Experimental investigation of pollutant's emissions during solid biofuels combustion under FBC condition

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General aspects

Biomass utilization, in particular its combustion has been significantly promoted in the EU during the last decade. The interest is even larger in regions where the population does not have access to central household heating service or alternative and environmentally friendly heating systems are not available due to specific socio-economic factors. However, the emissions of those devices are of a great concern and primary interest to the society even if the state of the art combustion technology is applied [1]. Therefore the focus of this study is on the pollutants formed during the combustion of biomass residue.

The main goal was to experimentally investigate key pollutants and kinetic parameters, characterizing the single particle combustion of biofuels, which have been produced mainly from biomass residue: *softwood (SW)*, *sunflower husk (SF), rape (RP)*, and *wheat straw (WS) pellets*, and *cherry stones (CS)*. The choice of the biofuels is based on the concept, prescribed in the relevant legislation for resource utilization [2]. The softwood pellets contain up to 10 % softwood residue and bark, and were presented here merely for comparison reason. The cherry stones were not pelletized because preliminary study showed that often they are burnt as received. In addition, the used biomass based fuels are freely available at the Bulgarian energy market.

Thus the main gas phase products, the kinetic parameters and the particulate matter (PM) were measured in the flue gas during single particles combustion of the above-noticed biofuels in conditions typical for fluidized bed combustor (FBC). The work is still in progress thus herein some preliminary results are presented.

Materials and methods

The biofuels were burnt into the formation rate unit (FRU), described elsewhere [3-5], which was upgraded in the context of the current work plan. Accordingly a single fuel particle is prepared and burnt into the FRU chemical reactor.

The concentrations of the main gas phase products (CO_2, CO, NO and SO_2) was measured shortly after the fuel particle combustion, following the procedure described in [5]. For that purpose, EasyLine Continuous Gas Analyzers Model EL3020 was used, which main features and principles are summarized in [6, 7].

An additional sampling and analysis procedure was implemented, together with the appropriated devices, which allowed measuring the PM in the exhaust gases in parallel with the gas phase products [6, 7]. In this experiment an aerosol spectrometer analyzer (Welas digital 2000) was used to measure particle size and concentration. Apparently under the chosen conditions merely ultrafine PM was detected (150 - 325 nm).

Overall 15 series of experiments were carried out where more than 600 individual samples were burnt out at the following conditions: atmospheric pressure; temperature: 700, 750, 800,

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850 and 900 °C; oxygen inflow concentration O_2 = 21 vol. %, 13 vol. % and 5 vol. %; and mass of a single fuel particle in the range of 0.1 to 0.3 g.

Preliminary results

The investigated biofuels were characterized in terms of the following analyses: proximate, ultimate and ash analyses. In addition the fuel's high heating value (HHV) was obtained with calorimetric bomb. General results were summarized in Table 1.

Table 1. Chemical characterization of the investigated solid biofuels

Parameter measured	Softwood (SW) pellets	Sunflower husks (SF) pellets	Rape /colza (RP) pellets	Wheat straw (WS) pellets	Cherry stones (CS)
	1	2	3	4	5
Proximate analyses (wt %, as analyzed)					
Moisture	6.89	7.52	9.86	9.62	9.98
Ash	0.65	2.88	4.59	9.80	1.13
Volatile organic compounds	78.77	76.93	78.53	72.53	81.12
Fixed carbon (by dif.)	13.69	12.67	4.59	8.02	7.76
Ultimate analysis (wt%, as analyzed)					
Carbon	47.77	54.04	49.64	48.39	54.29
Hydrogen	6.48	8.45	8.24	8.59	7.90
Sulfur	0.02	<0.05	<0.05	<0.05	<0.05
Nitrogen	0.14	3.00	2.67	3.25	4.40
Chlorine	na	<0.10	<0.10	<0.10	<0.10
Oxygen (by dif.)	38.05	23.96	24.85	20.20	22.15
C/H	7.4	6.4	6	5.6	6.9
C/O	1.3	2.3	2.0	2.4	2.5
Ash analysis (wt %, dry basis)					
SiO_2	2.74	1.01	2.47	57.79	3.58
Al_2O_3	5.37	0.15	0.97	3.93	0.43
Fe_2O_3	1.72	0.92	0.25	1.37	0.43
MnO	1.60	0.02	0.06	0.17	0.05
CaO	33.29	20.44	29.07	8.12	13.00
MgO	7.44	11.95	9.36	2.82	10.57
BaO	0.18	0.01	0.05	0.01	0.01
Na_2O	0.98	0.57	2.48	0.93	0.8
K_2O	15.76	28.78	17.80	12.11	24.16
Cr_2O_3	<0.01	0.07	<0.01	0.01	<0.01
TiO_2	0.32	0.14	0.08	0.20	0.14
ZnO	0.93	0.06	0.01	0.07	0.08
CuO	0.03	0.03	0.01	0.04	0.07
SrO	0.01	0.02	0.01	0.04	0.03
P_2O_5	5.78	5.88	11.67	2.57	26.65
Moisture at 105°C	0.61	4.40	0.23	2.04	5.60
Losses on	23.82	29.51	25.68	9.50	19.74

Parameter measured	Softwood (SW) pellets	Sunflower husks (SF) pellets	Rape /colza (RP) pellets	Wheat straw (WS) pellets	Cherry stones (CS)
	1	2	3	4	5
ignition (LOI)					
High heating value, (MJ/kg, dry basis)					
HHV	19.38	20.28	18.69	16.79	23.62

na – not analyzed.

Time history of the flue gas emissions and the rate of the fuel particle combustion were studied in terms of the main gas phase products (CO_2, CO, NO, SO_2). Figure 1 presents the reaction rate calculated with respect to the carbon conversion and the mass of the biofuels burnt under the FBC conditions according to eq. 1:

$$\frac{dX_{C,fuel}}{dt} = \frac{m_{c,burnet}(\Delta t)}{\xi_C \cdot m_{fuel,0}}, \qquad (1)$$

where $m_{c,burnet}(\Delta t)$ is the mass balance of the carbon in the burnt fuel particle per detention interval; ξ_C the fraction of carbon, based on the ultimate analyses; $m_{fuel,0}$ denotes the initial mass of a single fuel particle sample. The values were averaged versus the temperature (700; 750; 800; 850; 900 °C) and the inflow O_2 partial pressure (21; 13 and 5 kPa).

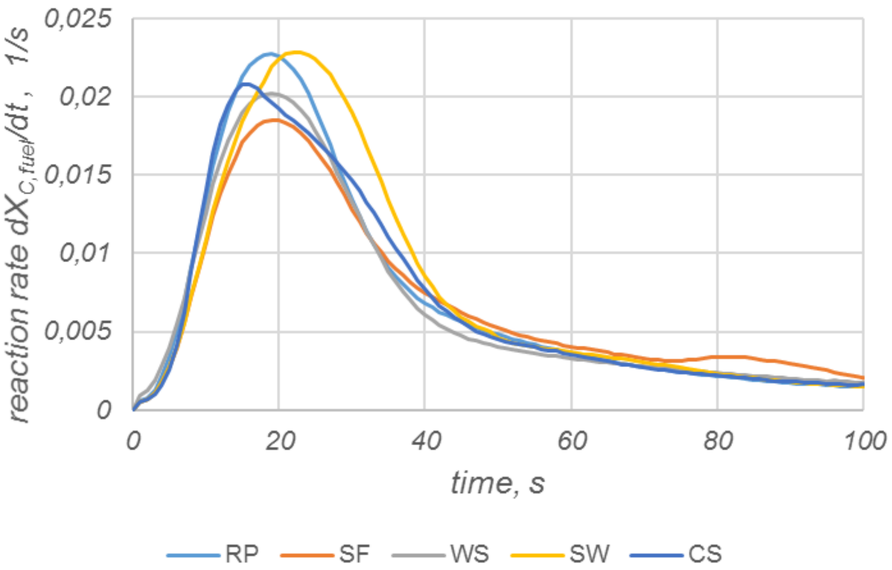

Figure 1. Mass normalized reaction rate for five biofuels burnt in FBC conditions.

Figure 2 presents the mass normalized PM measured during single particle combustion of the five biofuels in the FRU. The values were averaged over all temperatures (700; 750; 800; 850; 900 °C) and inflow O_2 partial pressures (21; 13 and 5 kPa).

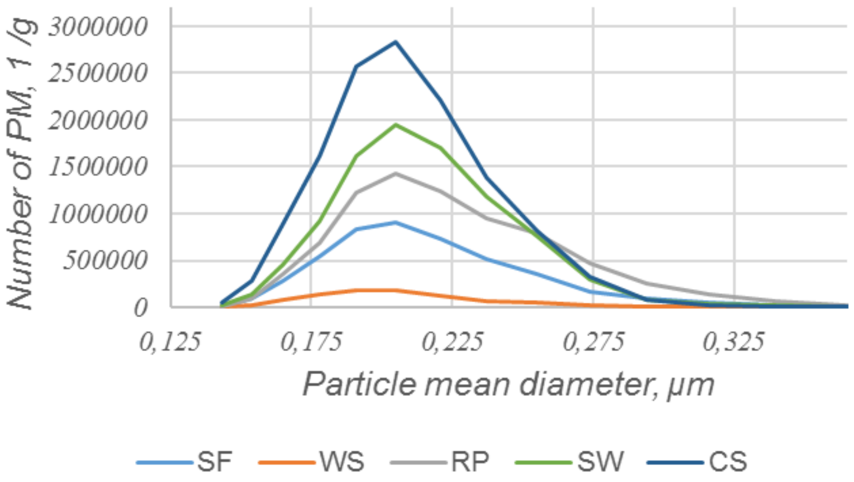

Figure 2. Mass normalized size distribution of PM for five biofuels burnt in FBC conditions.

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