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Corona Discharge Properties Near Metal and Dielectric Surface

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***Abstract*: This following research of the properties of a coronary discharge has a serious impact on the study of metallurgy. There are a lot of cases of practical use of the corona discharge functions. An example is the creation of electrostatic precipitators for the purification of industrial gases from solid and liquid particles. Using the corona discharge method, for example, smoke is cleaned in the production of sulfuric acid, air in non-ferrous metal foundries and other harmful industries.**

Shape of the corona discharge made utilizing cone shaped and round and hollow terminals was examined. The most electrical characteristics of discharge of this type are decided.

Corona discharges are characterized by weak currents within the extend of one microampere at voltages on the arrange of 10 kilovolts and adequately week gleam discharge. Electric fluctuations within the discharge current circuit within the extend 1 kHz-120 MHz are enlisted. To think about the oscillatory forms, there were used electric and attractive tests, signals from which were sent to the Tektronix TDS 2024B oscilloscope working within the frequency analyzer mode. The electrical tests were spoken to by metal poles 1-10 cm in length and 4-5 mm in diameter. As magnetic tests, there were used coils (diameter 2-4 mm, number of turns 70-140, wire thickness 0.1 mm) set in protective dielectric walled in areas. These tests were located at a separate of 0.5-1.0 m from the release. Possible waves in plasma are suggested to explain these oscillations.

***Keywords* : corona discharge, electrodes, electric oscillation processes, metallography, physics of metals, plasma waves.**

I. INTRODUCTION

Talking about the process of corona discharge, firstly it's worth emphasizing that generally surface discharge is usually a constant electrical discharge, which ordinarily happens at the surface of external insulin conjointly causes the failure within the electrical cover framework. There is high voltage among the causes of surface discharge [1, 2].

Cases of corona discharges are considered as generally low power partial electrical discharges that develop in zones of exceedingly concentrated electric areas such as at small diameter wires, needles, or sharp edges on the electrode at or close atmospheric pressure [3-5]. Corona discharges are characterized by frail currents in the range of one microampere at voltages on the order of ten kilovolts and a sufficiently weak glow discharge.

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Among unusual properties is the appearance of high-frequency oscillations in the frequency range from kilohertz units to hundreds of kilohertz, which was first found in the works [6, 7].

Oscillation forms with frequencies up to hundreds of megahertz are showed in different works related to corona discharges [8-12]. Set of tests connected with this phenomenon was also described in literature [13-17].

Of interest for study are properties of near-electrode corona discharge layers in which wave processes can arise [18, 19]. Surface corona discharge forms can be used in systems for the modification of surfaces of inorganic and organic materials. Moreover, application of corona discharge could be found as an electrostatic precipitator, in electrostatic printing and deposition, in ozone production, ionization counting and particle charging [20]. General scheme of corona discharge system is shown on the Fig. 1 [17].

II. METHODOLOGICAL FRAMEWORK

A. Electrical characteristics

The plot of the test setup for studying the corona discharge is appeared in Fig. 1, 2.

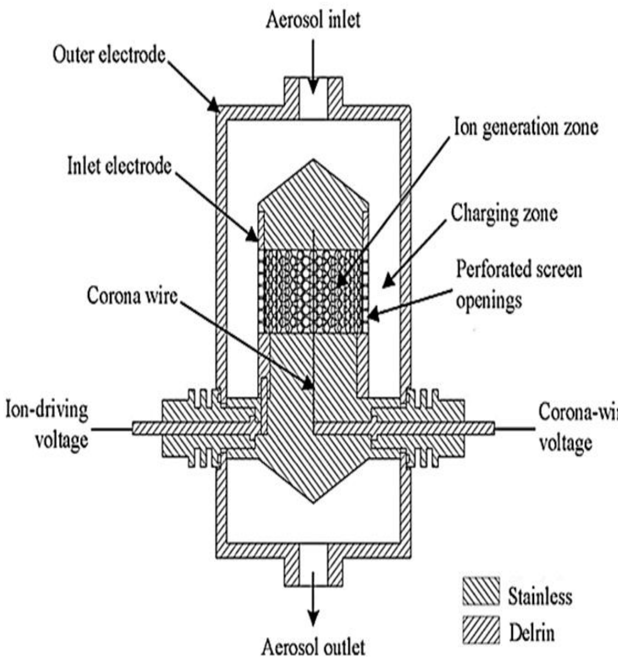

Fig. 1. The general scheme of corona discharge system

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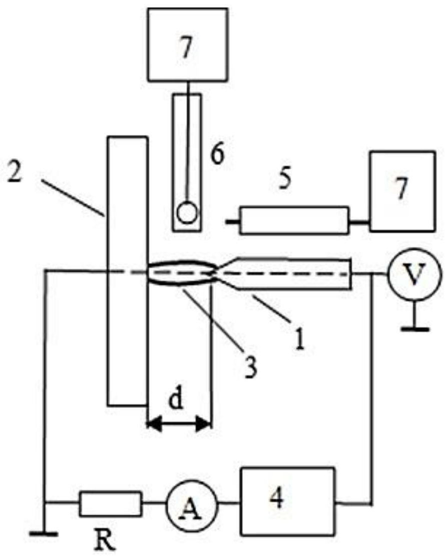

Fig. 2. The scheme of the test setup [19]

In the test, we used an electrode with a conical shaped working surface (1) (steel, copper, 3-5 mm in diameter, cone angle α = 200-300) and a cylindrical electrode (2) (aluminum, steel, 35-45 mm in diameter, thickness 10-15 mm), located at a distance d = 0.5-40 mm.

A high-voltage power supply (4) with a voltage of 1-30 kV and a current of up to 1 mA was used. As a rule, a voltage with positive polarity was applied to the conical electrode (1), and with a negative voltage (2) – to the cylindrical electrode. In the discharge circuit, limiting resistances of R = 0.5-100 MΩ were placed.

For taking a picture, we used a Panasonic Lumix DMC-FZ45 camera (exposure time 10 ms). When voltage is applied to the electrodes, breakdown occurs and the corona discharge ignites. Corona discharge image is shown in Fig. 3.

The shine is ordinarily blue or violet, and the intensity of the shine is frail enough. Within the current extend, I = 1-50 μA, this corona discharge encompasses for an almost of a shape with a widh of 2-3 mm and an extent equal with the dimensions of the interelectrode space of 0.5-5 mm. At high currents within the locale I = 70-150 μA and the voltage values U = 4-20 kV, the discharge may be branched and also consist of 2 or several slim channels. Corona discharge modes have diverse electrical characteristics.

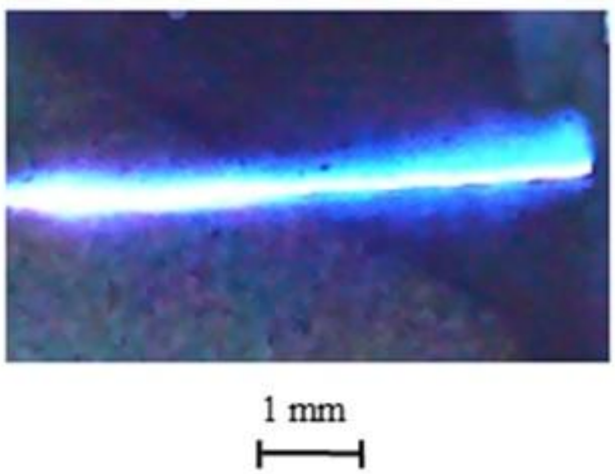

Fig. 3. Corona photos (exposure time 10 ms)

Let us consider the main mode of this corona discharge. The voltage dependence of U on the space between the electrodes d within extend of values U = 1.5-3.5 kV and d = 0.5-5 mm is approximately direct. The discharge current is found within the range I = 1-40 μA. Current-voltage characteristic of this mode's discharge is explained by implies of a quadrate reliance in (1) [6]:

$$I = \frac{(8\pi\varepsilon_0 \mu U(U-U_C))}{(d^2\ ln(d/r_0))} \tag{1}$$

The amount of UK is found from (2-4):

$$U_c \approx \frac{E_k r_0 kV}{cm} \tag{2}$$

$$E_c \approx 31\delta(\frac{1+0.308}{\delta r_0})^{1/2} \tag{3}$$

$$\delta = \frac{p}{p_n} \tag{4}$$

(p-pressure, p_n-pressure under normal conditions) and is U_C = 1.9 kV with anode radius r_0 = 0.05 mm.

III. RESULTS AND DISCUSSION

A. Study of electrical oscillations

To study the oscillatory forms, in the work there were used electric and magnetic tests, signals from which were sent to the Tektronix TDS 2024B oscilloscope working within frequency analyzer mode. The electrical tests were represented by metal poles 1-10 cm in length and 4-5 mm in diameter. As magnetic tests, there were used coils (diameter 2-4 mm, number of turns 70-140, wire thickness 0.1 mm) put in dielectric enclosures. These tests were located at a distance of 0.5-1.0 m from the discharge.

Agreeing to estimations, the current within the discharge circuit may be a sequence of beats taking after with the recurrence ν = 1-10 kHz. The most frequencies are as takes after:

- 5.7 ± 0.3 kHz;
- 43 ± 2 kHz;
- 95 ± 5 kHz;
- 220 ± 11 kHz;
- 3.1 ± 0.16 MHz;
- 11 ± 0.6 MHz;
- 24 ± 1 MHz;
- 28 ± 1.4 MHz;
- 57 ± 3 MHz;
- 82 ± 4 MHz;
- 97 ± 0.4 MHz.

The range of the corona discharge's electrical oscillations is appeared in Fig. 3. The isolated beat has the shape of a peak with a driving edge of 10-20 μs length and with a fall on the trailing edge of 200-300 μs duration.

For concentration of plasma, values within corona discharge n_e = 10^4-10^{10} cm^{-3}, the scope of values of plasm recurrence in (5).

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$$\omega_p = (\frac{4\pi n_e e^2}{m_e})^{1/2} \quad (5)$$

will be in the following area in (6):

$$\omega_p = 5.5*10^6 - 5.5*10^9 c^{-1} \quad (6)$$

Lower concentrations of electron $n_e = 10^4\text{-}10^6\ cm^{-3}$ exist close the flat surface of a cylindrical cathode [8]. Higher concentration values of $n_e = 10^7\text{-}10^{10}\ cm^{-3}$ are displayed within area encompassing the pointed portion of the cone shaped anode, where electron torrential slides are nucleated.

So, the discharge arising oscillations in the area of v = 1-120 MHz may be related with the excitation of high-frequency plasma waves in a corona discharge medium [21-24]. According to the work, the characteristics in the HF range of electromagnetic radiation can be related to the consideration of phenomena occurring in lean micron films on the solid surface [25-27].

In view of the dispersion law for electromagnetic waves in a metal, at frequencies below frequency of the plasma (7):

$$\omega_{p0} = (\frac{4\pi N_e e^2}{m_e})^{1/2} \quad (7)$$

(N_e is the combination of electrons within metal), plasmon waves can exist. These waves can engender in thin films with a density of 1-100 μm (Fig. 4). So, the plasmon waves' excitation with frequencies within v = 100 kHz-200 MHz range is conceivable in a thin surface layer of the cone shaped anode within the corona discharge case [28, 29]. Lower frequencies within the amount of v = 1 kHz-100 kHz may be compared to the region of sound plasmons.

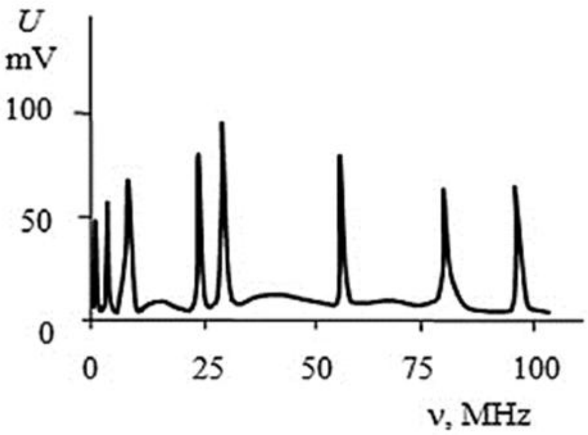

Fig. 4. Spectrum of electric corona discharge

B. Study of the surface of electrodes

Within the plan of this corona discharge, the most noteworthy current density is accomplishing close the apex of the cone shaped anode and on the plane surface of the cathode in contact with discharge. When the corona discharge is working for 10-15 minutes, gray raids are shaped on the surface of the anode near the tip (material: steel, copper). The electrode surface was inspected with the Hitachi TM1000 electron magnifying instrument (resolution 80 nm).

The picture of the surface of the steel anode at a separate of almost 0.1 mm from the apex appears in Fig. 5. An impact of the corona discharge is expressed within the presence on the depressions surface and structures within the strips form. These depressions' normal sizes are about of 0.5-1.0 μm, and they have an abnormal lengthen shape with a normal amount of 7-10 on an area of 20×20 μm.

The groups may be found on the surface in a course predominantly perpendicular to the generatrix of the cone and have a thickness of 0.2-0.4 μm and a length of 5-10 μm. In view of depressions presence on the surface of the anode, these current channels of corona discharge with a size of somewhat 1 μm near the metal surface are formed.

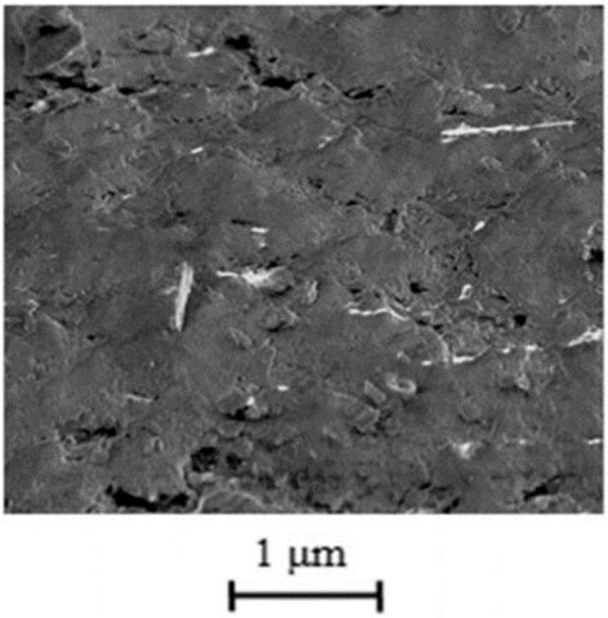

Fig. 5. Anode surface image

The current density in the channels is increased due to the compression of the common and the evaporation of the metal occurs upon interrelationship with the surface. So, near the anode surface, the corona discharge can consist of many separate current channels.

IV. CONCLUSION

The results of the interrelationship of the discharge and the metals' surface are obtained. The study of surface of the anode shows the microstructure of the metal under the action of corona discharge.

Corona discharge characteristics between conical and cylindrical electrodes were studied. There are detected two main modes of this discharge, which have different volt-ampere characteristics and ranges of voltage and current values. When this discharge exists, electrical oscillations occur. The frequencies of oscillations registered in the experiments in the range from 1 kHz to 120 MHz were compared with the frequencies of plasma waves that can exist in the plasma of a given discharge. The structure of plasma waves arising in the region close to the cathode surface of 0.5-1 mm thick is considered. The appearance of plasmon waves is possible in a thin surface layer of a cathode metal with a thickness of 1-10 μm. The study of the surface of the anode shows the microstructuring of the metal under the action of the corona discharge.

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