PLASMA ASSISTED COMBUSTION OF PARAFFIN

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The results of experimental investigations of plasma assisted paraffin combustion and paraffin fusion kinetics are represented in this work. Current-voltage characteristics of discharge in current range from 200 to 400 mA were measured. Emission spectra of plasma torch and flame in range of wavelength from 200 to 1100 nm were registered. Temperature of flame T and rotational temperature T_r^* were measured.
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1. INTRODUCTION

It is know that gasoline, diesel, and turbine engines could soon burn cleaner or be more fuel efficient through the application of Plasma Assisted Combustion. The technology consists of an electronic device that can be attached to an existing fuel injector that applies electrical voltage to the atomized fuel stream prior to combustion - generating a plasma in the fuel. This effect essentially breaks down the long chains of hydrocarbons in the fuel into smaller parts - allowing the fuel to be burned more completely, resulting in more miles per gallon, or reducing harmful emissions. The using of plasma for rocket engineering can to help resolve a series of additional problems. It is the fuel regression rate [1] or steerability of rocket engine wholly. The general advantages of paraffin as a green fuel are high caloricity, ecological compatibility, safety of keeping and high chemical inertness to external factors, etc. [2]. The results of assembly investigations of plasma assisted stearin combustion and paraffin fusion kinetics are represented in this work.

2. EXPERIMENTAL SET-UP

The commercial stearin was used as a investigated paraffin. Scheme of plasma dynamic system (PDS) for plasma assisted stearin combustion (PASC) are shown in Fig. 1. It consists of main stainless steel chamber (1), in which through a dielectrics (3) two copper electrodes by diameter of 4 mm are entered. Transversal blowing arc (TB-Arc) was used as plasma source. The gas was injected into the main chamber tangentially to the copper electrodes and flowed out through the gas gape between copper electrodes in the form of plasma torch (4) into the cylindrical stainless steel chamber (6). Plasma torch (4) was enclosed by cylindrical steel net (5). Steel net (4) by diameter 1 cm and length of 4 cm was attached to the cylindrical chamber (6). Space between net (5) and chamber (6) was filled by the stearin (7). The voltage was supplied between the water-cooled copper electrodes (2) with the help of the DC power source (PS) powered up to 10 kV. Air flow was created by compressor and controlled by rotameter in range from 0 to 500 cm^3/s. Static pressure outside the chamber was ~1 atm. The flame (8) was formed during the discharge burning in the stainless steel chamber. The voltage between copper electrodes was registered by voltmeter (V) with the step of 200 V. Discharge current was registered by ammeter (A) with the step of 20 mA.

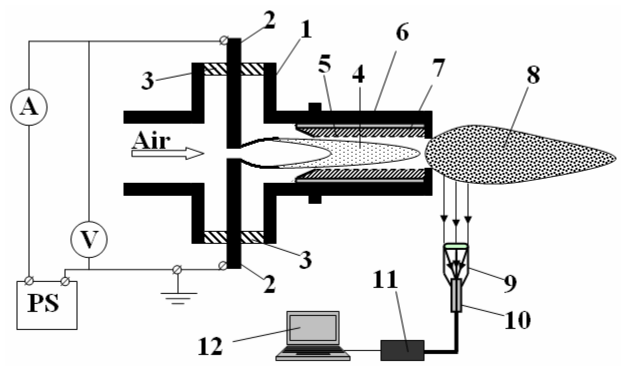

Fig. 1. Scheme of PDS PASC

Diagnostics of the TB-Arc plasma and PASC was conducted by means of optical emission spectroscopy. Optical system consists of optical head (9), which focused parallel beams on optical fibre input, spectrometer Solar TII (11), computer (12). Fig. 1 shows scheme of experimental set-up for diagnostic of the PASC flame (8). Cylindrical chamber (6), cylindrical net and stearin for diagnostic of the TB-Arc plasma torch (4) were detached from the main chamber.

3. RESULTS AND DISCUSSIONS

The typical current-voltage characteristics of the TB-Arc working with stearin at different airflow rates are shown in Fig. 2. The voltage was decreased with increasing of discharge current. Trend lines have approximately slopes at minimum (grey) and maximum (black) air flows.

The current-voltage characteristics of the TB-Arc working with stearin and without stearin at airflow rate G=55 cm^3/s are shown in Fig. 3. Trend line for regime with stearin have steeper slope than for regime without stearin. Stearin vapour hindered discharge burning.

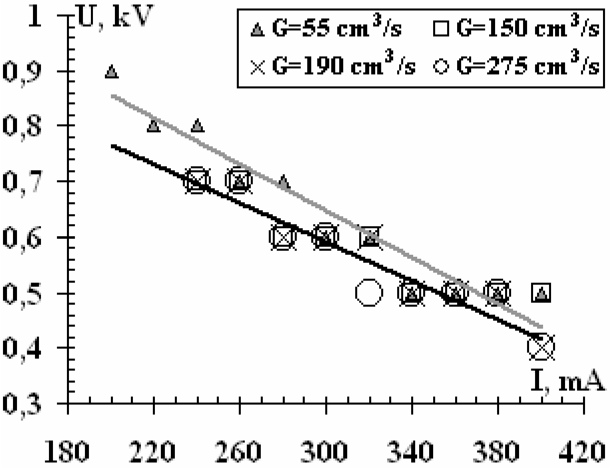

Fig. 2. Current-voltage characteristics of the TB-Arc with stearin at different airflow rates

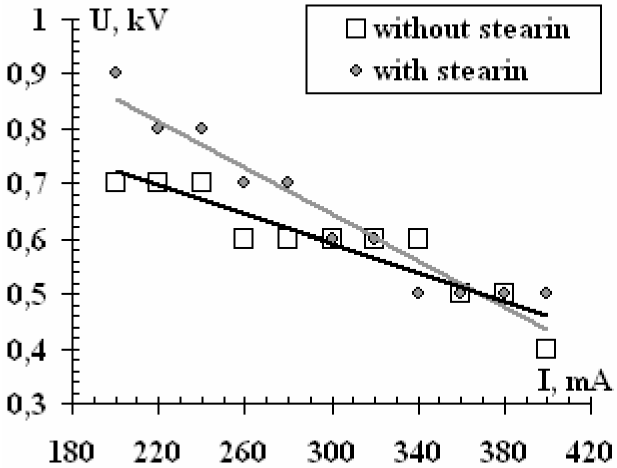

Fig. 3. Current-voltage characteristics of the TB-Arc with and without stearin at airflow rate G=55 cm^3/s

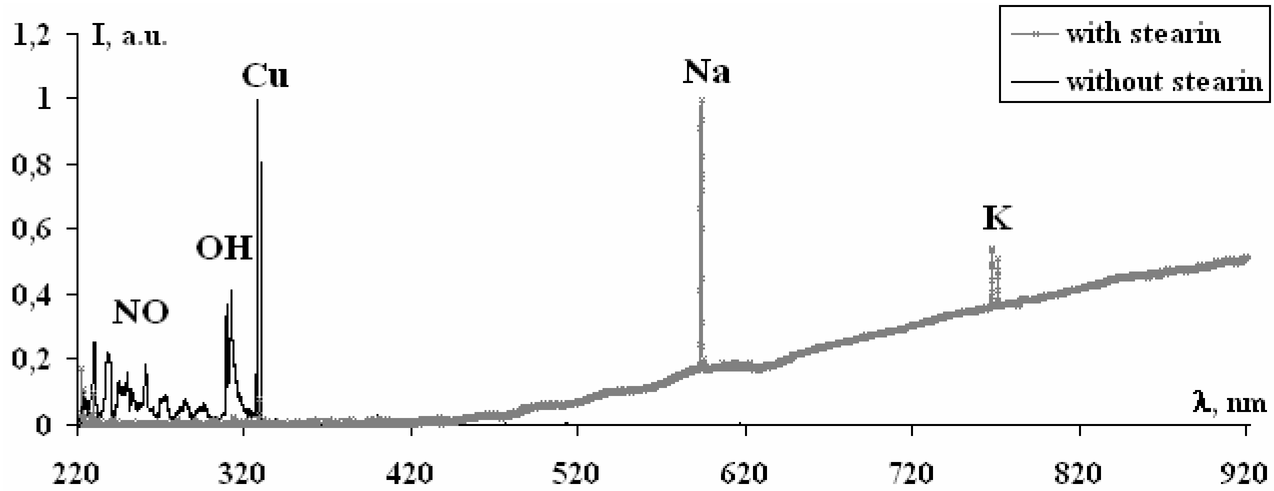

Fig. 4. Emission spectra of plasma torch (without stearin) and flame (with stearin)

Emission spectra of plasma torch (without stearin) and flame (with stearin) at discharge current 300 mA, voltage 0,6 kV, air flow 55 cm^3/s are shown in Fig. 4. Emission spectra were normalized on their maximum of intensity (with stearin λ=588,99 nm and without stearin λ=324,75 nm). Bands of hydroxyl OH, monoxide NO and lines of copper Cu (324,75 nm; 327,39 nm), sodium Na (588,99 nm; 589,59 nm), potassium K (766,49 nm; 769,89 nm) are in Fig. 4. Emission spectra of flame at plasma assisted stearin combustion are close to blackbody spectra.

To determine rotational temperature T_r^* SPECAIR [3] was used. Rotational temperatures measured by hydroxyl bands OH were T_r^* = 2700±500 K for regime without stearin and T_r^* = 2300±500 K for regime with stearin. Flame temperature was obtained (T= 2500±100K) by original technique. Emission spectra of blackbody at different temperatures in range from 1200 K to 3000 K, with step by 100 K, were calculated and normalized (λ=900 nm). Equation 1 for spectra calculating was used:

$$\mathrm{I} = \frac{hc^2}{\lambda^5}\left(\exp(\frac{hc}{kT\lambda}) - 1\right)^{-1} \qquad (1)$$

The kinetics of n- paraffin melting ($C_{18}H_{38}$ and $C_{22}H_{46}$) was investigated for paraffin temperature above melting temperature with using of author's patented method [4]. The melting was supervised simultaneously during measurements of shear modulus. The typical time profiles of shear modulus represented in Fig. 5, 6.

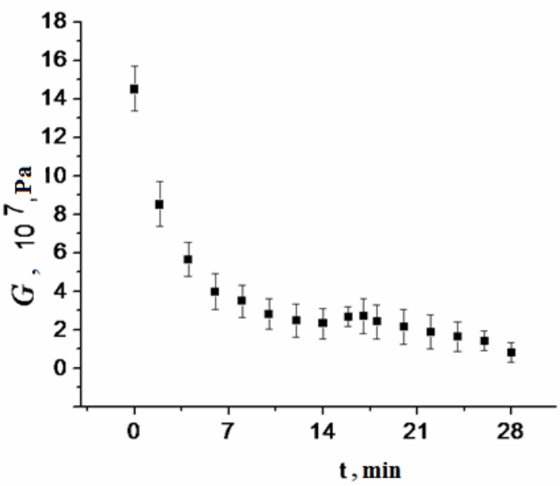

Fig. 5. Time profile rigidity modulus: $C_{22}H_{46}$

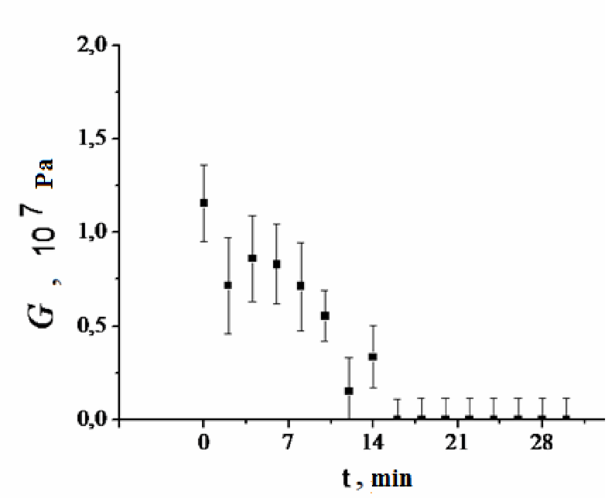

Fig. 6. Time profile rigidity modulus: $C_{18}H_{38}$

It was determined that the time of full melting for $C_{18}H_{38}$ – sample was 14 for fused $C_{18}H_{38}$ is null and for $C_{22}H_{48}$ isn't null. It specifies on that the structure of first substance melt is the liquid and structure of second is the elastically - viscosity object.

The time profile of squared diameter changing for paraffin particles was measured during burning process at burning kinetics investigation. The combustion of paraffin particles was made with using stationary torch. The obtaining experimental results were enabled to define burning constant rate. It was 0,402 mm^2/s.

The paraffin weight in reactor to combustion was 3 g. The time of full fuel combustion was ~ 20 s for value of air flow into reactor 150 cm^3/s. The steady torch was existed for ratio of fuel energy to energy that was inputted to electrical discharge ~ 100 (= 136,8 / 1,2).

4. CONCLUSIONS

The basic components on emission spectra of TB-Arc plasma are the bands OH, NO and lines of electrodes material (Cu).

Emission spectra of flame at plasma assisted stearin combustion were close to blackbody spectra.

Temperature of flame at plasma assisted stearin combustion was ~ T_{PASC} = 2500±100 K.

Ratio of fuel energy to inputted energy into electrical discharge was ~ 100.

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СЖИГАНИЕ ПАРАФИНА ПРИ ПОМОЩИ ПЛАЗМЫ

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Представлены результаты экспериментальных исследований сжигания парафина при помощи плазмы и кинетика плавления парафина. Измерены вольт-амперные характеристики разряда в диапазоне токов от 200 до 400 мА. Получены эмиссионные спектры плазменного факела и пламени в диапазоне длин волн от 200 до 1100 нм. Определены температура пламени и вращательная температура T_r^*.

СПАЛЮВАННЯ ПАРАФІНУ ЗА ДОПОМОГОЮ ПЛАЗМИ

О.А. Недибалюк, В.Я. Черняк, С.В. Ольшевський, Л.А. Булавін, Ю.Ф. Забашта, О.Ю. Актан, О.С. Свєчнікова, С.Г. Орловська, Ф.Ф. Карімова, М.С. Шкоропадо

Представлено результати експериментальних досліджень спалювання парафіну за допомогою плазми і кінетика плавлення парафіну. Виміряно вольт-амперні характеристики розряду в діапазоні струмів від 200 до 400 мА. Отримано емісійні спектри плазмового факелу та полум'я в діапазоні довжин хвиль від 200 до 1100 нм. Визначено температуру полум'я та обертальну температуру T_r^*.