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POWER CHARACTERISTICS OF THE ELECTRIC FIELD OF A STREAMER FORM OF A CORONA DISCHARGE

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The article presents the results of theoretical and experimental studies of the processes of force action of electric fields of the streamer form of a corona discharge. The pulse voltage and discharge current were oscillography in the needle–plane electrode system at different pulse voltage frequencies and the maximum pulse frequency at which the stability of the discharge current in the experiment is observed was determined. The research results were compared with similar results of electric fields of a corona discharge with constant voltages.

Keywords: corona discharge, streamer form, Coulomb force, electric field, frequency, particle charge, field intensity gradient.

Aerosol particles in the electric fields of a corona discharge are affected by forces of various physical nature. These include: The Coulomb force, i.e. interactions of charge on particles with an electric field; pander motor force due to the inhomogeneity of the electric field; mirror image force acting on the deposited particles; particle gravity; force of interaction between charged aerosol particles; force due to gas flow; braking force of the air flow; force due to electric wind.

Of these, the Coulomb force is decisive in the deposition of aerosol particles. The remaining forces are an order of magnitude or smaller, and are not taken into account in practical calculations [1, 2, 3, 4, 5].

In sharply inhomogeneous electric fields, the greatest electric field strength is in the areas immediately adjacent to the corona electrodes. Therefore, the Coulomb force will depend on the location of the particle in the interelectrode space, i.e. from its coordinates:

$$F_k = q^2 radE. \quad (1)$$

where q is the excess charge of an aerosol particle, C;
E is the electric field strength, V/m.

In sharply inhomogeneous electric fields, when powered by unipolar voltage pulses, the electric field strength will also change with time. Therefore, the Coulomb force will be determined by the dependence:

$$F_k = q^2 radE(t). \qquad (2)$$

The electric field strength in the electric fields of the streamer form of the corona discharge changes according to the law:

$$E(t) = U_{C2.св}/H = \{(1/p_2 - p_1)\cdot((p_2U_a - i_a)p_1e^{p_1t} - (p_1U_a - i_a)p_2e^{p_2t}) + U_a\}/H \qquad (3)$$

where UC2.sv is the voltage of the discharge gap in the pause between pulses;
H is the distance between the electrodes;
Ua is the amplitude of the impulse voltage;
p_2, p_1 - roots of the characteristic equation:

$$p_{1,2} = \{-C_1 C_2 R \pm [(C_1C_2R)^2 - 4(C_1C_2L)(C_1+C_2)]^{0,5}\}/(2C_1 C_2L), \qquad (4)$$

where C_1, C_2, R, L, are the parameters of the power supply circuit of the discharge gap with unipolar voltage pulses.

Hence it follows that in the electric fields of the streamer form of a corona discharge, the Coulomb force is determined by the parameters of the power source elements, i.e. there is a dynamic mode of the process, in contrast to the electric fields of a corona discharge of constant voltages, where such a dependence practically does not exist.

To confirm dependence (3), an experiment was carried out in which the nature of the change in the forces of interaction between the electrodes was studied when fed with unipolar voltage pulses. The stand for these studies (Fig. 1, a) consists of a grounded electrode 5 - an aluminum alloy disk 0.5 mm thick, which was suspended on six springs 4 on a dielectric hoop 3 (Fig. 1, c). A mechanotron 1 [6] was connected to the center of the grounded electrode using a rigid rod; (1b). The experiment was carried out with and without shielding electrode 8° to reveal the effect of the discharge gap capacitance on the force of interaction between the electrodes. In the experiment, the average electric field strength was set equal to $7x10^{5}$ V/m according to the effective value of the pulsed voltage with a frequency of 75 c^{-1}.

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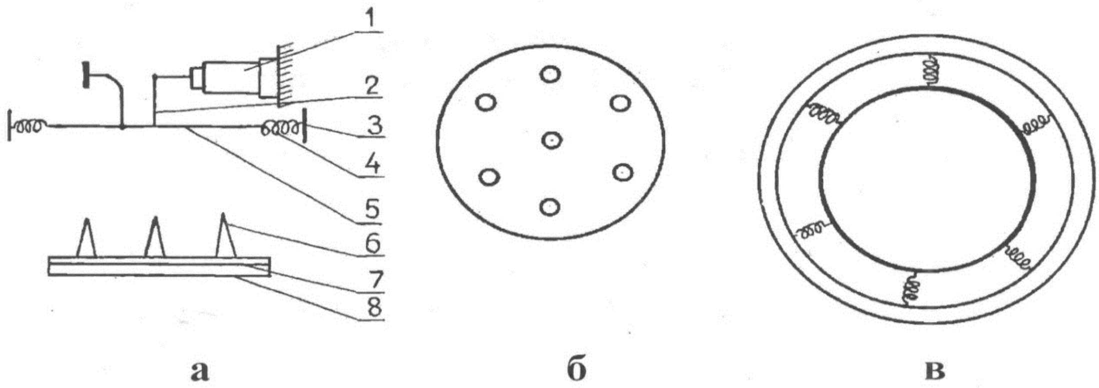

Fig.1. Scheme of a stand for studying the nature of the change in the electric field strength in the discharge gap when powered by a pulsed voltage

Oscillograms of the attractive force and, accordingly, the nature of the change in the electric field strength in the discharge gap (lower) and the type of pulsed voltage (upper) are shown in Fig.2. It can be seen from the oscillograms that the force of action on the grounded electrode only along the pulse front adequately describes the shape of the voltage pulse. In this case, the amplitude of the force lags behind the amplitude of the voltage pulse in time. The decrease in the force impulse is adequately described by formula (3). Comparison of the oscillograms of the process taken without a shielding electrode and with a shielding electrode showed that the process of the decay of the force impulse in the presence of a shielding electrode proceeds more slowly.

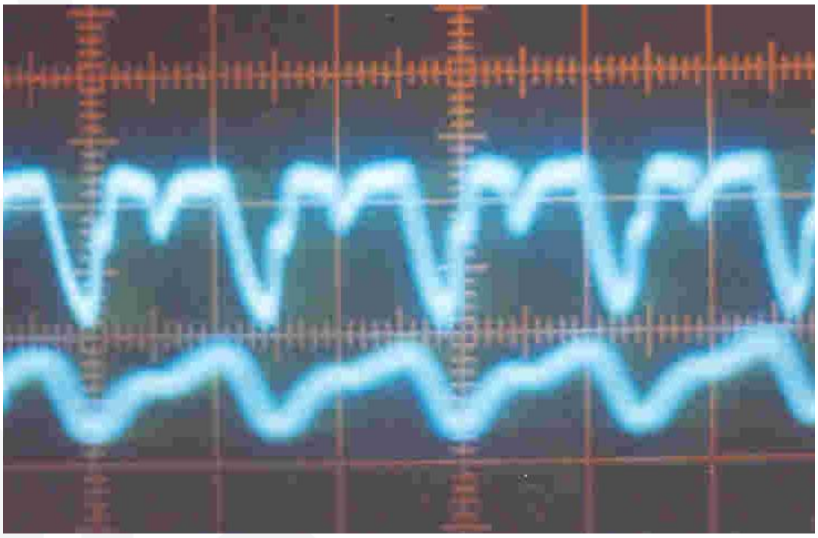

Fig.2. Oscillogram of the impulse voltage (upper) and the interaction force between the electrodes (lower)

Comparison of the power characteristics of the electric fields of the corona discharge of constant and pulsed voltages was carried out according to the force of adhesion of material particles to the grounded plane.

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In this case, the particles are held on the grounded plane by the force of the mirror image, the magnitude of which is proportional to the square of the charge on the material particle and inversely proportional to the square of the distance between the center of the charge and its reflection on the plane.

The studies were carried out according to the following method (Fig.3). A circle 2 with a diameter of 20 mm was cut out of the fluoroplast with a thickness of 0.15 mm and placed in the center of the grounded plane 3 under the corona needle 1. A nylon thread 6 was attached to the edge of the circle, which was attached to a spring dynamometer 6 at the other end. clamp 7. Interelectrode distance 40 mm. A voltage of $2.4x10^{4}$ V was applied to the corona needle. In the experiment, to eliminate the influence of the Coulomb force, i. the interaction of the particle charge with an external electric field, the test body was charged from the corona needle electrode, then the corona electrode was disconnected from the high voltage source and grounded using a high-voltage switch BB, and the electric motor of the dynamometer drive was simultaneously turned on. The strength of the mirror image was determined by the dynamometer at the moment of separation of the fluoroplastic circle from the grounded plane.

The charge value in C of a fluoroplastic circle was calculated by the formula

$$q=(2Fr^{2})^{0,5}, \qquad (5)$$

where F is the force of separation of the circle from the grounded plane, N;

r is the thickness of the fluoroplast, m.

The specific surface charge density in C/m was determined by the formula:

$$\sigma_S = q/S, \qquad (6)$$

where S is the area of the fluoroplastic circle, equal to 314 mm ^{2}.

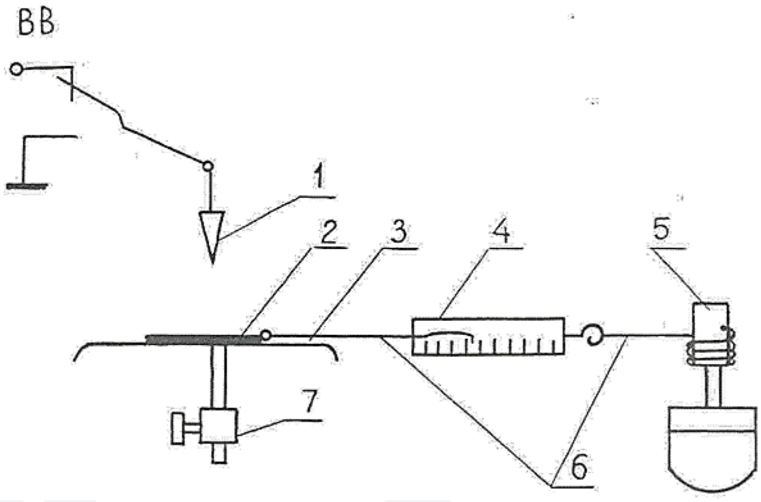

Fig.3. Scheme of a stand for measuring the force of adhesion of a test body to a grounded plane

The experiment was carried out in triplicate.

Table. Results of comparative studies of the adhesion forces of a test body to a grounded plane in the electric fields of a corona discharge of constant and pulsed voltages.

Options	Parameter values					
Pulse frequency, c $^{-1}$	Constant pressure	70	122	154	200	210
Sticking force of the test body to the grounded plane, H	0,62	1,11	1,21	1,37	1.63	1,44
Surface charge, 10 $^{-4}$ Kl	0,747	1,0	1,04	1,11	1,21	1,14
Surface charge density, 10 $^{-4}$ Kl / mm ^{2}	9,48	12,64	13,2	14,06	15,32	14,4
Exceeding the sticking force at impulse voltage over constant voltage		1,79	1,94	2,21	2,63	2,31

An analysis of the measurement results (table) shows that the mirror image depends significantly on the frequency of the pulsed voltage and increases to a frequency of 200 c $^{-1}$, then decreases. This is due to the fact that for the power supply circuit used, the limiting frequency of the stability of the streamer form of the corona discharge is 200 c $^{-1}$. At this frequency, the mirror image force is 2.63 times greater than that of a DC corona discharge. Similarly, the magnitude of the surface charge and its density increase. This implies the conclusion that in the electric fields of the streamer form of the corona discharge, the efficiency of deposition of aerosol particles will be much more efficient than in the electric fields of the DC corona discharge. The validity of this conclusion is also due to the fact that the magnitude of the electric field strength when powered by a pulsed voltage is greater than the field strength when powered by a constant voltage.

One of the advantages of the streamer form of the corona discharge is also the revealed regularity of the dependence of the nature of the force effect of the electric field on the parameters of the elements of the power circuit, which are related by dependence (3). This is of particular importance for various technological processes performed in strong electric fields, and will make it possible to fine-tune the ongoing processes by changing the parameters of the elements of the power circuit.

CONCLUSION

It has been experimentally established that the electric field strength of the discharge gap changes according to the law of voltage change between the electrodes of the discharge gap. Accordingly, the electric forces acting on dust particles in the electric field also change.

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At a frequency of 200 c $^{-1}$, the strength of the mirror image, the magnitude of the charge and its density are 2.63 times higher than similar parameters for corona discharge of constant voltage.

The results of the conducted studies allow us to conclude that the electric fields of the streamer form of a corona discharge are highly efficient compared to a corona discharge of constant voltage.

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