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HEAT-EMISSION CHARACTERISTICS OF SOME ENERGY PLANTS

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ABSTRACT: Biomass makes an important potential during alteration of fossil fuel by heating process. There is no possibility of using bio-fuels without a judgment of their influence to environment. Knowledge of biomass burning characteristics is also very important before its use. This study is mainly focused on gas emissions of briquette bio-fuels. Burned fuels are converted to the briquettes of a 65 mm diameter. CO_2, CO, O_2, SO_2, NO_x and HCl concentrations were checked. Air surplus coefficient (n) set of other values of heating characteristics were also measured. Highest ranges of values were achieved by combusting of energy sorrel.
Key Words: Energy plants, heat emission, bio-fuel.

BAZI ENERJİ BİTKİLERİNİN YANMA EMİSYON KARAKTERİSTİKLERİ

ÖZET: Biyokütle fosil yakıtlar için önemli bir potansiyel enerji kaynağı durumundadır. Biyokütlenin çevreye olan etkileri tam olarak tespit edilmeden kullanılması uygun değildir. Ayrıca, kullanılmadan önce biyokütle yakma karakteristiklerinin bilinmesi gerekmektedir. Bu çalışmada, briket formundaki biyokütlenin yanma gaz emisyonları incelenmiştir. Bu amaçla 65 mm çapında briketler oluşturulmuştur. Briket formundaki biyokütlelerin CO_2, CO, O_2, SO_2 NO_x ve HCl konsantrasyonları incelenmiştir. Bununla birlikte, hava fazlalığı katsayısı (n) ve bazı ısıtma karakteristik değerleri de incelenmiştir. En yüksek değerler kuzukulağı briketinin yakılması sonucu elde edilmiştir.
Anahtar Kelimeler: Enerji bitkileri, ısı emisyonları, bio-yakıt.

1. INTRODUCTION

An energetically use of biomass for a renewable source of energy has a lot of positive aspects. It helps to solve ecological, agricultural and forestry problems (McBurney, 1995; Malaťák, 2003). Biomass based fuel almost does not contain any sulphide. Also the other waste gases from phyto-fuels are more suitable in comparison with other fossil fuels. The ash remained after burning can be used as a fertilizer with a good content of calcium, magnesium, potassium and phosphorus (Sladký, 1986; Sladký and Váňa, 2002).

The share of renewable and secondary sources of energy will be increased from current 2.5 % to 3…6 % in 2010. This is also affected by entering of the Czech Republic to EU and using of financial support for renewable sources of energy. EU uses 12 % of renewable sources of energy nowadays (Anonymous, 1999; Váňa, 2002).

The polluting substances namely solid, liquid and gaseous substances have a negative influence at the atmosphere straight or after the chemical or physical changes in the surrounding air. These substances also harm the health of people, other organisms. Most important polluting substances are SO_2, CO, CO_2, and NOx (McBurney, 1995; Price, 1998; Pastorek et al, 1999; Hutla and Sladký, 2001; Malaťák, 2003).

Characteristics of phyto-mass and choosing the right type of burning equipment are important for biomass. Stoichiometric analysis must be done for energy content. Stoichiometric calculations for burning process are basic for any type of heat calculations. These calculations are also important for solving the whole problem and for controlling the burning equipment, as well (Pastorek et al, 1999; Malaťák, 2003).

Finding out of emission's parameters of chosen bio-fuels is done by using of compressed bio-fuels. These might be compressed to the different shapes by applying different pressures. Bio-fuels take a lot of space, and this increases shipping costs, storage etc, if they are not compressed to the compact shape. Compressed bio-fuels are also better in order to obtain better qualities of combustion.

The main point of the research is to set each of any stoichiometry calculation for analyzed bio-fuels. Especially; a heating value of bio-fuel (Qn) according to ČSN 44 1310 (Anonymous, 2001-b), theoretical amount of oxygen (Omin) and the air (Lmin) for an ideal combustion, theoretical volume amount of dry waste gases (vsspmin), percentage of volume amount of CO2, SO2, H2O, N2, O2, theoretical weight and volume concentration of (CO2 max) in dry waste gases are set by stoichiometry calculation. Final chosen stoichiometry parameter of phyto-mass is shown in Table 1

2. MATERIAL AND METHOD

In this study, mixtures of energy sorrel, canary grass, sudan grass, sorghum, poplar bark and soft coal are used for determining heat emissions. During the measurements the following concentrations were checked: carbon dioxide CO2, carbon mono-oxide CO, oxygen O2, nitrogen mono-oxide NO, nitrogen dioxide NO2, sulfide dioxide SO2, and hydrogen chloride HCl. Measurements were realized by using of fireplace combustion equipment with an 8 kW power and briquette phyto-mass (65 mm diameter). Element analyses of each element consisting briquette phyto-mass, followed by stoichiometry of combusting processes were done. Their stoichiometry is complemented by fuel characteristics. These are necessary for any heat concerned equation and setting of any emission concentration such as SO2, CO, CO2 and NOx.

The first step within any stoichiometry calculation of fuels and a thermal work of combustion equipments is the element analysis of fuel (Anonymous, 1998-a; Anonymous, 1998-b). Elements analysis is very important for any stoichiometry analysis, thermal effectiveness and losses of combustion equipments. It also influences a thermal work of combustion equipment. So called elementary analysis is used during the detection of solid fuels. This element analysis is for finding out a weight percentage of C, H, O, S, N and all of the water consisted in the fuel. Element analysis is done by elemental analyzer (multi EA, producer ChromSpec) for determination C, N, S, Cl. Chromatograph is used for detection of combustible components (GC MS, producer Perkin Elmer). For determination of combustible heat and heating power samples Calorimeter IKA C4000 is used. Final elements compositions are given in Table 2.

The GA-60 gauge was used for the setting of mass flows, emission factors and characteristics of solid particles by thermal use of phyto-mass briquettes. It is a multifunctional smoke gases analytical gauge. GA-60 gauge is also able to measure a temperature of surroundings (t_{ok}), waste gases temperature (t_{sp}), as well. By these temperatures along with the chemical parameters, the gauge provides a calculation of heating characteristics such as; flue loss (q_a), thermal-technical effectiveness of combustion (η_{kor}), air surplus amount (n) and other losses (Anonymous, 2001-a).

The measurement is focused on emissions (CO_2, CO, NO_x, SO_2, and HCl) produced by combustion of mixed briquette phyto-mass. CO_2 is determined by the measured concentration of oxygen and fuel's characteristic. Concerning to thermal parameters and emission conditions the fuel is then judged as combustion equipment.

Table 1. Final stoichiometry parameters of phyto-mass

		Fuels	Wood ships fresh Poplar	Wood ships dry Poplar	Poplar Bark	Energy Sorrel	Canary Grass
Q^r_i	Heating value	$MJ.kg^{-1}$	9.58	17.48	6.99	16.15	15.21
O_{min}	Theoretical quantity of oxygen for ideal combustion process	$m^3.kg^{-1}$	0.58	0.88	0.44	0.83	0.79
L_{min}	Theoretical air quantity for ideal combustion process	$m^3.kg^{-1}$	2.79	4.21	2.105	3.97	3.78
n	Overflow of the air (O_2 = 13 %)	-	2.63	2.63	2.63	2.63	2.63
v_{sspmin}	Theoretical cubical quantity of dry combustion gas	$m^3.kg^{-1}$	2.68	4.11	4.81	3.91	3.73
CO_{2max}	Theoretic cubical concentration of carbon dioxide in dry combustion gas	%	18.76	19.85	18.5	20.26	20.76
CO_2	Carbon dioxide	%	5.90	6.69	5.54	6.90	7.10
SO_2	Sulfur dioxide	%	0.0	0.0	0.0	0.01	0.0
H_2O	Water	%	15.36	9.99	19.18	9.71	9.75
N_2	Nitrogen	%	66.82	70.7	63.88	70.78	70.72
O_2	Oxygen	%	11.14	11.78	10.65	11.77	11.77

Table 2. Elementary analysis of burned solid phyto-mass

		Wood ships fresh poplar	Wood ships dry poplar	Poplar Bark	Energy Sorrel (Rumex tianschanicus)	Canary Grass (Phalaris arundinacea)
W^r_t	Water content (%)	42.73	8.86	53.57	7.95	9.12
A_r	Ash (%)	1.43	1.64	2.61	4.45	6.74
C^r_t	Carbon - C (%)	9.58	17.48	3.69	42.70	41.81
H^r_t	Hydrogen - H (%)	27.17	44.02	0.2	5.42	4.85
N^r_t	Nitrogen - N (%)	4.43	6.03	0.008	1.65	0.84
S^r_t	Sulphide - S (%)	0.43	0.78	19.77	0.11	0.07
O^r_t	Oxygen - O (%)	0.006	0.01	0.007	37.61	36.45
Cl^r_t	Chlorine - Cl (%)	23.8	38.64	0.69	0.11	0.12

Operation tests were made according to standard ČSN European Norms 13229 (Anonymous, 1998-a). A closeable furnace was used for heating tests. In order to obtain values the convection pass (these were dependent on rated power) was in a restricted limit range 12 ± 2 Pa (values of static pressure in a measured area of emissions). An average concentration of CO during measurements and other gaseous emissions was counted to the value of 13 % (O_2). By the standard mentioned above, all of the average values of CO have to meet limit values for certain class of CO, it is mentioned in Table 3.

Table 3. Classes of CO emissions for solid fuel combustion (Anonymous, 1998-a)

Class of CO appliances	Appliances with close door
	Limiting value of class emissions CO, % (at 13 % O_2)
Class 1	≤ 0.3 *
Class 2	> 0.3 ≤ 0.8 *
Class 3	> 0.8 ≤ 1.0 *

* 1 $mg.m^{-3}$ = 0.0001 %

An efficient use of thermal energy by the operation of consumer in concordance with data provided by manufacturer and by the combustion of experimental fuels is judged by efficiency. Measured efficiency has to be in a concordance with limit values for certain class given in Table 4.

Table 4. Efficiency classes by rated heat power (Anonymous, 1998-a)

Classes	Appliances with close door
	Limiting value of class efficiency %
Class 1	≥ 70
Class 2	≥ 60 < 70
Class 3	≥ 50 < 60
Class 4	≥ 30 < 50

Combustion equipment is designed to burn any kind of wood or wooden briquettes. Its most important part is a steel palette or a part of iron with the thickness of 5…8 mm. It is covered by the sides and from the top by feolit bricks. These provide an accumulation of heat and radiate it for a certain time after the end of heating process. Accumulation bricks are covered by an insulating layer of special made and shaped insulating layer of calcium silicate. Doors are equipped with a ceramic glass with resistance up to 750 °C. Emissions are conducted to the flue way of a 150 mm diameter (Anonymous, 1998-a).

3. RESULTS AND DISCUSSION

Among the variable factors which influence thermal work of any combustion equipment, bio-fuel stoichiometry, mass flows and emission factors are also very important air surplus coefficient and a total water content of bio-fuel (McBurney, 1995; Malaťák, 2003). By obtaining the basic stoichiometry parameters of bio-fuels it is possible to effectively judge, design and check a work of observed combustion equipment (Malaťák, 2003). All the water contained in a bio-fuel and air surplus coefficient is primary factor which may influence thermal work of combustion equipment (McBurney, 1995; Pastorek et al, 1999; Malaťák, 2003). All of the calculated stoichiometry values are then used by the calculation of thermal output and losses of combustion equipment.

Hydrocarbons and other incompletely burned products have the same characteristic features as a CO. This is an important indicator of a burning process quality. By the comparison of measured and worked values of CO with emission classes all of the fuels were meeting the criteria of class 2, where the limit is 10 000 $mg.m^{-3}$ by 13 % of referential oxygen (Table 3).

Values of NO_x are easy to measure in the case of all observed fuels. There is no limited value of NO_x because of its low power of heat output. However, if a comparison is done for a limit value of NO_x (250 $mg.m^{-3}$ by 11 % O_2) with the requirements to get a certificate of „Ecologically save product", concerned to water heating boilers for central heating systems with combusting of biomass up to 0.2 MW (Anonymous, 2001-c). In this case that limit value is not overcome by using of any fuel.

The air surplus coefficient (n) is a very important working parameter, which influences emissions as well as heating system efficiency. It also determines an amount of oxide parts and a furnace temperature.

Optimal working temperature is possible to set in the case of consumers of this class in a power range $1.4 \leq n \leq 2.6$. Values determined by this interval were obtained by burning the briquettes of Canary Grass, briquettes of Power Sorrel and Canary Grass in ratio of 3:2 mixture and Soft Coal 10% m/m, briquettes of Canary Grass and Gold-of-pleasure in ratio 1:1 mixture. Soft Coal 15% m/m and briquettes of Canary Grass a Poplar Bark 1:1 mixture with additional 10 % m/m Soft Coal (Table 5). More than 70 % of technical-thermal effectiveness were achieved (class 1) by combusting of briquette mixture of Canary Grass and Sorghum, briquette mixture of Canary Grass and Gold-of-pleasure. To the class 2 (effectiveness n=60 < 70 %), it is possible to place briquette mixture of Canary Grass and Poplar Bark 1:1+ 10 % m/m Soft Coal.

The briquette mixture of Power Sorrel and Canary Grass in ratio of 3:2 with additional 10 % m/m Soft Coal, briquette of Canary Grass and briquette of Sorrel were in class 3 (effectiveness n=50 < 60 %).

Final average values of CO and NO_x ($mg.m^{-3}$) emission of burned phyto-mass briquettes were given in Figure 1.

The highest CO emissions were obtained from energy sorrel briquette. However, NO_x emissions of all phyto-mass briquettes were almost in the same level.

4. CONCLUSION

There is a need to increase the percentage of biomass production for the betterment of national economy, efficient use of local funds, and increase of employees, decrease of noxious emissions of CO_2, SO_2 and NO_x to the environment.

Heating quality requirements are increasing, even in the point of view of its influence to the environment. In the case of local heat consumers, mostly family houses, there is no way how to solve a problem of emissions like in the case of big equipments. It is necessary to prefer standardized high quality fuels.

Table 5. Results of working measurements of gaseous and heat-technical parameters

	Temp. of gas	O_2	n z O_2	CO_2	CO (O_2=13%)	SO_2 (O_2=13%)	HCl (O_2=13%)	NO_x (O_2=13%)	Technical - thermal effect of combustion
	°C	%	0	%	$mg.m^{-3}$	$mg.m^{-3}$	$mg.m^{-3}$	$mg.m^{-3}$	%
Briquette – Energy Sorrel briquettes Φ 65 mm	361.22	14.90	3.67	5.53	4392.80	0.00	103.34	127.66	59.56
Energy Sorrel and Canary Grass in ratio 3 : 2 and Soft Coal 10% briquettes Φ 65 mm	562.86	8.85	1.84	11.20	1843.77	0.00	128.88	159.33	57.76
Energy Sorrel and Sorghum in ratio 3 : 2 and Soft Coal 10% briquettes Φ 65 mm	478.73	13.95	3.10	6.47	4232.95	0.00	73.49	173.56	82.9
Briquette –Canary Grass briquettes Φ 65 mm	487.05	10.24	2.01	9.92	1805.03	0.00	177.65	219.63	55.90
Canary Grass and Gold-of-pleasure in ratio 1 : 1 and Soft Coal 15% briquettes Φ 65 mm	554.41	7.10	1.54	12.83	3057.32	227.29	125.11	154.60	85.40
Canary Grass and Poplar Bark in ratio 1 : 1 and Soft Coal 10% briquettes Φ 65 mm	474.93	11.93	2.47	8.24	4361.46	11.94	155.23	191.91	60.30

All of the values obtained by measurement are counted to normal conditions. (by the temperature $t = 0^oC$ and a pressure $p = 101.325$ kPa and for a referential amount of oxygen O_r, it's value is $O_r = 13$ %.

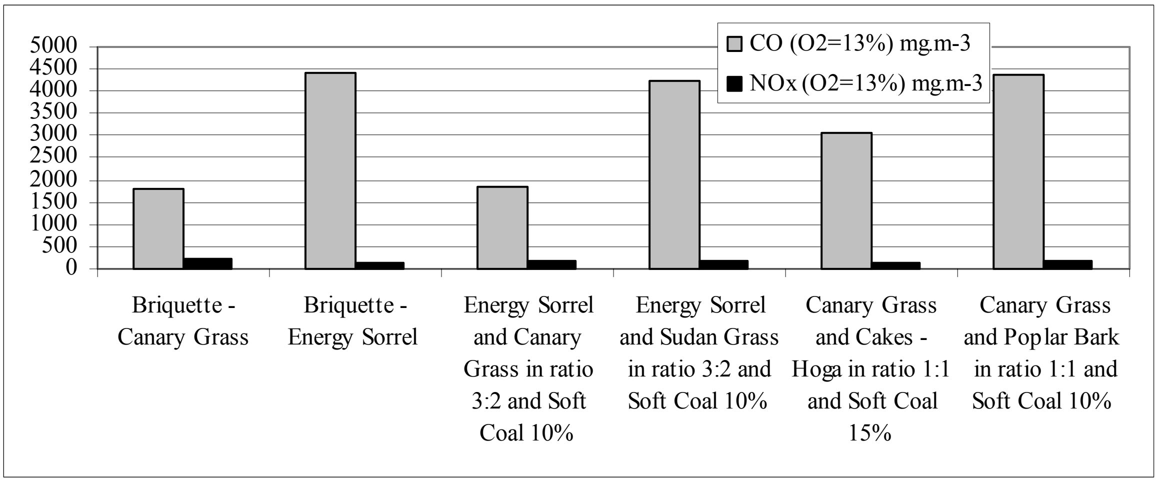

Fig.1 Final average values of CO and NO_x ($mg.m^{-3}$) emissions of burned phyto-mass briquettes converted to 13% amount of Oxygen contained in waste gases

From the currently produced plants energy sorrel and canary grasses have the highest production potential. They also have a large and perspective development. As mentioned in the other researches, emission parameters of fuels consisted of pure sorrel does not necessarily meet the standards and requirements demanded for use in certain combustion equipments.

Analyzed briquette fuels show good emission parameters given by class 2 and effectiveness in a range of classes 1 to 3. These might be suitable for similar local heating systems after the proving of other certificate requirements.

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