Electrophysical and heat properties of the discharge with liquid anode

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Abstract. The low-temperature plasma of the gas-discharge was analyzed that generates between the jet and dropping liquid anode and metal cathode at the ambient pressure. The study results of electrophysical properties and heat processes in the discharge combustion area are presented.

1. Introduction
The profound data have been obtained in the field of discharge generation between solid electrodes [1-3]. Currently, discharges are of higher concern to generate in the ambient air between the dropping jets of conductive liquids and the metal electrode [4-12]. This technology of gas discharge formation is attractive for both fundamental and applied researches. Discharge forms and types, electrophysical and spectral properties, plasma composition, plasma component distribution by energy and concentration are of high interest in the field of fundamental researches. Physical properties of discharge generation along the jet and at the border of electrode interaction are attractive. Hydrogasdynamic and heat processes are of concern that emerges within the electrode spacing in the zone of discharge generation. In addition, discharge of this type is relevant in view of practical application in various industries. Aircraft and mechanical engineering sectors face problems on local formation of item inner and outer surface micro-pattern.

2. Experiment
The gas discharge between the jet and dropping liquid anode and metal cathode was studied at the pilot plant with the direct current source and controlled DC voltage up to 4000 V at the rated current of up to 10 A.

The following research methods were applied to address the tasks specified:
1. Gas discharge current and voltage oscillations were analyzed by the digital oscillograph GDS – 806 S.
2. The infrared scanner FLIRA6500SC was used for the electrode surface thermography. The data obtained were processed by the ALTAIR Software v5.91.010.

Combustion of the gas discharge within the electrode spacing was identified at the voltage of U=600-1000B, current I=1.2-4.8A, jet length l_c=30 mm, ambient pressure p=〖(10〗^5 Pa, a copper plate d_a=1 mm was taken as the cathode.
Gas discharge current and voltage oscillations were analyzed by the digital oscillograph GDS – 806 S. It was identified that the discharge between jet and dropping liquid anode and copper cathode burns as impulses with the current pulsation frequency $\nu = 30-70$ Hz (Fig. 1).

This is due to the fact that the electrolyte is intensely vapors generating local steam and gas zones when the potential is supplied to electrodes in the area of the electrolyte and copper electrode contact. Where the environment in the steam and gas shell complies with ionization process conditions, the disruptive discharge generates therein followed by abrupt rise of temperature and pressure values. This causes shock wave generation that result in spreading of the steam and gas shell and jet delivery. In turn, it results in higher resistance in the steam and gas shell followed by the discharge termination, the circuit breaks and the current drops to 0. This process regularly occurs.

Electrode surface thermography in the area of gas discharge combustion was performed by using the infrared scanner FLIRA 6500 SC. The data obtained were processed by the ALTAIR Software v5.91.010.

Based on surface temperature logs (Fig. 2) in the area of discharge combustion, the temperature along the jet and dropping anode varies $T_k \approx 46-69^\circ$C. The temperature of the copper cathode (Fig. 3) is $T_a \approx 54-69^\circ$C.
The temperature reaches \( T_{\text{max}} = 69^\circ \text{C} \) in the area of discharge combustion. It is identified that when the gas discharge is burned, the temperature along the jet and dropping anode drops. This is explained by the fact that the heat input, prior to the disruptive discharge, is due to the electrocaloric effect. Upon the disruptive discharge, the heat input to the jet reduces against the decline in total resistance and drop of jet voltage.

3. Results
1. Peculiarities of discharge are identified to generate between the jet and dropping liquid anode and metal cathode.
2. The discharge is identified to generate as the current impulses with the current frequency \( \nu = 30-70 \) Hz.
3. Thermographs of temperature distribution of liquid anode and metal cathode surface are obtained.
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References
[1] Reiser Yu.P., Physics of Gas Discharge (Edition 3, updated and revised). Dolgoprudny, 2009. - P. 734.
[2] Reiser Yu.P., Schneider M.N., Yatsenko N.A. High-Frequency Capacitive Discharge: Physics.Experimental Technique. Appendices. M.: Nauka, 1995. – P. 320.
[3] Fortov V.E., Son E.E., Gaysin F.M., Bromberg L., Son K.E., O John Khe, I Khe Iong. Plasma Technology (in Korean) Moscow Institute of Physics and Technology, KOFST, 2006. –P. 135.
[4] Gaisin A.F. 2013 High Temperature 6 863 – 866
[5] Akishev Yu.S., Grushin M.E., Karalnik V.B., Monich A.E., Pnkin M.V., Trushkin N.I., Kholodenko V.P., Chugunov V.A., Zhirkova N.A., Irkhina I.A., Kobzev E.N. Plasma Physics. 2006. V. 32. No. 12. P. 1142.
[6] Gaisin A.F., Sarimov L.R. 2011 Plasma Physics Reports 6 535 – 540
[7] Dautov G.Y., Dautov IG, Fayrushin II, Kashapov N.F. 2013 Journal of Physics: Conference Series 1 012014
[8] Kirko D.L., Savelov A.S., Vizgalov I.V. Russian Physics Journal. 2013. V. 55. No. 11. P. 1243-1247.
[9] Machala Z., Jedlovsy I., Chladekova L., Pongrac B., Giert D., Janda M., Sikurova L., Polcie P. Eur. Phys. J. D. 2009. V. 54. P. 195.
[10] Pongrác B., Machala Z. IEEE Trans. Plasma Sci. 2011. V. 39. P. 2664.
[11] Kim H.H., Teramoto Y., Negishi N., Ogata A., Kim J.H., Pongrác B., Machala Z., Gañán-Calvo Alfonso M. J. Aerosol. Sci. 2014. V. 76. P. 98.
[12] Lu Y., Xu S.F., Zhong X.X., Ostrikov K., Cvelbar U., Mariotti D. EPL. 2013. V. 102. No. 1. P. 15002.