THE ELECTRIC FIELD CONTROL OF HEAT GENERATION BY CO-FIRING THE RENEWABLE WITH GASEOUS FOSSIL FUEL

M. Zake[1], *I. Barmina*[1], *A. Meijere*[1,2]

[1] *Institute of Physics, University of Latvia, 32 Miera str., LV-2169 Salaspils, Latvia (mzfi@sal.lv)*
[2] *Riga Technical University, Faculty of Transport and Mechanical Engineering, 6 Ezermalas, LV-1014 Riga, Latvia*

Introduction. The intensive using of the fossil fuels (coal, fuel oil, natural gas, etc.) for heat generation results in the formation of huge amounts of greenhouse gases (CO_2, NO_x, CH_4, etc.), released into the Earth's atmosphere, which evolve the greenhouse phenomenon, affecting the Earth climate and threatening the health of people. A way to solve this problem is to replace the fossil fuel by the renewable energy source (wind energy, solar energy, wood biomass, wood waste, etc.). The alternative approach to this problem is co-firing of the fossil fuel with a renewable one [1, 2]. Moreover, co-firing of the renewable fuel with the fossil fuel in different combinations is well founded not only from the aspects of global warming, but also from the aspects of saving reserves of the fossil fuels [3]. On this account the recent experimental study is carried out, when the ignition and burnout of the disperse layer of a renewable fuel (wood granules) is enforced and stabilized by using the gaseous fuel – propane flame with the aim to investigate and appreciate the main factors that promote the effective and stable heat production with a lower release of greenhouse emissions. Kinetic study of the wood biomass ignition and burnout, flame temperature, composition, radiation and heat release by co-firing the wood granules with the propane flame has shown [4] that for the stoichiometric combustion conditions inside the gasifier the rate of unsteady heating, gasification, ignition and burnout of the wood char is highly depending on the rates of additional heat supply into the bed of gasifier from the propane flame flow. Consequently, previous investigations have shown that an increased rate of the stoichiometric propane/air supply with an increased amount of the additional heat supply into the wood bed decreases the duration of no-flaming response and promotes faster thermal decomposition, ignition and burnout of the wood char and volatiles with a more intensive heat production at higher temperatures inside the flame reaction zone, while a more intensive release of greenhouse emissions NO_x [5] is also observed. Therefore, additional control of heat production by co-firing the wood granules with propane flame flow is required with the aim to provide additional control of the formation of greenhouse emissions and composition of combustion products. With account for this, a method for electric control of fuel burnout and heat production by co-firing the renewable with fossil fuel is developed.

1. Experimental set-up. A laboratory-scale gas/wood biomass co-firing experimental device, consisting of a laboratory-scale premixed propane/air burner, a wood biomass gasifier, charged by wood granules and a water-cooled channel (Fig. 1), downstream which the dominant combustion of the volatiles is developing, is described in [4]. The electric control of co-firing the wood granules with propane is carried out using the electrode, axially inserted downstream the flame of volatiles. The bias voltage of the central electrode in this study could be varied within a range from -3 kV to $+3$ kV, while the ion current is limited to

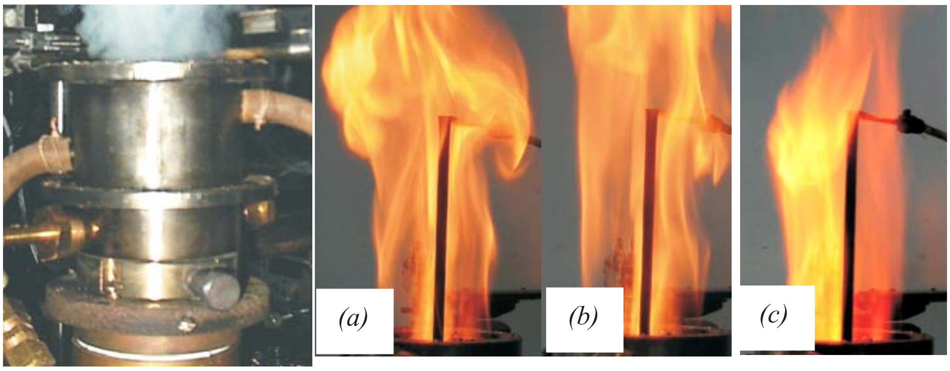

Fig. 1. The digital image of the rimental device and the electric field effect on the shape of the free flame of volatiles: (*a*) – $U = +3$ kV, (*b*) – $U = 0$, (*c*) – $U = -3$ kV.

1 mA, producing evident variations of the flame shape (Fig. 1), provoked by the field-enhanced variations in a rate of unsteady heating and volatilisation of wood granules and burnout of volatiles and wood char.

The recent study of the electric field effect on co-firing the wood granules with propane flame flow is carried out under stoichiometric combustion conditions inside the gasifier and at constant additional heat supply from the propane flame flow into the layer of wood granules, limited by 20% from the total heat amount produced during the co-fire. The electric field effect on the heat production was estimated from the kinetic study of the flame temperature, radiation and calorimetric measurements of the cooling water flow, using the computer data assembling and recording system PC-20TR. The electric field-enhanced variations in the composition of the products by co-firing the wood granules with propane flame flow are analysed using the laboratory scale gas analyser – Testo 35^{R}.

2. Experimental results and discussion. Pevious investigations of the electric field effect on the flame formation have shown that the electric force produces the radial motion of gaseous species in the field direction [6], so producing the field-enhanced processes of heat/mass transfer inside the flame reaction zone and local variations in the flame temperature, composition and rates of reactions with direct influence on the flame shape and length, depending on the bias voltage and polarity of the central electrode. Similar variations in the flame temperature, composition, rates of reactions, flame shape and length are fixed in recent experimental study of the electric field effect on co-firing the wood granules with propane flame flow. Consequently, for the constant additional heat supply into the gasifier

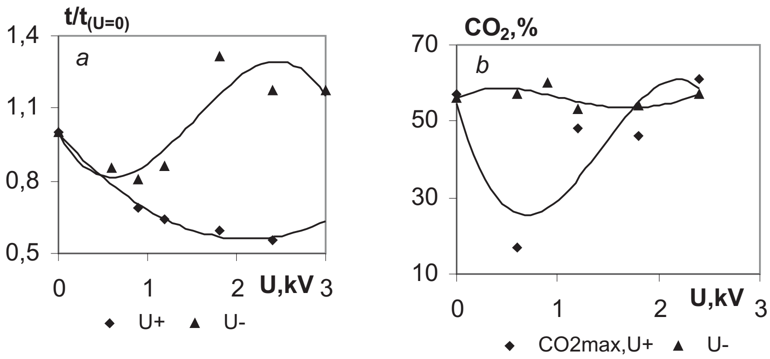

Fig. 2. The electric field effect on the ignition time of volatiles (*a*) and formation of CO_2 (*b*) inside the gasifier.

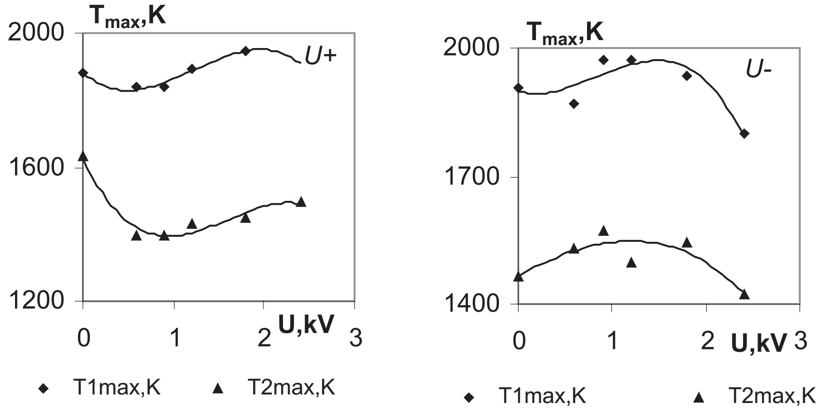

Fig. 3. The electric field effect on the peak value of the flame temperature inside the gasifier ($T1$) and in the flame of volatiles ($T2$).

from the propane flame flow and under stoichiometric combustion conditions inside the gasifier a faster release and burnout of volatiles (C_2H_2, CH_4, C_2H_4, etc.) and a faster heat production, increasing the rate of the temperature rise and the peak value of the temperature inside the gasifier and flame of volatiles, can be achieved by increasing the positive bias voltage of the central electrode. In fact, for such field configuration the electric force drives the radial motion of positive ions and gaseous species from the central part of the flame to the water-cooled channel walls, so enhancing the reverse motion of the flame compounds inside the gasifier that gradually slows down the convective flow of the propane flame, penetrating through the porous layer of wood granules downstream the gasifier. As a result, increases the residence time of reactions, developing inside the gasifier, so completing the thermal decomposition of wood granules, enhancing ignition and burnout of volatiles, decreasing ignition time of volatiles with more intensive formation of CO_2 inside the gasifier (Fig. 2) and correlating increase in peak value of the temperature (Fig. 3). As one can see from Figs. 2 and 3, the field-enhanced burnout of volatiles inside the gasifier, determining the field-enhanced formation of CO_2 and increase in the peak value of temperature can be achieved for $U > +1,2$ kV.

The reverse and less pronounced electric field effect on the flame composition and temperature is observed for the negative bias voltage of the central electrode, when the electric force produces the radial heat/mass transfer of the volatiles from the outside part into the central part of the flame by enhancing the axial con-

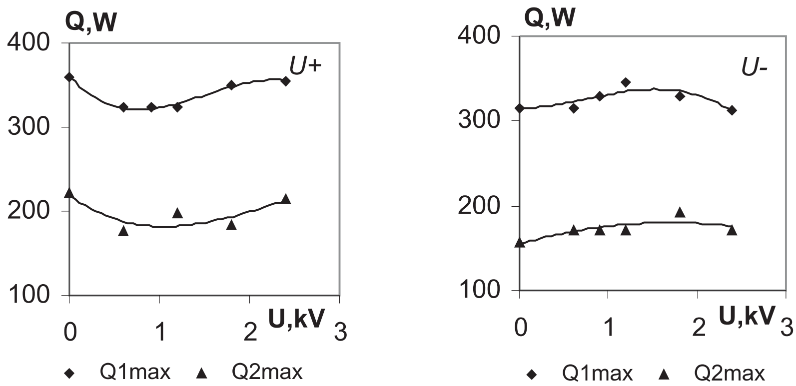

Fig. 4. The electric field-induced variations in heat loss from the gasifier ($Q1$) and flame of volatiles ($Q2$).

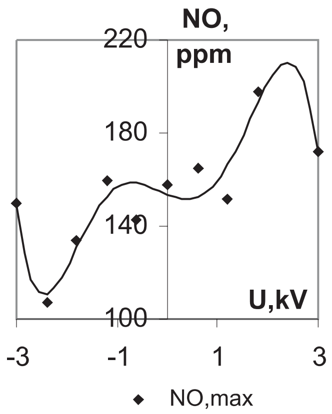

Fig. 5. The electric field effect on the mass fraction of NO in the products.

vective flow of the gaseous species downstream the gasifier and flame of volatiles, decreasing the residence time of thermal decomposition of wood char and volatiles, whereas increasing the ignition time of volatiles (Fig. 2). Under such conditions, slightly decreases the release of volatiles (C_2H_2) and the main products CO, CO_2 (Fig. 2) with a correlating decrease of the peak value of temperature in a limit of $U > -1,2$ kV (Fig. 3).

Actually, the field-induced variations of burnout of volatiles and wood char, producing the variations in peak value of temperature, are related to the field-induced variations in heat loss from the gasifier and flame of volatiles, by increasing the heat loss from flame for $U > +1,2$ kV (Fig. 4), when the electric force enhances the radial flame expansion (Fig. 1), whereas decreasing for $U > -1,2$ kV, when the electric force confines the reaction zone of volatiles (Fig. 1, Fig. 4).

As one can see from Fig. 3, the co-firing of wood granules with the propane flame flow produces relatively high peak values of the temperature inside the gasifier and flame of volatiles, so producing a relatively high value of thermal-NO production, coming up to 180–200 ppm for the positive bias voltage of the central electrode, when the electric field enhances the burnout of the volatiles, increasing the peak value of the temperature and residence time of reactions (Fig. 5, Fig. 3). The field-enhanced decrease of the NO emissions in the products has been achieved for the negative bias voltage of the central electrode, correlating with a decrease of the peak value of the temperature inside the gasifier and in the flame of volatiles (Fig. 5, Fig. 3).

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