COMBUSTION OF ETHANOL+AIR MIXTURE SUPPORTED BY TRANSVERSE ARC PLASMA

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The influence of preliminary plasma reforming of fuel on plasma combustion efficiency was investigated. The ethanol was chosen as researched fuel. The electrical discharge in the gas channel with a liquid wall was used for preliminary ethanol reforming. The burning was supported by transverse arc discharge in a flow of mix air + reformed ethanol. Emission spectroscopy of plasma was applied to control of burning process. Offered a plasma method for testing of burning efficiency of fuel.
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1. INTRODUCTION

Today the generation of non-equilibrium plasma is very actual for power engineering. The large attention is devoted to hydrogen power engineering with the purpose of use hydrogen as fuel. As this is ecologically pure fuel. But storage and transportation of hydrogen are rather dangerous. Therefore plasma technologies for fuel reforming is represent a major interest. Adding of free hydrogen in fuel reduces harmful exhaust and increase burning efficiency of fuel. The additions of hydrogen reduced quantity of NO_x. Besides thus the octane number of fuel is increased. The results were received in Massachusetts Institute of Technology, at work with fuel received from petroleum [1]. The addition of hydrogen raises of burning efficiency: there is faster lighting of a mix, the wave of burning is distributed faster and there is more complete combustion of a mix. The efficiency of the engine is increased by 30 %, and in exhaust by 80 % decreases the quantity of NO_x. It is very important, that this method does not demand alteration of the engine.

For study of burning efficiency the ethanol was used in our researches. It is urgent and it is economically favourable, as the ethanol can be received from different agricultural cultures by using known technologies.

2. EXPERIMENTAL SET-UP

The hydrogen was obtained by plasma reforming of ethanol. Experimental set-up for reforming of liquid hydrocarbons is shown on Fig.1. It consists of a quartz tube from above tightly closed by a cover. Both the system of gas inlet, outlet, and electrodes system, between which is igniting the auxiliary discharge in the gas channel with a liquid wall, were built in the cover. The tube from below was closed by flange, which was one of the electrodes of secondary discharge. The plasma of glow discharge was another electrode of the secondary discharge. Both the discharges auxiliary (Is) and secondary (Id) were ignited from sources of a constant voltage. The discharges were burned in volume of ethanol. The volume of ethanol was hold constant with the help of informed vessels system. As a result of such treatment on the outlet of reactor the mix air + C_2H_5OH + H_2 + C_xH_y +… was obtained. For removal from mix of ethanol vapour it was directed to a condenser.

At the treatment of pure ethanol in the plasma reformer except free hydrogen in a liquid the solid phase soot was formed. This property was used for generation of nanoparticles in this system. For burning we needed to reduce quantity of soot, which was formed during experiments. The distillate added to ethanol with this purpose.

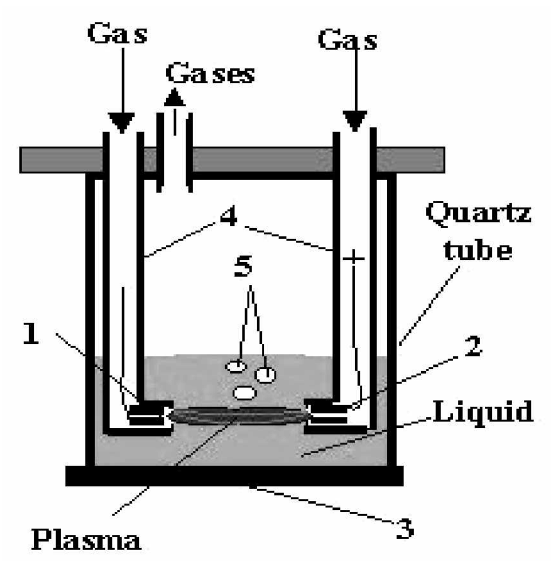

Fig.1. Experimental set-up: 1, 2 – electrodes of auxiliary discharge, 3 –electrode of secondary discharge, 4 - glass pipes, 5 - gas bubbles

The measurements of emission spectra of plasma in a mix ethanol + distillate in a range of the attitude of concentration from 0 up to 96 % were spent during the work.

Plasma radiation was measured by portable rapid PC-operated CCD-based multi-channel optical spectra analyser (MOSA), which has a wide wavelength survey (200-1100 nm) with spectral resolution (~0.2 nm).

3. RESULTS AND DISCUSSIONS

Some emission spectra of the discharge in the gas channel with a liquid wall for various compound of a mix are shown on Fig.2 and Fig.3: Fig.2 - pure ethanol (Is=200 mA; Us=1,5 kV; Ud=2,2 kV; Id=0 mA); Fig.3 - 58 ml of ethanol + 36 ml of distillate (Is=200 mA; Us=2,4 kV; Ud=2,0 kV; Id=0 mA).

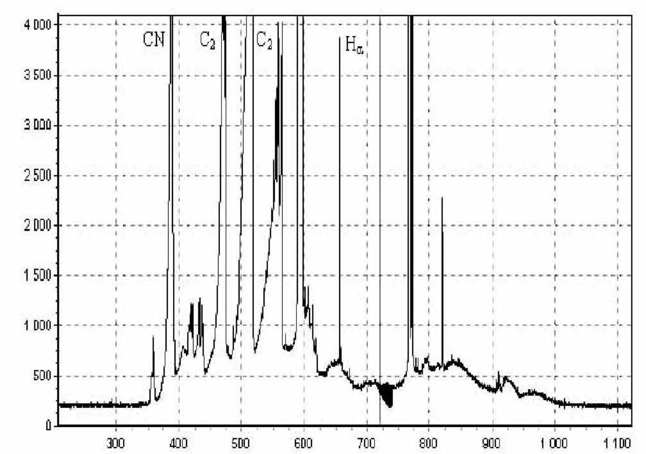

Fig.2. The typical emission spectrum of the discharge in the gas channel with liquid hydrocarbon (ethanol) wall

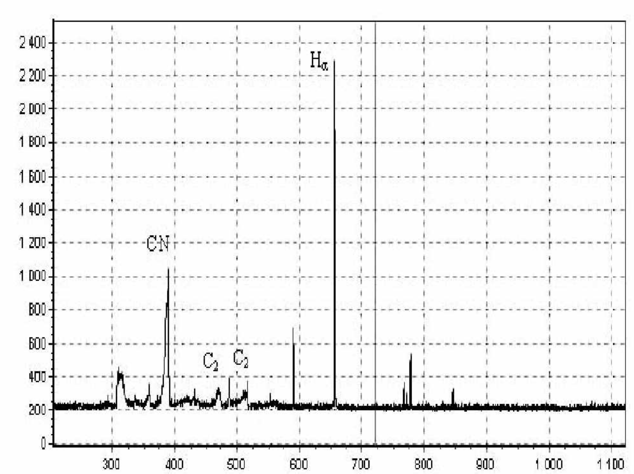

Fig.3. The typical emission spectrum of the discharge in the gas channel with liquid hydrocarbon (ethanol + distillate) wall

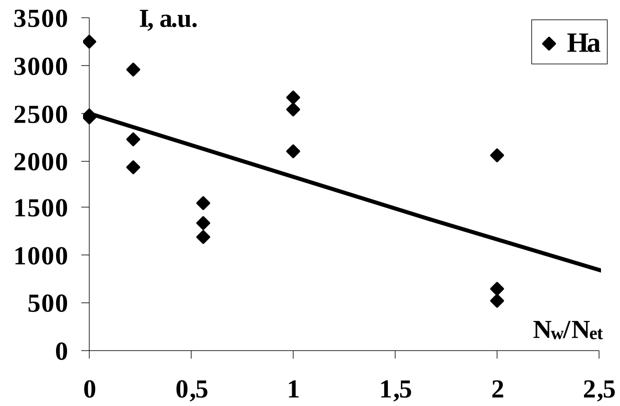

Fig.4. The typical dependence of intensity of a line of hydrogen on the relation of concentrations of water to concentration of ethanol

It is visible that at increase of quantity of water in a mix intensity of a hydrogen line H_a is decreases. At the same time the relative share of hydrogen, in comparison with bands of C_2 and CN [2], is considerably increased at practically constant temperature.

The intensity distributions of emission spectral line H_a from distillate concentrations in solution is shown on Fig.4. It is visible, that at change of distillate concentration in a solution in a range from 0 up to 1 intensity of a hydrogen line decreases not considerably. But thus the quantity of generated soot, during plasma reforming, considerably decreases. These results are shown on Fig.5.

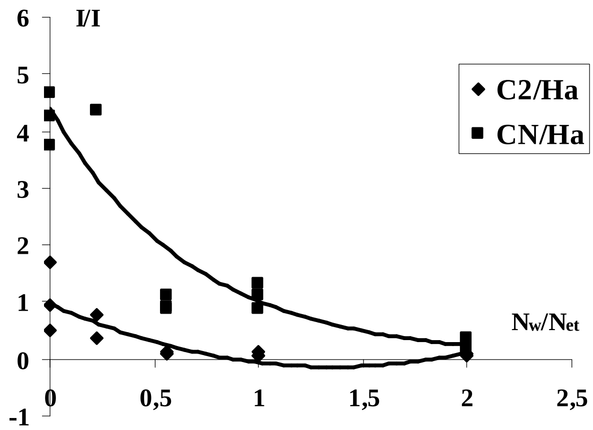

Fig.5. The typical dependence of intensity of C_2 and CN bands on the relation of concentrations of water to concentration of ethanol

The determination of burning efficiency is a sufficiently difficult task. The various techniques are used for research of this question. The automobile companies use engines as test devices, apply devices principle of operation of which is based on colorimetric of fuel. We offered a plasma method for testing of burning efficiency of fuel. It is based on the basis of the transversal arc discharge, which burns in a flow of fuel or combustible mixes. This method allow investigate are: comparison of distributions of optical emission spectra of plasma in arc, comparison of distributions of different energy plasma parameters in arc, change of the shape of a plasma torch of arc, calorimetric of arc.

The scheme of experimental set-up for examination of plasma-assisted combustion of reformed ethanol: after plasma reforming a mix air + H_2 + C_xH_y +… added to the basic flow air + ethanol, in which transverse arc discharge was ignited. The scheme of reception of air and ethanol basic flow - the flow of air was supplied in test-tube with ethanol. The mix of air + ethanol was obtained on the outlet of test-tube. To change the proportion between mixed components the heating of the ethanol was carried out. The discharge was ignited in the obtained mix between two copper electrodes from a source of a constant voltage.

The temperatures distributions of excited electron level population of copper and oxygen atoms along to the gas flow for a case of burning of discharge in air and in a fuel mix decreasing along to the gas flow under the linear law.

The comparison of temperatures distributions for plasma of air and plasma of a mix is shown that the addition of impoverished fuel mix in the discharge does not influence on temperatures distributions of electron level population of electrodes material atoms and components of blowing gas. And it is clear as exists exponential dependence of speed of energy levels population from temperature.

The scheme of the test device for definition of burning efficiency with use of calorimetric measurements is shown on Fig.6.

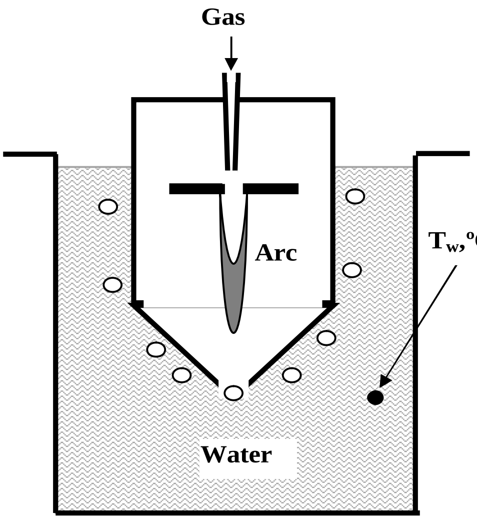

Fig.6. Scheme of calorimeter

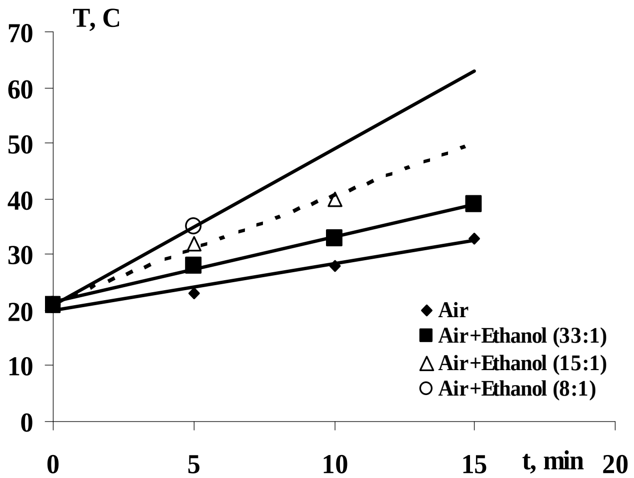

Fig.7. Dependences of water temperature in a calorimeter on the arc burning time

The transversal arc discharge burns in a flow of a combustible mix inside of the metal cylinder with a cone end. In a bottom of a cone there is an aperture serving for release of gas. The cone is placed in the water with temperature that fixed with the help of the thermocouple. The results of research are represented on Fig.7, where the water temperature dependences on the arc burning time are shown. The temperature of water grows with increase of fuel concentration in a mix. It is necessary to note, that the given method is very sensitive, as we work with impoverished mixes which basically do not burn.

CONCLUSIONS

The experimental results obtained in our laboratory have shown that the plasma liquid systems with secondary discharges can be very effective for reforming of liquid fuels.

The experimental results show that transverse arc plasma could be efficiently applied for assisting combustion of impoverished hydrocarbon-air mixes.

The offered plasma method of definition of burning efficiency of fuel based on the transversal arc discharge is highly sensitive.

ACKNOWLEDGEMENTS

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ГОРЕНИЕ СМЕСИ СПИРТ+ВОЗДУХ, ПОДДЕРЖИВАЕМОЕ ПЛАЗМОЙ ПОПЕРЕЧНОЙ ДУГИ

В.В. Юхименко, В.Я. Черняк, В.В. Наумов, Ю.П. Веремий, В.А. Зражевский

Исследовалось влияние предварительного плазменного реформирования топлива на эффективность горения. В качестве исследуемого топлива использовался спирт. Для предварительного реформирования спирта использовался электрический разряд в газовом канале с жидкой стенкой. Горение поддерживалось с помощью поперечного дугового разряда в потоке смеси воздух + реформированный спирт. Для контроля процессов горения использовалась эмиссионная спектроскопия плазмы. Предложен плазменный метод для тестирования эффективности горения топлива.

ГОРІННЯ СУМІШІ СПИРТ+ПОВІТРЯ, ЩО ПІДТРИМУЄТЬСЯ ПЛАЗМОЮ ПОПЕРЕЧНОЇ ДУГИ

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Досліджувався вплив попереднього плазмового реформування палива на ефективність горіння. В якості досліджуваного палива використовувався спирт. Для попереднього реформування спирту використовувався електричний розряд в газовому каналі з рідкою стінкою. Горіння підтримувалось за допомогою поперечного дугового розряду в потоці суміші повітря + реформований спирт. Для контролю процесів горіння використовувалась емісійна спектроскопія плазми. Запропоновано плазмовий метод для тестування ефективності горіння палива.