INFLUENCE OF CORONA DISCHARGE ON PARAFFIN COMBUSTION

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This article presents the results of investigation on the corona discharge and its influence on the water surface during electrolysis and paraffin combustion. The dependences of the voltage-current characteristics of the discharge from the distance between tungsten needle and grounded metal plate are presented. Emission spectra of flame radiation during the paraffin combustion with the working corona discharge were investigated. The temperature of the paraffin flame was determined from the continuous radiation spectrum.

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INTRODUCTION

Works [1-3] showed that the presence of corona discharge leads to the disturbance of the liquid surface. [1-2] showed that corona discharge causes polygonal cells to appear on the surface of the liquids with low conductivity. Our earlier experiments [4] showed that charged particles generated by corona discharge increase the vaporization rate of distilled water droplets. In addition, studies showed that charged particles have a more significant impact on the surface tension of liquids with low electrical conductivity (melted stearin, oil) than on more conductive liquids (water, bio glycerol). Liquids with low electrical conductivity are fragmented into small droplets under the influence of charged particles. This leads to the increase of the ratio between the surface area and volume of liquid. The rise of the area-to-volume ratio in hydrocarbon droplets can be used to increase the speed of mixing hydrocarbon with oxidant and the rate of hydrocarbons vaporization. All of this will allow to increase the combustion efficiency of the hydrocarbons with low electrical conductivity and to decrease the size of combustion chambers. This work focuses on the study of the corona discharge and combustion of melted paraffin under the influence of corona discharge.

1. EXPERIMENTAL SET-UP

Fig. 1 shows the schematic representation of the experimental system for the investigation of the influence of corona discharge on the paraffin combustion. System consists of the 30 mm long tungsten needle (cathode) with 100 μm diameter (1). Pieces of paraffin with the known weight were placed on the thermocouple (2) near the grounded stainless-steel plate (3). The tungsten needle (1) was located perpendicular to the grounded stainless-steel plate (3) at the distance h, which could be regulated in a 0-20 mm range. The negative corona discharge was powered using power source (4) that was able to provide voltage up to 8 kV. Voltmeter (5) was used to measure the voltage on the measuring resistance R_2 of the voltage divider with the 1/1000 coefficient. Voltmeter (6) was used to obtain the readings from the thermocouple (2). Ammeter (7) was used to measure the current of corona discharge. Fig. 2 shows the electric scheme of the corona discharge power source.

Fig. 3 shows the schematic representation of the experimental system for the investigation of the influence of corona discharge on the bubbles created on the water surface during water electrolysis. Electrolysis was conducted using БП-100 power source, which was connected to two stainless-steel electrodes. One of the electrodes was shaped as a ring 12 mm in diameter with the 3 mm mesh was placed on the water surface and grounded. Another solid plate electrode was submerged in water. Tungsten needle was located at 10 mm from the water surface.

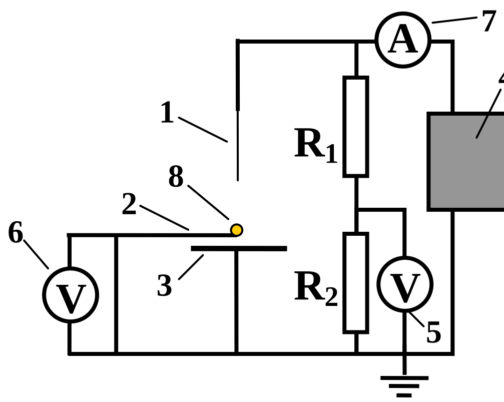


Fig. 1. Schematic of experimental setup: 1 – tungsten tip (cathode); 2 – thermocouple; 3 – grounded stainless-steel plate; 4 – power source; 5,6 – voltmeters; 7 – ammeter; 8 – paraffin

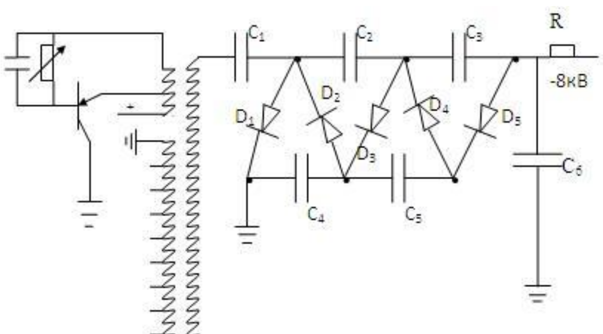


Fig. 2. Electric scheme of corona discharge power source: C_1, C_2, C_3, C_4, C_5, C_6 – capacitors; D_1, D_2, D_3, D_4, D_5 – diodes; R – ballast resistance

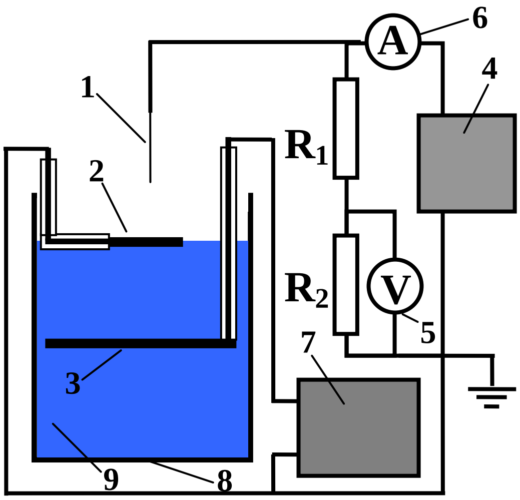


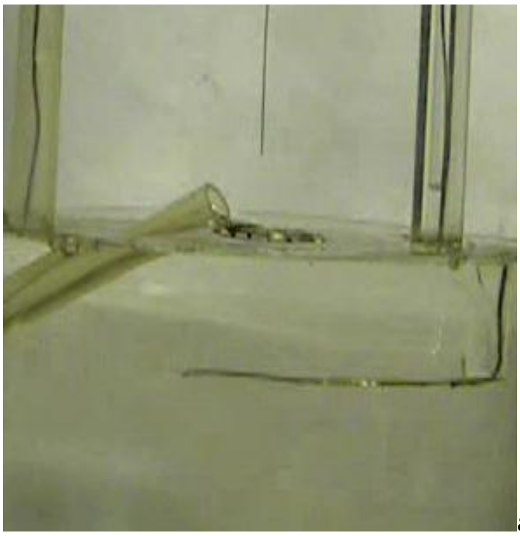
Fig. 3. Scheme of the experimental system for the investigation of the influence of corona discharge on the bubbles created on the water surface during electrolysis: 1 – tungsten tip (cathode); 2 – grounded stainless-steel electrode; 3 – stainless-steel electrode submerged in water; 4 – power source; 5 – voltmeters; 6 – ammeter; 7 – БП-100 power source; 8 – glass container; 9 – water

The visual observation of the influence of corona discharge on the paraffin combustion and bubbles created during water electrolysis was conducted using a digital video camera. Optical emission spectroscopy was used to measure the emission spectra of the paraffin flame. Obtained emission spectra of the paraffin flame were used to estimate the flame temperature.

2. RESULTS AND DISCUSSION

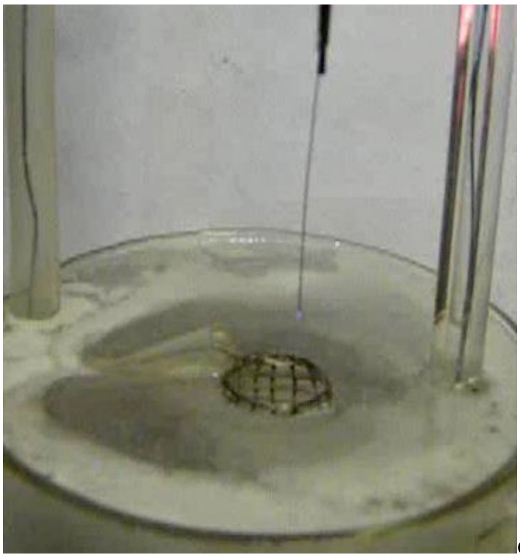
Fig. 4 shows the photograph of the system used for the study the influence of corona discharge on the water surface during electrolysis. See Fig. 4,a shows the photograph of the experimental setup when both electrolysis and corona discharge are off. See Fig. 4,b and see Fig. 4,c show photographs of the experimental setup during the water electrolysis and corona discharge operation. Bubbles, created near the submerged electrode, rise and aggregate near the water surface in the case of turned off corona discharge. The surface tension of water prevents the bubbles from disappearance. When corona discharge was turned on most bubbles on the water surface near the mesh electrode disappear except for those in the area near the walls of a glass container in which water electrolysis takes place (see Fig. 4,c). Gas bubbles can burst due to the decrease of surface tension. The decrease of the surface tension can be caused by the presence of the charged particles, produced by the corona discharge, on the water surface.

Fig. 5 shows the voltage-current characteristics of the corona discharge obtained for the different distances between the tungsten needle point and the grounded stainless-steel plate. At the short distance it is possible to achieve higher discharge current at the voltage that can be provided by the power source (see Fig. 5).



a

b



c

Fig. 4. Photographs of the experimental setup used for studying the investigation of the influence of corona discharge on the bubbles created on the water surface during electrolysis: electrolysis and corona discharge are off (a); electrolysis and corona discharge are on (b, c)

Breakthrough takes place at 5 mm distance and discharge voltage over 6 kV and discharge channel appears between the tungsten needle and plate electrode. Corona discharge does not appear if the discharge voltage is lower than the critical voltage U_c. Fig. 6 shows the dependences of the ratio between the discharge current and discharge voltage (I/U) on the discharge voltage (U), which were measured at the different distances between the tungsten needle and the grounded metal plate. The linear trend lines built for these dependences cross the discharge voltage axis at the value of critical voltage, which was U_c = 2.2 kV.

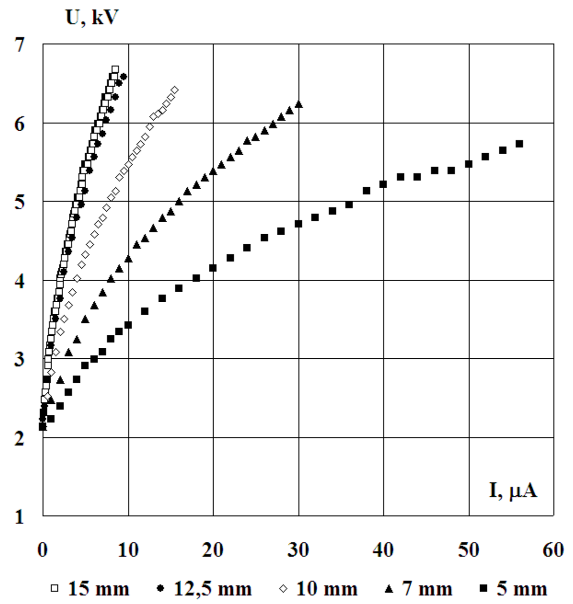


Fig. 5. Current-voltage characteristics of corona discharge in air at different distance between tungsten needle and grounded stainless-steel plate

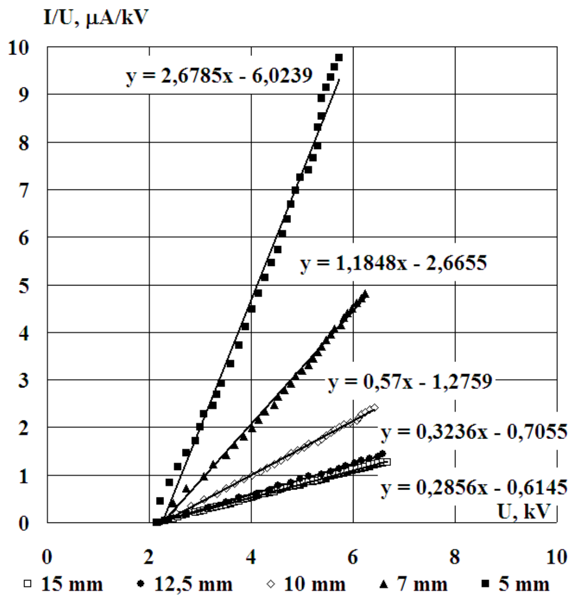


Fig. 6. The dependences of the ratio between the discharge current and discharge voltage (I/U) on the discharge voltage (U), which were measured at the different distances between the tungsten needle and the grounded metal plate

Fig. 7 presents the photographs of the paraffin combustion with the corona discharge being turned off (see Fig. 7,a) and on (see Fig. 7,b). The flame shape changes when the corona discharge is turned on. The height of the flame decreases and its width increases. This can be caused by two factors: the electric field and the stream of charged particles, which are produced by the corona discharge (so called “ionic wind”). The time of complete paraffin combustion is shorter when corona discharge is turned on.

Fig. 8 shows the experimental emission spectrum of the paraffin flame and the modeled spectra of the black body calculated using Planck’s law, which were normalized at wavelength 900 nm. The flame temperature during the operation of corona discharge was found to be determined by the continuous spectrum at the temperature 2200±200 K.

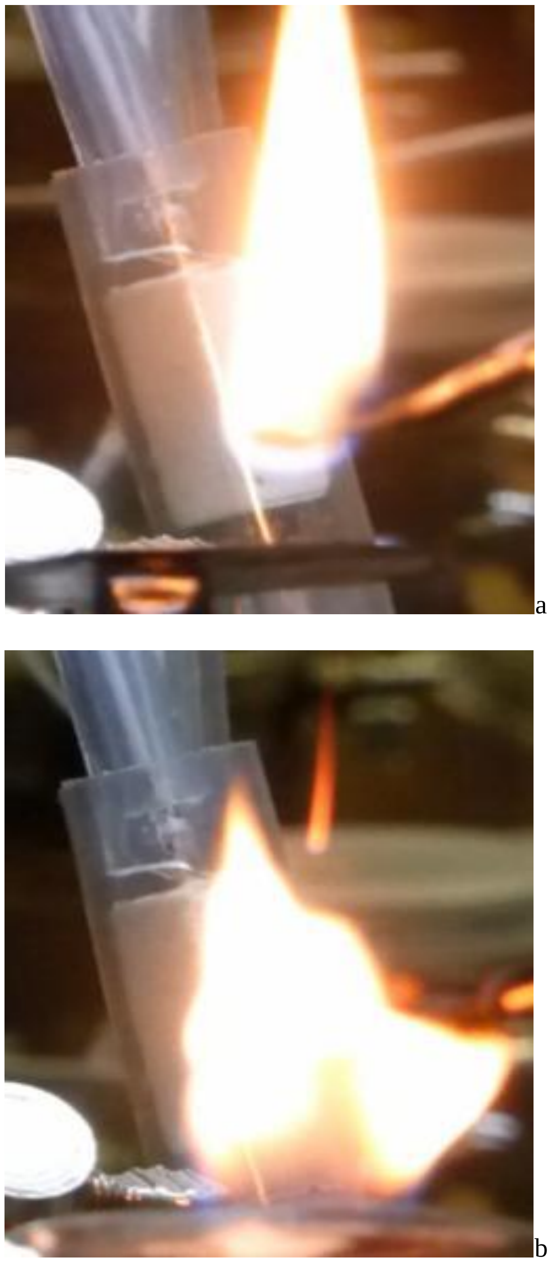

a
b

Fig. 7. Photo of paraffin combustion: corona discharge – “off” (a); corona discharge – “on” (b)

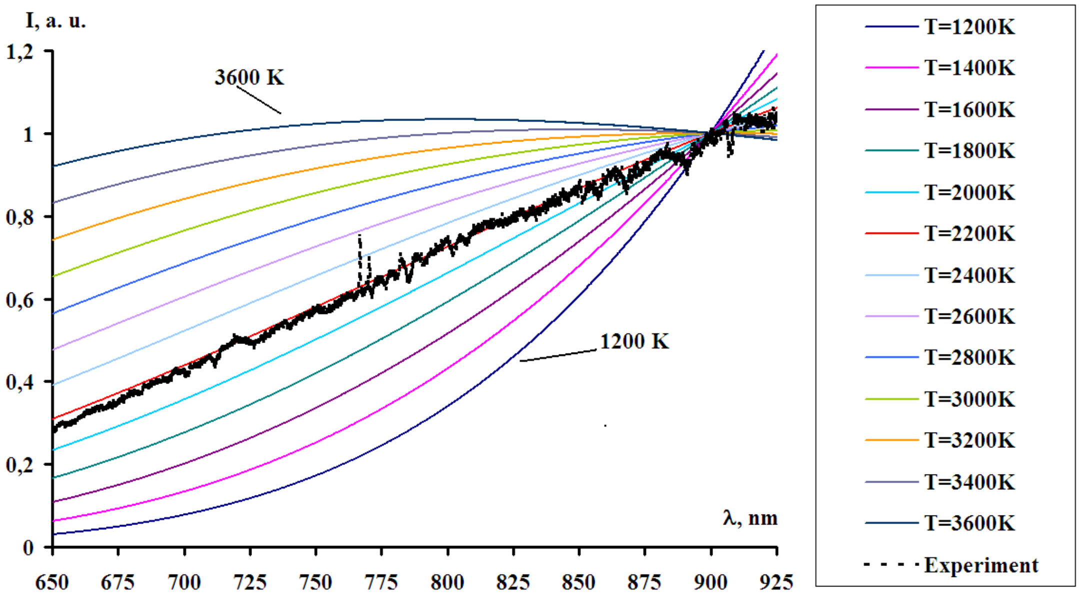


Fig. 8. Comparison between the experimental emission spectrum of paraffin flame and continuous spectra calculated using Planck's law at different temperature

CONCLUSIONS

The shape of paraffin flame changes under the influence of corona discharge. The height of the flame decreases and its width increases. This can be caused by two factors: the electric field and the stream of charged particles, which are produced by the corona discharge (so called "ionic wind"). The time of complete paraffin combustion is shorter when corona discharge is turned on. The flame temperature was determined from the continuous spectrum at the temperature 2200±200 K.

ACKNOWLEDGEMENTS

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ВЛИЯНИЕ КОРОННОГО РАЗРЯДА НА ГОРЕНИЕ ПАРАФИНА

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Представлены результаты исследования коронного разряда и его воздействие на поверхность воды во время электролиза и процесс горения парафина. Представлены вольт-амперные характеристики разряда в зависимости от расстояния вольфрамового острия к заземленной металлической плоскости. Исследованы эмиссионные спектры излучения пламени при горении парафина с включенным коронным разрядом. По сплошным спектрам излучения определена температура пламени парафина.

ВПЛИВ КОРОННОГО РОЗРЯДУ НА ГОРІННЯ ПАРАФІНУ

О.А. Недибалюк, І.І. Федірчик, В.Я. Черняк

Представлено результати дослідження коронного розряду та його вплив на поверхню води під час електролізу і процес горіння парафіну. Представлені вольт-амперні характеристики розряду в залежності від відстані вольфрамового вістря до заземленої металевої площини. Досліджено емісійні спектри випромінювання полум'я під час горіння парафіну з увімкненим коронним розрядом. За суцільним спектром випромінювання визначено температуру полум'я парафіну.