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Theoretical and experimental ground of the fuel energy efficiency improvement by an activation of the burning reaction molecules-reagents

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A b s t r a c t. In theory and experimentally a method of fuel options energy efficiency rise due to an activation of burning reaction molecules-reagents under high voltage electric field action is grounded. A variant of the technical realization of the offered method is described.

K e y w o r d s: high voltage, electric field, activation, energy efficiency, RedOx.

INTRODUCTION

The economy of fuel and energy resources due to the rise of efficiency of the use of power equipment is one of the basic tasks of modern science and production. Accordingly, a greater expenditure of power equipment per unit of products has a greater negative specific influence on environment. Therefore, a rise of the power equipment use efficiency is valid both for economy in general and, by necessity, for every industry from the viewpoint of economic and ecological efficiency of their functioning.

At present, traditional fossil power equipment is the basic energy source of practically all the economies of the world. Thermal energy sources are traditional and they supply to the most traditional power equipment. Thermal energy is created in te process of fossil fuels incineration in the oxidizing gas environment, that is at the motion of oxidizing-restoration chemical reactions. Therefore, at the use of power equipments optimization is an important task of the motion of chemical reactions.

The process of molecules-reagents activation at burning exothermic reactions is an object of our theoretical and experimental researches.

The technical and technological researches aim at the optimization of burning reaction of hydrocarbon fuels in the air under the high tension electric field.

The article presents the results of theoretical and experimental studies the target of which is the efficiency of motion of exothermic reactions of burning on the example of incineration of hydrocarbon gaseous fuel in mid-air under high voltage electric field.

MATERIALS AND METHODS

The fuel heating value and temperature of flame are basic fuel properties. The fuel heating value (specific burning warmth) is the quantity of warmth (MJ/kg), which is selected at the complete burning of 1 kg of hard or liquid fuel, or 1 m^3 of gaseous fuel. In practice, it is possible to distinguish higher Q_h^f and lower Q_l^f heating value of fuel [1]. A higher heating value is the description of fuel at its complete burning and condensations of the well-educated aquatic pair during burning. So, as in the real terms an aquatic pair is thrown out in the atmosphere, therefore in the heating engineering computations and reference literature under the term heating value of fuel we understand a lower heating value of fuel, in which the warmth of aquatic pair condensation is taken into account. The important question is whether it is possible to change the heating value of every traditional power equipment, or non-traditional one, of a strictly definite and constant size, by means of the proper technologies in the direction of increase.

Processes of generation of warmth are linked, mainly, with the reducing- oxidizing (RedOx) exothermic burning reactions. For the optimization of these processes it is expedient to consider them from the viewpoint of the chemical kinetics theory. The dependence of reactionary properties of the chemical system on the inlying energy, structure and atomic and molecular reagents composition is the basic question of modern theory of chemical kinetics.

Still in 1889 Arenious created the law of chemical kinetics [2], known as the law of his name. This law expresses the possibility of motion of chemical reactions between molecules-reagents. He links the constant of speed

of reaction with energy of activating (E_A), which characterizes the power state of molecule and is written down as:

$$k = k_0 \cdot e^{-\frac{E_A}{RT}}, \quad (1)$$

where: k_0 - preexponential constant; R - gas constant, even 1,987 cal/grad·mol; T - temperature in the degrees of Kelvin scale, °K; e - basis of natural logarithms.

To find an activating energy, reaction speed is caat a different temperature and for every value of speed constant. After taking the logarithm of both parts of formula (1) get a formula:

$$\ln k = \ln k_0 - \frac{E_A}{RT}. \quad (2)$$

For a greater comfort of computations decimal logarithms are used:

$$\lg k = \lg k_0 - \frac{E_A}{4,575T}, \quad (3)$$

where: the number 1/4,575 - module of translation of natural decimal logarithms, increased by R = 1,987.

Energy of activation can be defined with the formula

$$E_A = (\lg k_0 - \lg k)4,575T. \quad (4)$$

From formula (4) it is evident, that the energy of activation of molecules relies straight proportionally on temperature.

A process of activation of the molecular system consists in the transformation of power state of electrons on the higher power level.

The explanation of the given process can be illustrated by means of power diagram of atom (molecules) in Fig.1

A process of excitation of atom (molecules) consists in transition under action of power factor of one or a few valency electrons from the stationary shell in atom (molecule) on higher excitation levels.

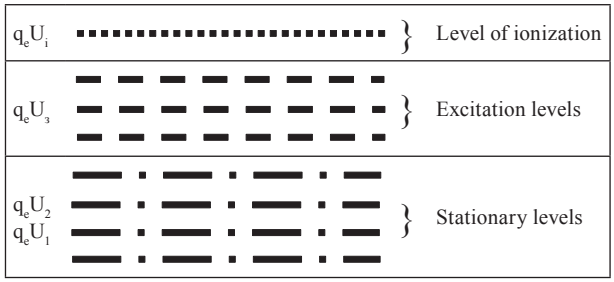

Fig. 1. Power diagram of atom

To release an electron from a molecule of methane, one should get the quantum energy lower than 12.6 eV [3], for ethane and propane – 11.5 eV, for oxygen molecules - 15.5 eV [4] - the quantum of energy lower than the energy of ionization, but sufficient to transfer an electron in an excited state. For computations we take the value of quantum energy of activation molecules about 5% lower than the energy of ionization.

Molecules activation by light is the result of inelastic collision of molecules and quantum of light [5]. With sufficient quantum energy of electromagnetic radiation, electrons move from molecule stationary energy levels to excitation levels. This quantum energy of light (E_l) is calculated by the formula:

$$E_l = h_o \nu, \quad (5)$$

where: h_o – Planck's constant ($6,626 \cdot 10^{-34} \cdot$ J c); ν - electromagnetic wave frequency (Hz).

The frequency was calculated of electromagnetic radiation needed to activate the aforementioned molecules and the results were put into Table 1.

As seen from the obtained results, for the activation of molecules the so called vacuum ultraviolet rays can be used with a wavelength within 100 nm or less. Getting radiation with such parameters in normal states is problematic. Therefore, photoactivation of molecules without special training parameters of the environment is not effective.

After our working hypothesis, for activating of molecules-reagents, except for thermal, it is possible to use other outsourcings with energy. If external energy sources are constant and secure the source of pulsating energy, frequency of which answers resonance frequency of molecules of reagents, it is possible to attain an effect of their translation in the active voice with the substantially lower power expenditure. Complementing the formula (4) by the effect of action on molecules-reagents we will get other factors:

$$E_A = E_{AT} - E_{A3} = [(\lg k_0 - \lg k)4,575T] - Wb, \quad (6)$$

where: W - energy obtained from outsourcings; b - coefficient of the use of external energy by molecules-reagents.

From formula (6) it is evident that thermal energy of activation can be lowered due to the use of other sources of molecules activation.

Table 1. Options of electromagnetic radiation activation

Molecule	Ionization energy, eV	Activation energy			Light frequency, Hz	Electromagnetic wave length, nm
		eV	J / molecula	J / mol		
Methane	12,6	11,91	$19,08 \cdot 10^{-19}$	$11,48 \cdot 10^5$	$2,87 \cdot 10^{15}$	104
Ethane	11,5	10,87	$17,41 \cdot 10^{-19}$	$10,48 \cdot 10^5$	$2,63 \cdot 10^{15}$	114
Propane	11,5	10,87	$17,41 \cdot 10^{-19}$	$10,48 \cdot 10^5$	$2,63 \cdot 10^{15}$	114
Oxygen	15,5	14,65	$23,47 \cdot 10^{-19}$	$14,12 \cdot 10^5$	$3,54 \cdot 10^{15}$	85

To the external energy sources for the activation of molecules-reagents it is possible to take, for example, electromagnetic radiation or irradiation by the stream of the charged particles. In [6] a method is described of obtainment of molecules with the set properties of chemical communications. It consists in operations on a molecule with no less than two degrees of freedom, electromagnetic radiation or stream of the charged particles, which translate a molecule from one quantum power to another. The electromagnetic stream and infra-red laser radiation will initialize and increase the reactionary power of matters [7]. The positive influence of heterogeneous stationary electric field on the flowline of the reaction of burning is described in [8,9].

From all the possible methods of molecules activation we selected the components of RedOx burning reaction for the research on electro-activating. The liquid gas propane was chosen as the reducing component, and the oxygen of air as an oxidant.

The developed experimental unit served the research on influencing efficiency of high-voltage pulsating electric field on the oxidant and fuel at incineration of propane. A functional diagram of the experimental unit is shown in Fig. 2.

The experimental unit works as follows. By the separate channels gaseous fuel and air enter the gas burner. On its way to the gas-ring oxidant in the electrode system 1 and fuel in the electrode system 2 are added to the activating action of the high-voltage pulsating electric field. Each of the electrode systems has a corpus in its composition, made from the dielectric material; entrance and initial opening; general electrode, executed as a metallic plate; and needle-shaped electrodes, placed to the general electrode athwart, which have different length with the purpose of the most effective carrying of fuel and oxidant. The frequency of electric field impulses is changed in the range 20-120 Hertz. The choice of the operations modes of the experimental unit was carried out by means of switches SA1 - SA4.

The oscillogram of the initial signal of sound generator (U_1) and oscillograms of initial signals of generator of high pulsating voltage (U_2) of the experimental equipment are shown in Fig. 3.

The research of efficiency of electro-activation on the oxidant and fuel at the incineration of propane was conducted in the variants:

1) - incineration without electro-activating (control);
2) - incineration with electro-activating of air;
3) - incineration with electro-activating of propane;
4) - incineration with electro-activating of air and propane together.

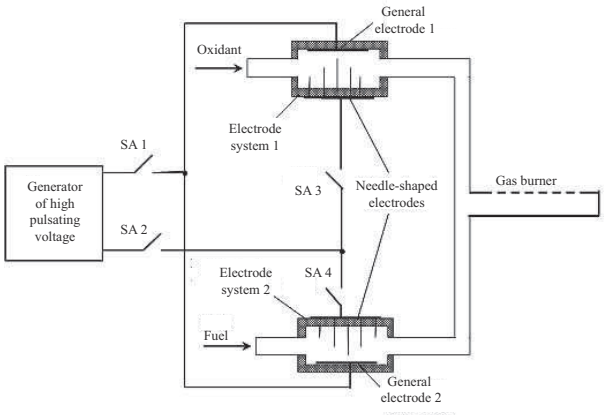

Fig. 2. The functional scheme of the experimental unit

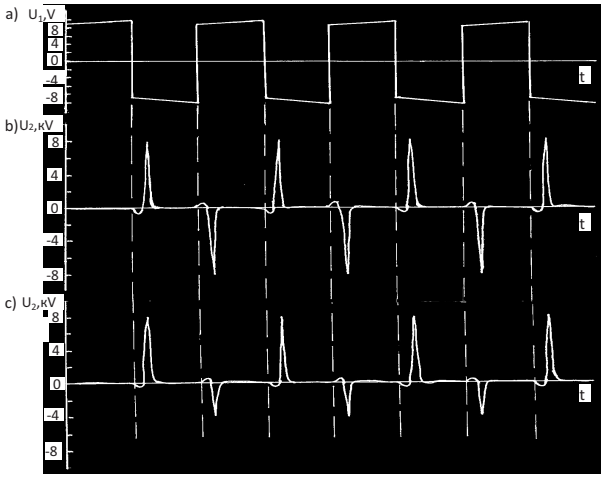

Fig. 3. Oscillograms of sound generator initial signal (a), Oscillogram of entrance signal of the electrode systems without straightening (b) and with straightening (c)

RESULTS AND DISCUSSION

The efficiency of electro-activating was tested by the time of heating 1,0 liter of water from 20 °C to 40 °C.

Table 2. Influencing of electro-activation of burning reaction components at the time of water heating

Method of incineration of fuel	Time of heating of water (c) at frequency of electric field, Hz						
	0	20	40	60	80	100	120
Without electro-activating (control)	124,0	-	-	-	-	-	-
With electro-activating of air	-	125,0	121,7	116,7	113,3	113,3	121,7
With electro-activating of propanou	-	120,0	113,3	110,7	110,0	112,3	110,7
With electro-activating of air and propanou	-	110,0	113,3	106,7	105,0	98,3	96,7
LSD							4,33

There were three repetitions of the experiment. The research results are given in Table 2.

The obtained experimental results show that electro-activation of burning exothermic reaction components of propane in mid-air reduces the heating time of 1 litre of water in an old tub practically in all variants of research. The most positive effect is observed at the action on both of the components of reaction of burning of high-voltage pulsating electric field with frequency 100-120 Hertz.

CONCLUSIONS

1. Activation of molecules-components of burning reaction by the high-voltage pulsating electric field results in the reduction of expenditure of fuel.

2. The highest efficiency of electro-activation (about 22 %) is obtained at the frequency of high-voltage pulsating electric field 120 Hertz and the activation of both the components of burning reaction.

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