following steps. The given vertical load is applied to the working roller (fig. 1). Then with the use of acceleration device I the friction machine was accelerated to achieve given linear velocity. Then the torque was applied to the roller 1, which was progressively increasing until the roller went into a skid. The studies were carried out for clear dry surfaces of the rail and working roller. The ozone supplement in the contact zone of the working roller and rail was realized with the use of barrier ozonizer.

At the expense of relational friction, the roller – rail contact zone undergoes intensive heating. According to the experimental technique the measured values are: forward speed of a friction machine boogie, angular velocity of the working roller, vertical load on the working roller and a frictional force in the roller – rail contact zone. This data allows to determine the temperature in a contact zone in a calculating way.

The results of experimental research are shown on fig. 2. It can be seen, that the ozoniesed air supplement increases the friction coefficient from 0.33 to 0.41. The temperature, corresponding to the maximum value of the friction coefficient, was reduced from 550^0C to 450^0C.

3. THE THEORETICAL SUBSTANTIATION OF THE EFFECTS OF OZON

As we know the most popular method of ozone production is the generation in a (является генерация в) barrier electric discharge. The active power of discharge, released in the discharge interval, is defined with formula [7]:

$$P = (2/\pi)\omega\,[C_D\,(V_0 - V_G) - V_G C_G]\,V_G, \qquad (1)$$

where: V_0, V_G – voltage on the conducting electrodes and the gas interval, respectively; B; C_G, C_D – capacity of the gas gap and dielectric, respectively; Ф; ω – supply frequency, Hz.

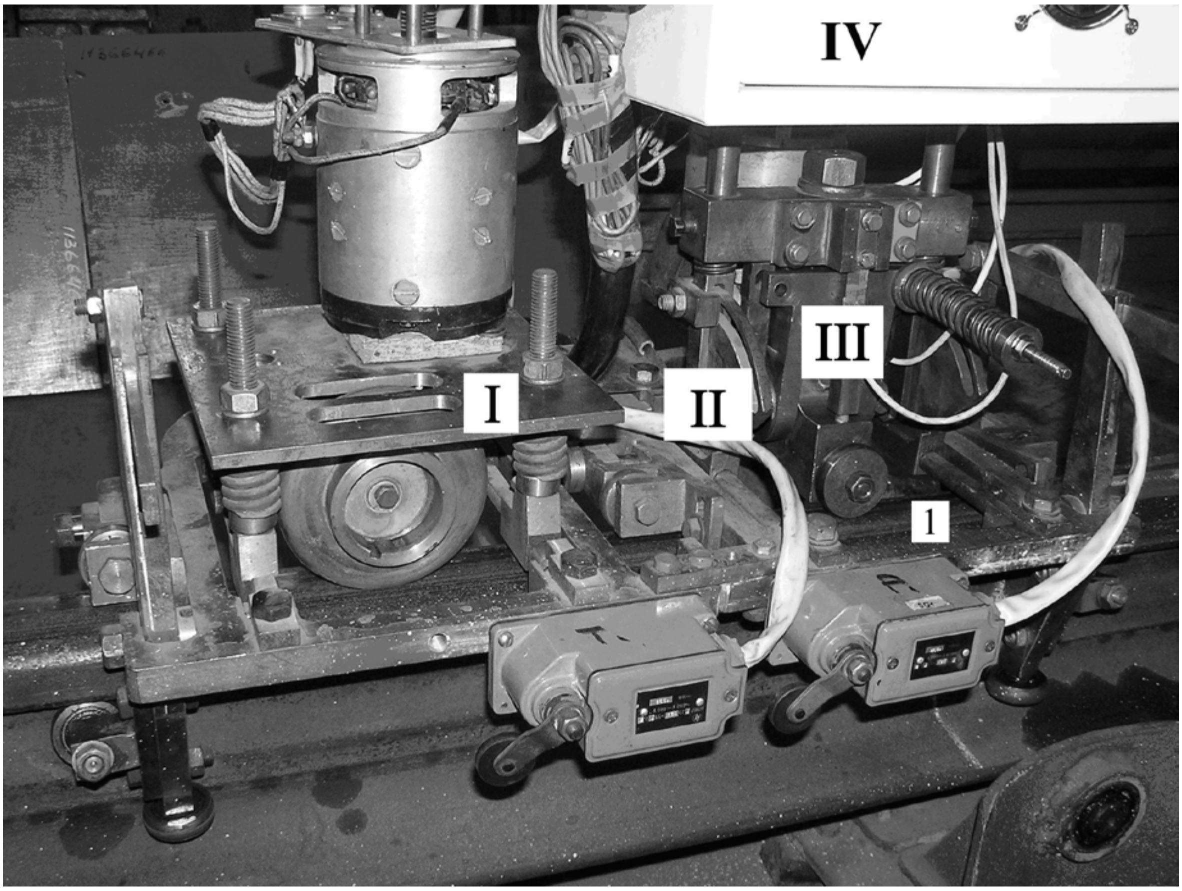

Fig. 1. General view of friction machines
Рис. 1. Общий вид машины трения

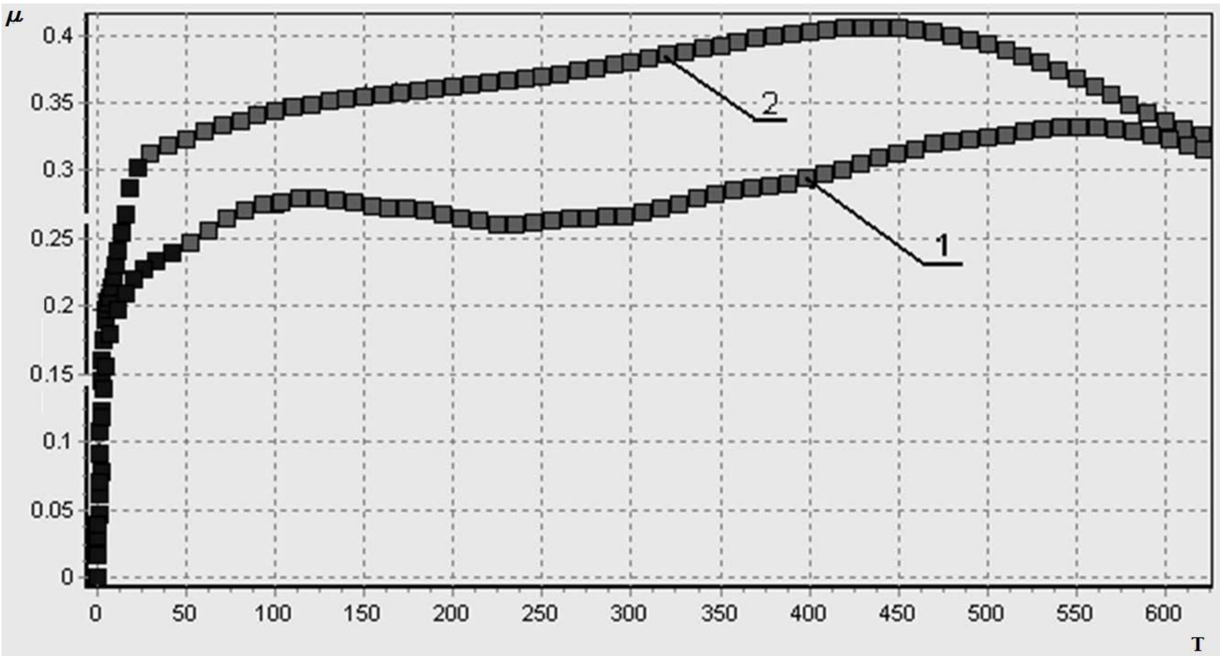

Fig. 2. Dependence of the coefficient of friction on the temperature in friction pairs "wheel-rail"; 1 - a dry rail, 2 - dry rail with the ozonized air
Рис. 2. Зависимость коэффициента трения от температуры в паре трения «колесо-рельс»; 1 - сухой рельс, 2 - сухой рельс с подачей озонированного воздуха

During the movement though the discharge zone oxygen molecules partly dissociate on the reactions [8]:

$$\begin{aligned} &O_2 + \overline{e} \to 2O + \overline{e}; \\ &O + O_2 \to O_3 + M; \\ &O + O_3 \to 2O_2; \\ &O + O + M \to O_2 + M. \end{aligned} \tag{2}$$

At the same time atomic oxygen reacts with oxygen molecule to form ozone.

In the barrier ozonizer, which is a cylindrical condenser, the intensity of magnetic field E is acting on the molecules of oxygen:

$$E = F / Q \tag{3}$$

where: F - force acting on point positive charge Q, placed in the given field point.

The density of electric energy in the barrier ozonizer:

$$W = \varepsilon\varepsilon_0 \frac{E^2}{2} \tag{4}$$

where: ε - permittivity of media inside condenser, ε_0 - electric constant, E - electric field strength between the plates of condenser.

Volume density of the energy:

$$W_p = \frac{W}{V} \tag{5}$$

where: V - a space volume in which energy produce.

During the reaction every molecule collides with others, a number of collisions per second is huge, and if the collisions were effective, all reactions end instantly, i.e. would proceed in the form of an explosion, but it’s not happening. A large decrease of temperature of reacting molecules system leads to their kinetic energy reduction, and their collisions become ineffective, and reaction speed is near zero. This happens because during the reaction molecules must be grouped to the activated complex. It can be formed only by active molecules, that have enough kinetic energy. A difference between the energies of activated complex, i. e. energies, that produced by charged condenser and initial molecules, i.e. ozone energy, is called the activation energy E_a (fig. 3) [9].

During the molecules approach their kinetic energy transforms to the potential one. The maximum of potential energy is corresponding to the energy of the activated complex. The energy barrier arises as the result of mutual repulsion of atoms of oxygen not connected chemically. Without necessary energy achieved, the energy barrier can’t be overpassed. Hence one of the terms for the most effective work of barrier ozonizer is production of energy (W), which contributes to the energy barrier overpassing for the largest number of ozone (O_3) energy connections production.

Hence the activate energy can be presented as:

$$E_a = W_p - W_k \tag{6}$$

where: W_k - kinetic energy of O_3 atoms:

$$W_k = eEL \tag{7}$$

There are many different factors which has influence on ozone concentration. Among them are ambient air temperature, humidity, pressure, air composition. For example, there is dependence between air water content (expressed through the dew-point temperature t_p) and O_3 ozone concentration after ozonizer. With the ambient air temperature -20 ºC the O_3 concentration in the ozonized air is ~ 16 % lower then maximal, which is reached with temperature -50 ºC [8].

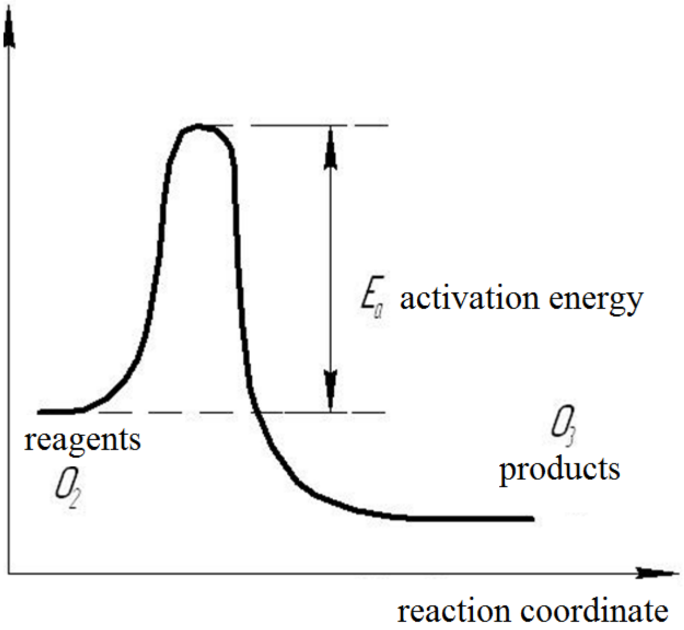

Fig. 3. Dependence of the energy of the reacting molecules from the coordinates of a chemical reaction
Рис. 3. Зависимость энергии реагирующих молекул от координаты химической реакции

The ozone concentration x in the barrier ozonizer can be expressed:

$$x = \frac{k_e \cdot a}{k_e + k_{1,t1} \cdot e^{\frac{E_a}{R} \cdot \frac{T_2 \cdot T_1}{T_2 + T_1}}} \left\{ 1 - \exp\left[-\frac{P}{V} \left(k_0 + k_{1,t1} \cdot e^{\frac{E_a}{R} \cdot \frac{T_2 - T_1}{T_2 \cdot T_1}} \right) \right] \right\} \quad (8)$$

where: T_1 – temperature of the liquid which cools the electrode ozonizer; T_2 – gas temperature in the reaction zone; $k_{1,t1}$ constant of decomposition at the temperature 20^0 C; E_a – activation energy of ozone decomposition reaction.

If we know the concentration of the material in the discharge gap the mole of the material can be defined - is the amount of s material, which contains $6{,}02 \cdot 10^{23}$ molecules (Avogadro constant), and that corresponds to the number of carbon atoms in 0,012 kg ^{12}C isotope.

Ozone formation takes place in a reversible reaction:

$$3O_2 + W \left[68\text{kcal} \left(285\text{kJ} \right) \right] \longleftrightarrow 2O_3. \quad (9)$$

If we know the mole of ozone and amount of energy we can find energy, escaped during the decay of ozone (W) and directed to the wheel – rail contact.

In the work [10] the surface layer is presented in the form of energy system. The change of the internal energy occurs under the action of complex influence of different thermodynamical forces: thermal, mechanical, chemical, diffusion, electromagnetic, etc.

As mentioned earlier, for friction coefficient reduction the oxide film destruction is necessary. The studies [11, 12] shown, that for the oxide film destruction it is necessary to tear the energy connections between the atoms of neighboring crystals on friction surface, i.e. pollution particles. The number of crystallites on the pattern frictional surface is equal to $\frac{S_o}{(na_0)^2}$, where S_o – frictional surface area of the pattern; a_0 – period of the crystal lattice; $(na_0)^2$ – area of the crystal cell face; n – the number of atoms attaching to on one edge of the crystal.

The number of violations of atomic bonds during friction:

$$N = \frac{S_o}{(na_0)^2} fn^2 \tag{10}$$

where: f – number of faces, on which there is separation of the crystal;

$f = 4k + 1$ (k =1,2,… – number of separated crystals in depth);

fn^2 – the number of atoms in the crystal faces.

Then the energy required for separation of the crystals will be equal to

$$E = E_0 N = E_0 \frac{fS_o}{a_0^2} \tag{11}$$

where: E_0 – binding energy of iron atoms in a crystal.

The thickness of the layer, wear during friction:

$$h = kna_0 \tag{12}$$

$$k = \frac{h}{na_0} \tag{13}$$

$$f = 4\frac{h}{na_0} + 1 \tag{14}$$

If the work of friction forces

$$A = Fvt = \mu pS_o vt \tag{15}$$

where μ – friction coefficient;

p – pressure on pattern;

v – friction velocity;

t – friction time

is comparable to the energy required for separation of crystals, then:

$$A = E \Rightarrow \mu pS_{обр} vt = E_0 \frac{S_o}{a_0^2}(4\frac{h}{na_0} + 1) \tag{16}$$

Since $4\frac{h}{na_0} >> 1$, in further calculation the unity should not be taken into account. Hence,

$$\frac{h}{t} = \frac{pvna_0^3\mu}{4E_0} \tag{17}$$

where $\frac{h}{t}$ – the intensity of layer changes in thickness due to wear of the friction.

Based on the above we can conclude that energy produced during the (W) ozone decay is enough to separate pollution particles from basic metal, and that’s why we can talk about full or partial destruction pollution layer in wheel – rail contact and therefore adhesion coefficient increases and that is confirmed experimentally

4. CONCLUSIONS

The possibility of ozone usage to increase adhesion coefficient is shown. To produce the latter the energy of electodynamical braking can be used.

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