

Plasmachemical processing of raw liquid hydrocarbons by sunk microarc-discharge

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Abstract. The characteristics of microarc discharge with electrodes sunk in the liquid hydrocarbons were investigated. The gas bubble formation process in the space between the electrodes was analyzed. The method of decomposition of heavy hydrocarbons to lighter fractions in plasma of micro-discharge with sunk electrodes is proposed.

In this paper we describe the method of deeper processing of raw liquid hydrocarbon materials for the production of light fractions and allotropic forms of carbon. As shown in [1 - 4] the microarc discharge between electrodes sunk into material is ideal for this purpose. In this case, the discharge is ignited directly into gases that are released from the raw liquid hydrocarbons and occupy a space between the electrodes. Microarc discharge with sunk electrodes was selected for hydrocarbons processing due to several factors. Firstly, discharge takes only limited area inside the liquid. Secondly, small microdischarge current and small energy input don't heat the gas up to the high temperatures when the raw hydrocarbons could split into atomic state, and then atoms could combine in certain fractions. Thirdly, there is no need for electrodes cooling as they are sunk in liquid. Also instantaneous hardening for getting target products are not required, as this process occurs naturally at the gas-liquid boundary.

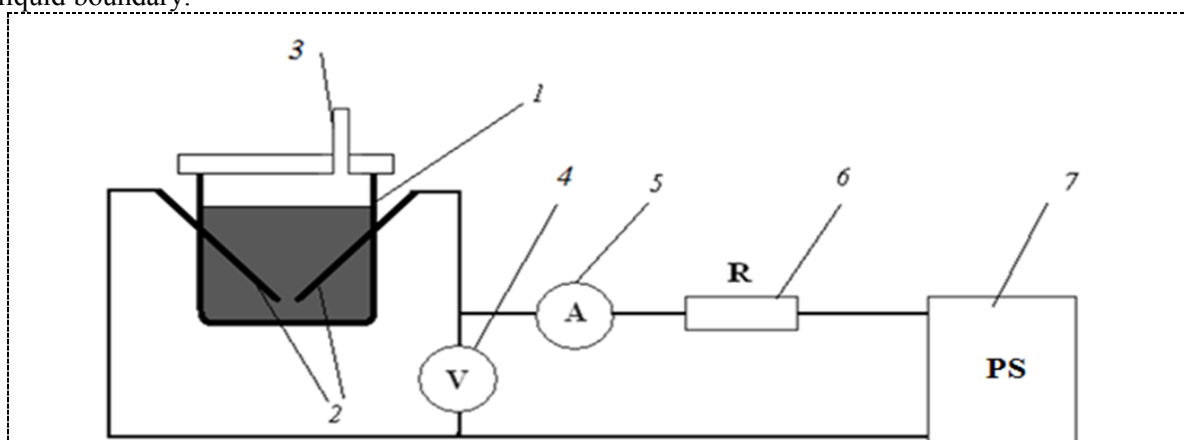


Figure 1. Schematic diagram of the experimental setup: 1 - container with the raw hydrocarbons, 2 - electrodes, 3 - gas exhaust tube, 4 - static voltmeter, 5 - ammeter, 6 - ballast resistance box, 7 - the power supply.



The laboratory setup for the decomposition of the raw hydrocarbon by microarc discharge is a ceramic crucible 1 with lid tightly closed. The lid has holes for the input and output of electrodes 2 and gas exhaust tube 3. The high-voltage regulated power supply 7 allows to submit the rectified voltage up to 15 kV. The ballast resistance 6 is connected to electrical circuit. The fuel oil was used as raw hydrocarbon material. Two copper electrodes 2 of 4 mm diameter are immersed in fuel oil.

To initiate of electric arc it was necessary for short time to connect the electrodes, and then separate them by a distance of a few millimeters (1-2 mm). High temperature of electrical microarc in the space between the electrodes provides enough pressure to support plasma area of the gas-vapor bubble inside the fuel oil. The boundary of this area is directly contacted with fuel oil. Due to the high temperature the high-boiling fractions of heavy hydrocarbons are in the plasma area and by impacts of fast electrons and high energy ions they are splitted into smaller fractions. Due to the action of buoyancy force gas-vapor bubble expands and floats. The decomposition of heavy hydrocarbons and the formation of light fractions in the chamber (between the surface of the fuel oil and lid) lead to pressure growth and the gas starts to leak out through a special exhaust tube into the prepared container.

During its movement in the liquid the bubble is reduced in volume. This could be caused by two phenomena. First, boiling and vaporization if the investigated liquid occurred only in a limited area because of their low thermal conductivity, so the vapours of hydrocarbon raw materials were absorbed back by the liquid. Second, the floating gas-vapour bubble was been cooled and its volume was reducing.

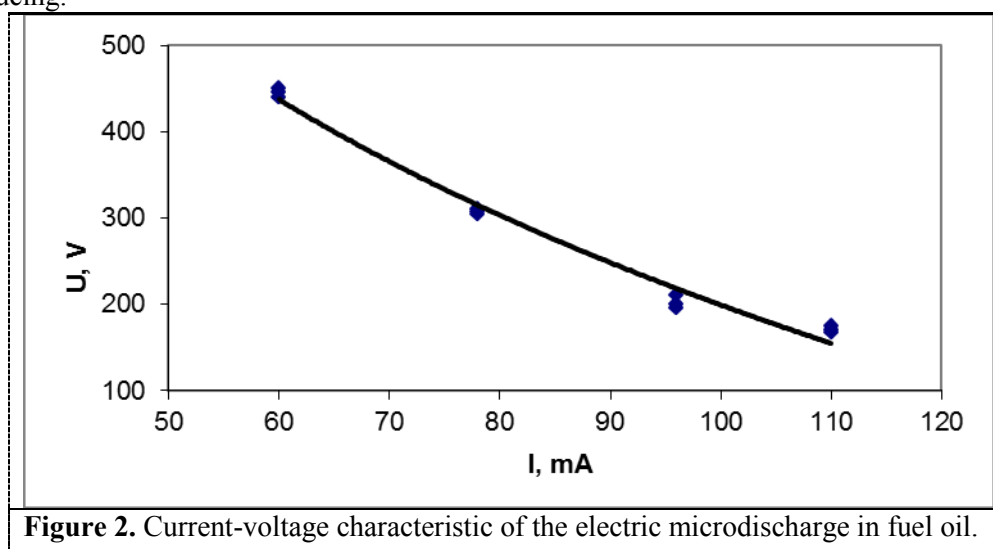


Figure 2. Current-voltage characteristic of the electric microdischarge in fuel oil.

The high viscosity and low thermal conductivity of the fluid enables the existing of extensive conductive region which expands since the discharge power is growing. The shape of these characteristics suggests that the conductive gas-vapour region increases in proportion to the discharge current. Falling volt-ampere characteristic of microdischarge in fuel oil (Fig. 2) is evident that the discharge is a high voltage arc discharge. At low currents the voltage reaches 0.5 kV. If we consider that the inter electrode distance is of the order of 1 mm, the reduced electric field E/N in that discharge is of the same order as in the glow discharge. Therefore, the mechanism of formation of charged particles is not purely thermal and is partly shock ionization. The existence of such mechanism of formation of charged particles and the presence of high-energy electrons in the plasma allow the use of high voltage arc for the decomposition of long hydrocarbon molecules in the fuel oil into shorter molecules.

The temperature of the arc depends on the current values per unit cross-sectional area of the electrode i.e. current density. The larger it is, the higher the temperature of the arc is. Here with heat sink from microarc is performed by free convection. However, at such high temperatures the molecules dissociate, that require more energy input. The pressure in area of electrical microarc sunk in fuel oil

corresponds to the depth of immersion of microarc. Since the depth of the fuel oil is just a few centimeters so the pressure is about atmospheric value.

Under such conditions, unlike electric microarcs in fuel oil from the free microarcs will be the following. Arc channel will be filled with gases and vapors of hydrocarbons of diverse factions. That part of the fuel oil that is in direct contact with microarc will be boiling, put in the discharge region various petroleum fractions. Surface boiling and relatively low thermal conductivity of the fuel oil are preventing the overheating of the bulk of fuel oil and its coking. Hydrocarbon molecules, being in the area of electrical discharge are attacked by fast electrons and ions of the discharge, as well as the excited atoms and molecules of hydrocarbon gases. As a result, most of the long hydrocarbons will be decomposed into shorter fractions. Formed hydrocarbon gases and vapors quickly leave the discharge region because of the effects of buoyancy forces and heat, giving place to the new flow of hydrocarbons. Hydrocarbons vapours consisting a great quantity of gasoline and other light fractions are dissolved in fuel oil, gradually turning it back into the oil. The gaseous fraction is also partially absorbed in the fuel oil, but most of them break out. After collecting of this gas it has a white color and it is heavier than air, despite the fact that its contains methane and hydrogen.

Microarcs electric power, which is released in the discharge, spends to heat the fuel oil, to heat the gas, to vaporization, to decomposition of heavy hydrocarbons, as well as to heat the chamber. Also, the processing of fuel oil by the sunk microarc forms coke deposits on the electrodes besides getting gas. Chromatographic analysis of released gases showed that half of them is ethylene, 36% is hydrogen and about 7% is methane.

References

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