J. Int. Environmental Application & Science, Vol. 11(4): 357-360 (2016)

Stoichiometric Model of Combustion Process of Lignite in "PP Kosova B"

Ismet Mulliqi[1], Milaim Sadiku[1, *], Luljeta Pula[1], Fisnik Osmani[2], Mehush Aliu[1]

[1]*University of Mitrovica "Isa Boletini", Faculty of Food Technology, Republic of KOSOVA;* [2]*University of Mitrovica "Isa Boletini", Faculty of Mechanical and Computer Engineering, KOSOVA*

Received September 18, 2016; Accepted December 07, 2016

Abstract: The interest to study the combustion processes has two benefits: transformation of chemical energy to thermal energy, which basically is a source of heat, the usage of exhaust gases as heat carrier used as a working body. For the modelling of combustion process of lignite in "PP Kosova B" accurate data for the analysis of dominant constituents were used. The Methodology of this research is based on laboratory research, famous equations of different authors and the special program Matlab. After the substitution of input values in the program that calculates burned moles of lignite constituents, the obtained results from the program Matlab for excess amount of air have been systematised in tables and diagrams.

Keywords: *Stoichiometric model, combustion, lignite, PP "Kosova B"*

Introduction

For the modelling of combustion process of lignite in "PP Kosova B" accurate data for the analysis of dominant constituents is required. These constituents are: carbon, hydrogen, nitrogen, moisture, sulphur and ash. Mass percentage of constituents in the 1 *kg* sample can be given as follows: *c* for carbon, *h* for hydrogen, *n* for nitrogen, *s* for sulphur, *w* for the moisture and a for ash. The model for our purpose is based on the basic knowledge for models, results from measurements, as well as on the famous equations of different authors.

Materials and Methods

For stoichiometric analysis of the combustion of lignite granules, we rely on the results of the measurements for physicochemical composition of powder coal. Mass percentage of the constituents' m_c, m_h, m_o, m_s, m_n, m_w and m_a is given in Figure 1.

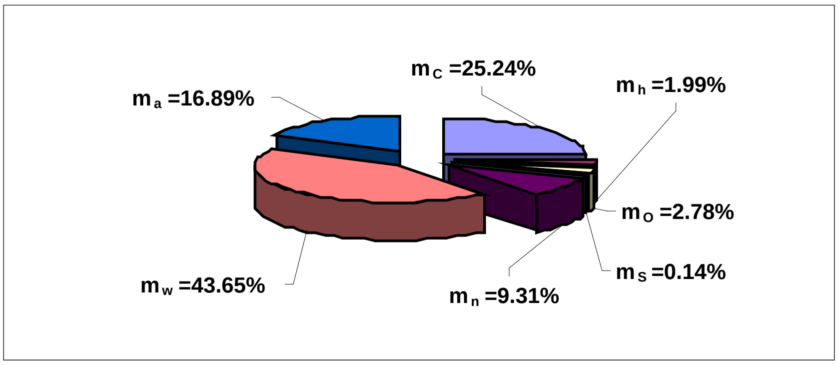

Figure 1. Composition of lignite that is used for combustion in "PP Kosova B"

Now let's do the stoichiometric analysis of combustion. We identify the stoichiometric moles of oxygen with m_s, for any consumed mole of oxygen from the constituents. Constituents of lignite that consume the oxygen are: carbon, hydrogen and sulphur. Thus for carbon we have the following reaction:

$$C + O_2 \rightarrow CO_2 \tag{1}$$

With the burning of 1 *mole* of carbon, 1 *mole* of CO_2 is produced and 1 *mole* of oxygen is required.
So, m_s for carbon will be: $m_{sc} = 1$.
Similarly, for hydrogen and sulphur it will be:

*Corresponding: E-Mail: milaim.sadiku@umib.net; Tel: +377(0)44639133;

$$H_2 + 0.5O_2 \rightarrow H_2O \qquad m_{sH_2} = 0.5 \tag{2}$$

$$S + O_2 \rightarrow SO_2 \qquad m_{sS} = 1 \tag{3}$$

Determination of overall moles of oxygen for kg of fuel (M_S) is done by multiplying individual value of m_s of consumed oxygen by each constituent according to its mass percentage, and then after summing them up we obtain the equation (Demneri *et al.*, 2003):

$$M_S = \frac{m_{sC}}{12} \cdot c + \frac{m_{sH_2}}{2} \cdot h + \frac{m_{sS}}{32} \cdot s - \frac{1}{32} \cdot o$$
$$M_S = \frac{1}{12} \cdot c + \frac{0.5}{2} \cdot h + \frac{1}{32} \cdot s - \frac{1}{32} \cdot o \tag{4}$$

Now let's determine the stoichiometric mass of air (L_0) for kg of fuel. As the mass percentage of oxygen in atmospheres air is 0.23, equation (5) follows:

$$L_0 = \frac{1}{0.23} \times 32 \times M_S \text{, [}\textit{kg air/kg of combustibles}\text{]} \tag{5}$$

The volume of dry air is determined by dividing L_0 by the density of the air that in STP is 1.293 kg/m^3:

$$V^0 = \frac{L_0}{1.293} \tag{6}$$

In order to provide a more complete combustion of the fuel in the boilers, it is often required to insert air in one more boiler that it is theoretically required V^0. Coefficient of excess air (λ) usually has a range value 1.1-1.5 (Black and Veatch). Therefore the required volume of air for the actual combustion process will be,

$$V = \lambda \cdot V^0 \tag{7}$$

Combustion products can be identified by assuming that a complete combustion takes place in the boiler. Combustion products are: CO_2, SO_2, N_2, excess of oxygen (O_2) and water vapour (H_2O). In order to take the right equation for calculations, it would be useful to take into consideration the concept for theoretical volume of combustion products (V_{cp}^0),which is a result of the need for the theoretical value of air.

$$V_{cp}^0 = V_{CO_2} + V_{SO_2} + V_{N_2}^0 + V_{H_2O}^0 \tag{8}$$

The volume of CO_2 for kg of fuel is given by the equation (9)):

$$V_{CO_2} = (22.41/12) \cdot c = 1.86 \cdot c, \text{ [}m^3_{CO_2}\textit{/kg of combustibles}\text{]} \tag{9}$$

Mass of carbon dioxide (m_{CO_2}) in combustion product can be calculated using equation (9) and the density of carbon dioxide that in STP is 1.977 kg/m^3.

Volume of SO_2 for kg of fuel is given by the equation (10):

$$V_{SO_2} = (22.41/32) \cdot s = 0.7 \cdot s, \text{ [}m^3_{SO_2}\textit{/kg of combustibles}\text{]} \tag{10}$$

Sum of the equations (9) and (10) will give us the volume of triatomic gases:

$$V_{RO_2} = V_{CO_2} + V_{SO_2} = 1.86 \cdot c + 0.7 \cdot s \text{ [}m^3_{RO_2}\textit{/kg of combustibles}\text{]} \tag{11}$$

Volume of nitrogen in the combustion product will be:

$$V_{N_2}^0 = 0.79V^0 + \frac{22.41}{28} \cdot n = 0.79 \cdot V^0 + 0.8 \cdot n, \text{ [}m^3_{N_2}\textit{/kg of combustibles}\text{]} \tag{12}$$

Mass of the nitrogen in the products of combustion is calculated by the equation (12) and the density of nitrogen that in STP is 1.25 kg/m^3.

Theoretical volume of exiting dry gases is the sum of equations (11) and (12),

$$V_{gth}^0 = V_{RO_2} + V_{N_2}^0 = 1.86 \cdot c + 0.7 \cdot s + 0.79 \cdot V^0 + 0.8 \cdot n \tag{13}$$

Water vapour in the combustion products comes from the combustion of hydrogen and from the moisture that is found in the fuel. If we assume that 1 *kg* of dry air contains 10g of moisture, then the amount of water vapour in the combustion products is given by the following equation (Black & Veatch, 1996).

$$m^0_{H_2O} = 9 \cdot h + w + 0.013V^0 \ [kg_{H_2O}/kg \ of \ combustibles] \quad (14)$$

Thus theoretical volume of water vapour will be:

$$V^0_{H\,O} = m^0_{H_2O} \big/ \rho_{H_2O} \quad (15)$$

Water vapour in the combustion products is overheated when the partial pressure is low, while the temperature is high. Assuming that water vapour behaves according to Avogadro's law, the value of ρ_{H_2O} is obtained from the relation below:

$$\rho_{H_2O} = 18.016/22.41 = 0.804 kg/m^3 \quad (16)$$

thus,

$$V^0_{H_2O} = \frac{9 \cdot h + w + 0.013V^0}{\rho_{H_2O}} = \frac{9 \cdot h + w + 0.013V^0}{0.804}, \ [m^3_{H_2o}/kg \ of \ comb.] \quad (17)$$

$$V^0_{H_2O} = 11.19 \cdot h + 1.24 \cdot w + 0.0161V^0, \ [m^3_{H_2o}/kg \ of \ combustibles] \quad (18)$$

Including the amount of excess air (λ >1), the actual volume of dry gases will be:

$$V_{dg} = V^0_{dg} + (\lambda - 1)V^0 \quad (19)$$

where: $(\lambda - 1)$ is excess of air.

Similarly, the actual volume of ware vapour is:

$$V_{H_2O} = V^O_{H_2O} + 0.0161(\lambda - 1)V^O \quad (20)$$

The total volume of gases for kg of fuel will be:

$$V_g = V_{RO_2} + V^0_{N_2} + V_{H_2O} + (\lambda - 1)V^0 \quad (21)$$

Volume fraction of triatomic gases, i.e. water vapour will be:

$$r_{RO_2} = \frac{V_{RO_2}}{V_g}; \quad r_{H_2O} = \frac{V_{H_2O}}{V_g} \quad (22)$$

From the total mass balance, mass of the gases will be:

$$m_g = 1 - a + 1.306 \times \lambda \times V^0 \quad (23)$$

Results and Discussion

After substituting the input values in the program for calculating the consumed moles of gas constituents, the obtained results from the program Matlab for excess of air are systematised in table 1 and shown in Figure 2.

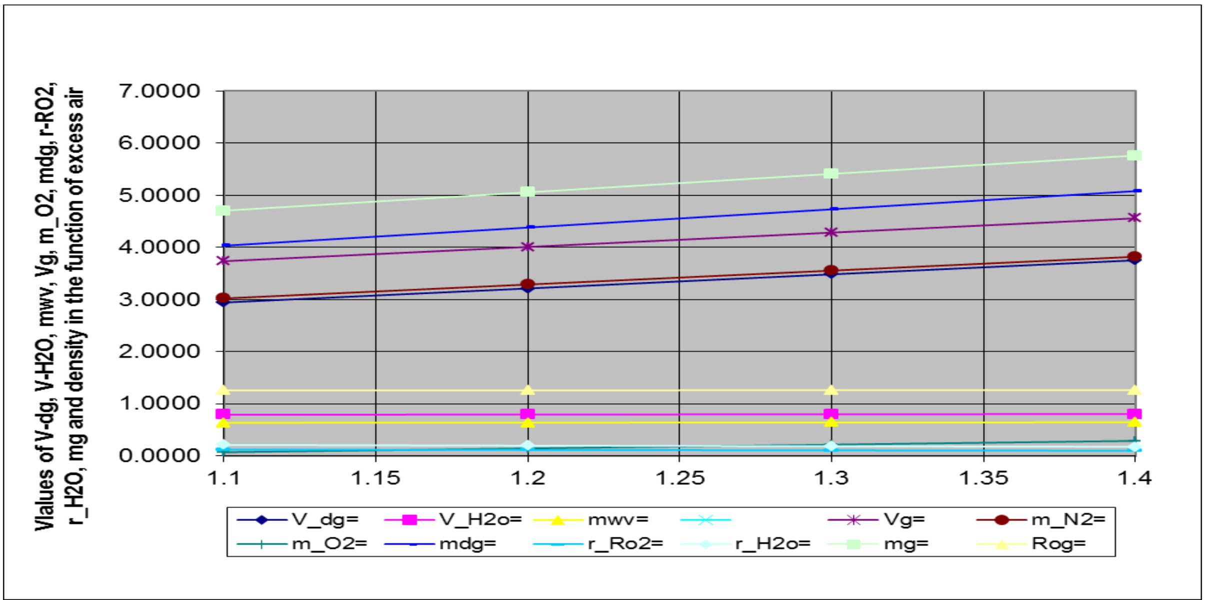

Figure 2. Excess air dependent composition of combustion products of lignite in "PP Kosovo B"

Table 1. Impact of excess air in the parameters of combustion process in “PP Kosova B”

Parameters of stoichiometric model	λ			
	1.1	**1.2**	**1.3**	**1.4**
M_s	0.02518	0.02518	0.02518	0.02518
L_o	3.48940	3.48940	3.48940	3.48940
$m_{real\ air}$	3.83834	4.18728	4.53622	4.88516
V^0	2.69869	2.69869	2.69869	2.69869
V_{CO2}	0.46946	0.46946	0.46946	0.46946
m_{CO2}	0.92813	0.92813	0.92813	0.92813
V_{SO2}	0.00098	0.00098	0.00098	0.00098
m_{SO2}	0.00029	0.00029	0.00029	0.00029
V_{RO2}	0.46956	0.46956	0.46956	0.46956
V^0_{N2}	2.20644	2.20644	2.20644	2.20644
V^0_{dg}	2.67600	2.67600	2.67600	2.67600
V^0_{H2O}	0.78787	0.78787	0.78787	0.78787
V_{dg}	2.94587	3.21574	3.48561	3.75548
V_{H2O}	0.79221	0.79656	0.80090	0.80525
m_{H20}	0.63694	0.64043	0.64393	0.64742
V_g	3.73809	4.01230	4.28651	4.56073
m_{N2}	3.02455	3.29104	3.55754	3.82404
m_{O2}	0.07260	0.14519	0.21779	0.29039
m_{dg}	4.03541	4.38435	4.73329	5.08223
r_{RO2}	0.12562	0.11703	0.10954	0.10296
r_{H2O}	0.21193	0.19853	0.18684	0.17656
m_g	4.70803	5.06048	5.41293	5.76538
ρ_g	1.25948	1.26124	1.26278	1.26414

Conclusions

Based on the results from the analysis of lignite that is used in “PP Kosova B” and other calculations we conclude that:

- During the combustion process of lignite in the boilers of “PP Kosova B”, regardless of the increasing of excess air, the value of the following parameters doesn’t change: volume and mass of CO_2, SO_2, other triatomic gases, volume of nitrogen in STP, dry gases, water vapour, overall number of moles of oxygen for kg of fuel, stoichiometric mass of air for kg of fuel.
- During the combustion process of lignite in the boilers of “PP Kosova B”, with increasing of excess air the value of the following parameters increases: volume and mass of real air, dry gases, nitrogen and oxygen, density of gases, whereas the volume fraction of triatomic gases and water vapour decreases.

References

Black & Veatch, (1996) *Power Plant Engineering*, New York: Chapman & Hall,.
Demneri I, Shtjefni A, Karapici R, (2003) *Termoteknika*, Pegi, Tiranë
Shërbimi i analizave- Gjenerimi /Inxhinjering -KEK
Knorre G, (1966), *Theory of combustor processes*, by Moscow-Leningrad
Instituti kërkimor hulumtues "Inkos" Sh.A. Kastriot
Mulliqi I, (2012) Impact of combustion time of lignite in the model of kinetic combustion in the boiler of "Kosova B", Ph.D. thesis, University of Prishtina, Kosova.