CONVERSION OF ETHANOL IN DYNAMIC PLASMA-LIQUID SYSTEM

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Experimental and theoretical research of the process of low-temperature transformations of mixture ethanol/water in nonequilibrium plasma of the electric discharge in gas channel with fluid wall was carrying out. The gas channel in liquids was created by two counter airstreams in liquids and vapor of the liquids. The gas chromatography and mass-spectrometric techniques for investigation of stable gas-phase conversion products were used. The power inputs on conversion of mixture in synthesis – gas were measured. The values of efficiency, coefficient of energy transformation, specific energy requirement of system were calculated. Experimental results indicate the possibility and efficiency of plasmachemical conversions of ethanol in syntheses-gas in such plasma-liquid system of the atmospheric pressure.
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1. INTRODUCTION

Plasma reforming of hydrocarbons is used by several experimental groups. Conversion of heavy hydrocarbons (HC) into the free hydrogen (H_2), carbon monoxide (CO) and other easily burning fractions allows improving efficiency of combustion and reducing atmospheric air pollution [1]. Research on alternative bio-fuels which can replace traditional fossil fuels, petrol and natural gas is also very actual due to environmental and energy saving problems [2]. The first trial in comparison of all existing technologies of plasma reforming system belongs to CEP [3]. In this article they provide an overview of the setting up, feasibility and efficiency of the existing technologies. The aim of this work was to calculate coefficient of energy transformation and efficiency for the conversion of ethanol in the poorly investigated electrical discharge in the gas channel with a liquid wall (DGCLW).

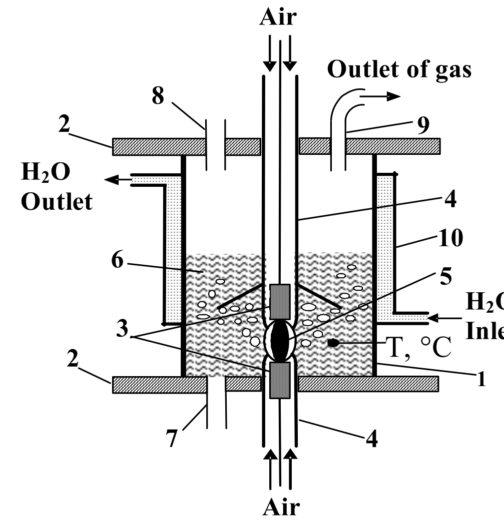

Fig. 1 Experimental set-up for conversion of ethanol in synthesis – gas.

2. EXPERIMENTAL SET-UP

Experimental set-up for conversion of ethanol in synthesis – gas is shown on Fig. 1. It consists of a cylindrical quartz test-vessel (1) sealed at the top and at the bottom by duralumin flanges (2) with a built-in electrode system (3). The cooper rod electrodes (3) were inserted into the quarts tubes (4) and installed coaxially one opposite other. The tubes (4) served also for the gas (air) inlet. A compressed atmospheric air was injected along electrodes (3) through the open nozzle ends (4) and formed a stable counter-flow gas channel surrounding by liquid ethanol (6). The electric discharge (5) was burned in the gas channel between the immersed electrodes where an electric breakdown occurred. The ethanol/water solution (5 mole of ethanol: 1 mole of water) was filled into the reactor through the drain pipe (7) at the bottom flange. The outlet connections (8) and (9) at the top flange were connected with a system of communicating vessels allowing control of the liquid level and pressure in the reactor.

The outlet pipe (9) served for transportation of the synthesis gas products from the reactor to the condensing vessel and further to the gas analysis. Because of the electric-discharge heat release and heating of plasma-treated solution in the reactor, an auxiliary cooling was provided by the water-cooled jacket (10). The temperature of work solution in the reactor was measured by the immersed thermocouple.

The mass-spectrometric and gas chromatography techniques for investigation of stable gas-phase conversion products were used. The monopole mass-spectrometer was used for the mass analysis.

The different modes of operations setting were investigated: the mode when "+" put to the electrode mounted in lower flange, and "-" put to the liquid ("liquid" cathode); the mode when "-" put to the electrode mounted in lower flange, and "+" put to the liquid ("liquid" anode); the mode with two solid electrodes.

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On Fig. 2 shows typical current-voltage characteristics of the DGCLW in ethanol-water solution 5:1 for three different modes.

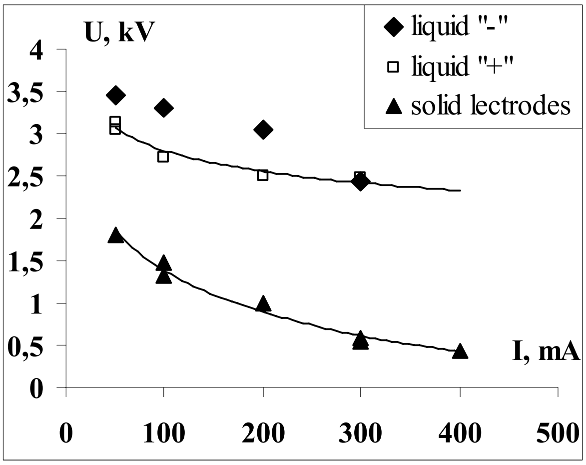

Fig. 2 Current-voltage characteristics of the DGCLW in ethanol-water solution.

3. RESULTS AND DISCUSSIONS

Comparison of calculations with experimental data is shown on Fig. 3. One can see that in case of $T = 323$K (as measured by thermocouple) calculated concentrations of most components are close to experimental values, while in case of $T = 355$ K some components essentially differ. At the same time, concentration of H_2 does not vary very much, because, on one side, content of water vapours in the reactor increases leading to the H increasing, and, therefore, to increasing of H_2; on the other side, the time of air flowing through the reactor decreases, therefore, H_2

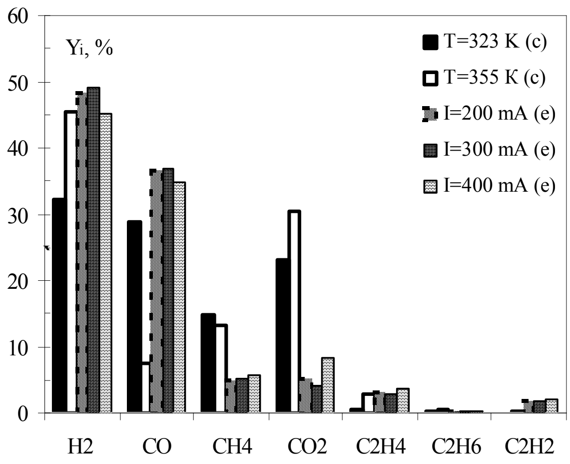

Fig. 3 Component content of syngas products.

yield decreases. Under the influence of complementary factors content of H_2 is steady-state.

On the grounds of calculation of coefficient of energy transformation - α (Fig. 4) and parameter of efficiency - η (Fig. 5) with use of thermochemical constants [4] is carry out comparison of plasmachemical efficiency of conversions of liquid ethanol in electric discharge in gas channel with liquid wall for different modes.

Coefficient of energy transformation was numerically calculate according following expression:

$$\alpha = \frac{\sum_i Y_i \times LHV\,(Y_i)}{IPE}. \qquad (1)$$

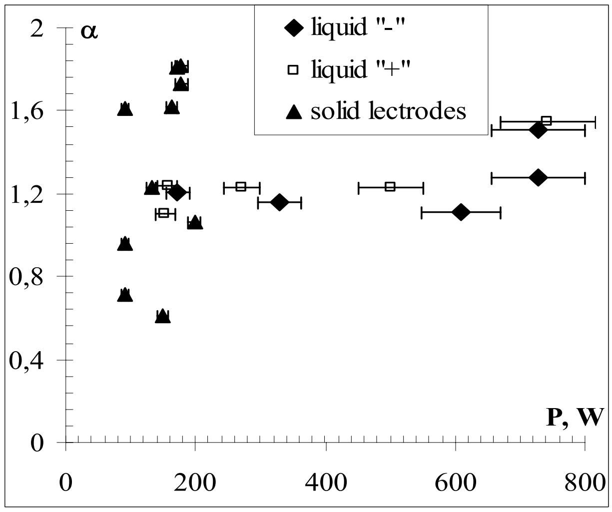

Fig. 4 Coefficient of energy transformation.

Parameter to efficiency was defined on [3]:

$$\eta = \frac{(Y_{H2} + Y_{CO}) \times LHV\,(H_2)}{IPE + Y_{HC} \times LHV\,(HC)}, \qquad (2)$$

here *IPE* is the input plasma energy, *Y* is the molar fraction and *LHV* is the lower heating value of syngas components, *HC* is the hydrocarbon fuel (ethanol). The formula (2) assumes that CO can be totally transformed into H_2.

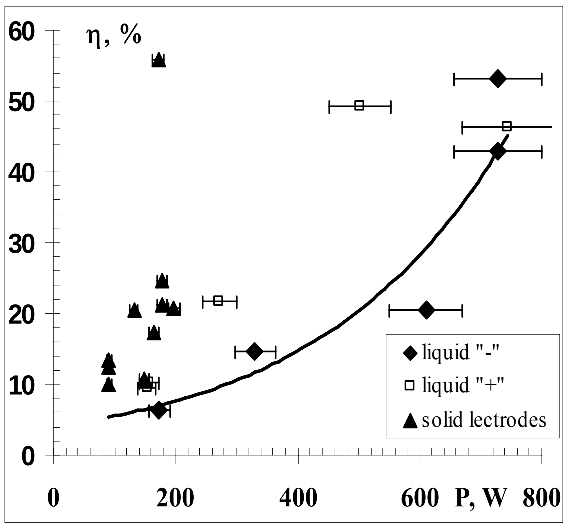

Fig. 5 Energy efficiency of ethanol reforming.

Comparison of plasmachemical efficiency of conversions of liquid ethanol in electric discharge in gas channel with liquid wall with other known plasmachemical methods is shown on Fig. 6.

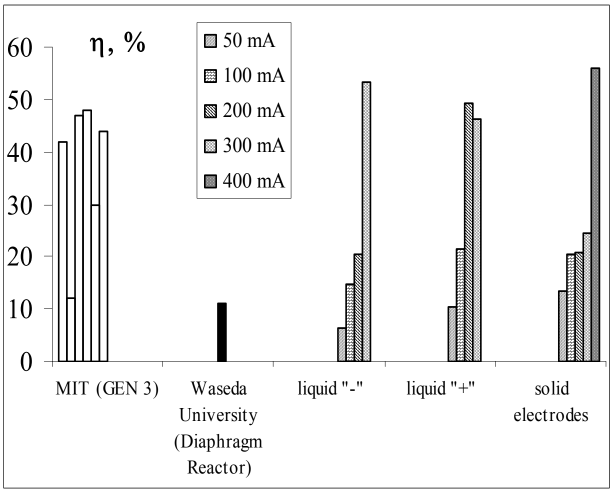

Fig. 6 Efficiency of non-thermal plasma processes.

4. CONCLUSIONS

1. The dynamic plasma-liquid system with the electric discharge in a gas channel with liquid wall is quite efficient in plasma-chemical reforming of liquid ethanol into synthesis gas.
2. At the ethanol reforming in the system with the electric discharge in a gas channel with liquid wall in mode with “liquid” electrodes is formed more gas than in mode with two solid electrodes.
3. The minimal value of power inputs in investigated discharge modes is ~2.4 kWh/m^3 at the power of output syngas of ~4.4 kWh/m^3.
4. It was shown that electric discharge in gas channel with liquid wall have high power efficiency and efficiency of the non-equilibrium plasma processes comparable to other known gas-discharge plasma sources of the atmospheric pressure such as diaphragm and arc types.

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КОНВЕРСИЯ ЭТАНОЛА В ДИНАМИЧЕСКОЙ ПЛАЗМЕННО-ЖИДКОСТНОЙ СИСТЕМЕ

В.В. Юхименко, М.А. Веровчук, С.В. Ольшевский, В.Я. Черняк, В.А. Зражевский, В.П. Демчина, В.С. Кудрявцев, А.И. Щедрин, Д.С. Левко, В.В. Наумов

Проводилось экспериментальное и теоретическое исследование процессов низкотемпературного превращения смеси этанол/вода в неравновесной плазме электрического разряда в газовом канале с жидкой стенкой. Газовый канал в жидкости создавался двумя встречными потоками воздуха в жидкости и парах жидкости. Для исследования стабильных газо-фазных продуктов конверсии использовались газовая хроматография и масс-спектрометрическая методика. Измерялись энергозатраты на конверсию смеси в синтез-газ. Рассчитывались эффективность, коэффициент трансформации энергии и удельное потребление энергии системы. Результаты экспериментов показали возможность и эффективность плазмохимической конверсии этанола в синтез-газ в такой плазменно-жидкостной системе атмосферного давления.

КОНВЕРСІЯ ЕТАНОЛУ В ДИНАМІЧНІЙ ПЛАЗМОВО-РІДИННІЙ СИСТЕМІ

В.В. Юхименко, М.О. Веровчук, С.В. Ольшевський, В.Я. Черняк, В.А. Зражевський, В.П. Демчина, В.С. Кудрявцев, А.І. Щедрин, Д.С. Левко, В.В. Наумов

Проводилось експериментальне та теоретичне дослідження процесів низькотемпературного перетворення суміші етанол/вода в нерівноважній плазмі електричного розряду в газовому каналі з рідкою стінкою. Газовий канал в рідині створювався двома зустрічними потоками повітря в рідині та парах рідини. Для дослідження стабільних газо-фазних продуктів конверсії використовувались газова хроматографія та мас-спектрометрична методика. Вимірювались енерговитрати на конверсію суміші в синтез газ. Обраховувались ефективність, коефіцієнт трансформації енергії та питоме споживання енергії системи. Результати експериментів показали можливість та ефективність плазмохімічної конверсії етанолу в синтез-газ в такій плазмово-рідинній системі атмосферного тиску.