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EXPERIMENTAL RESULTS CONCERNING THE CO-COMBUSTION WITH COAL OF DIFFERENT WASTE QUALITIES

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Abstract. The paper focuses on a novel approach concerning a co-combustion technology of waste with fossil fuel (coal) in fluidized bed on a 0,2 MJ pilot, with special regard to the emission reduction in the flue gases (particles, NO_x, SO_2), according to state of art technology, in order to meet the values stipulated by national laws. Supplementary, some conclusive remarks concerning the numerical simulation of the co-combustion process are given. Finally, one indicates recommendation for the research extension and future plans.

Keywords: Co-combustion, waste, numerical simulation

1. INTRODUCTION AND SCOPE

At the Bangkok reunion of the UN climate report in May 2007 one concluded that until 2015 the emission of greenhouse gases should be stabilized, in order to hope not to exceed with more than two degrees Celsius the average temperature. *Available technologies exist; the costs are not unrealistic as they are in the range of 0.12 % of the world global economic potential.* Not doing anything might be to expensive and late solution or postponed action will cost much more in comparison to prompt present action. The clock for the traditional energy system keeps ticking louder [1]. The global aim in the EC is that by 2010 to raise up to 21 % the ratio of renewable fuels in the general primary energy source sector. In the frame of the standard 2001/77/EG, one states for more input from the available national renewable energy sources, and simultaneous develop a harmonised, sure and integrated market for energy storage possibilities, and green certificates, attesting the electric and heat energy production from CO_2 free or neutral sources [2]. Data in [3] indicates as most cost attractive the waste biomass utilisation as energy renewable resource, especially in countries where biomass is naturally available, under different forms, securing a *national energy resource*. In the European definition of biomass a special concern is paid to municipal waste, in its biodegradable fraction, as well to classic biomass categories. An important issue for Romania's integration in the EU is the national "Strategy for utilization of renewable energy sources" [5], stipulating that in Romania, the share of renewable sources in the overall primary sources consumption should rise considerably. Also the national low concerning the strategy for utilization of renewable energy sources [6] is to be mentioned. The most tempting renewable source consists of biomass waste and hydropower [4], [5]. The *scope* of this paper is to present a novel technology for co-combustion of waste (in particular of agricultural origin) and to introduce some results from the flue gas cleaning. Gradual restrictive legislations on emissions from combustion sources have been increasing the interest in biomass combustion. Co-firing biomass with coal leads to economical & environmentally friendly use of fossil solid fuels by reducing pollutant emissions and provides residues' utilization instead of land - filling.

2. TEST RIG FOR CO-COMBUSTION

The preparation of the fuels is achieved preliminary, with an external mill. The facility comprises several main parts, and is comparable to recent state of art literature (Figure 1):
(i) The main burning subassembly comprising the furnace,
(ii) The heat transfer subassembly components are mainly forming the convective case,
(iii) The flue gases de-dusting system components comprise a cyclone separator,
(iv) The flue gases cleaning subassembly is formed by two scrubbing towers,

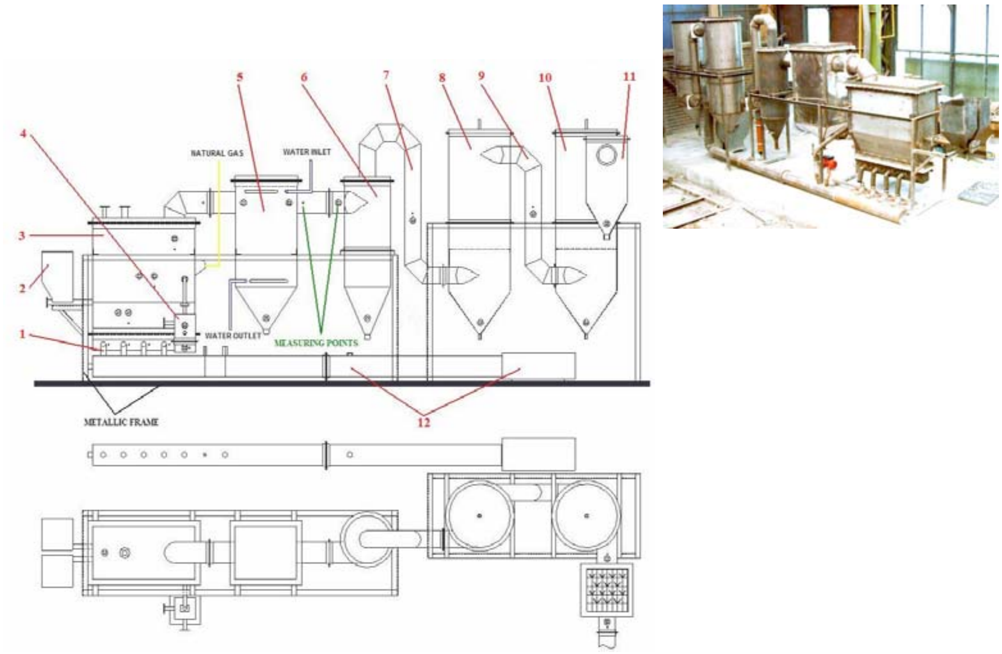


Figure 1. Design of the co-combustion facility in fluidized bed.
1. Air distributor, 2.Fuel feeding system, 3. Furnace, 4. Ash cooler, 5. Convective case, 6. Cyclone separator, 7. Cyclone-scrubber piping, 8. Scrubbing tower, 9. Scrubber-reactor piping, 10. Neutralization reactor, 11. Demister, 12. Air feeding system.

Previously to testing, one mixed available lignite with different biomass types, in controlled participations by mass. Details are comprised in [10], [11], and [12]. Table 1 gives main data of the functional facility. Table 2 gives information about the tested fuels; mainly data are in [13]. As it is presented in [14], co-firing of biomass with coal decreases the ash deposition rate relatively. One used as biomass participation rates of 5, 15 and 20-30 % (by mass).

Table 1: Characteristics of the co-combustion facility.

	Main characteristics
Thermal energy	0.21 – 0.42 MJ,
Flow of the system water	2 – 4 m^3/h,
Flow of compressed air for flue gases cleaning pumps	0.5 – 1 m^3_N/h,
Mass flow of coal (lignite)	25 – 50 kg/h
Flow of the washing liquid (p = 2 bar)	0.2 – 0.6 m^3/h
Electrical power consumption:	2 – 4 kWh,
Flow of combustion / fluidization air	200 – 300 m^3_N/h,
Flow of natural gas for the start	2 – 5 m^3_{st}/h
Mass flow of biomass	15 – 30 kg/h
Mass flow of the resulted ash	10 – 20 kg/h.

Table 2: Main characteristics of used fuels (fossil coal and waste biomass).

	Brown coal	Lignite	Wood saw dust residues	Straw wheat waste	Maize corn waste	Rogan corn waste
LHV (raw) [MJ/kg]	28	9	12.4	15	23.5	20.58
Moisture - raw [%]	5.1	50.4	33	10.6	4.1	3
Volatile matter – dry [%]	34.7	52.11	83.2	74.4	82.6	49.52
Ash (dry) [%]	8.25	15.1	0.34	6.1	12.2	45.1
Fixed C (dry) [%]	57.1	32.83	16.5	19.9	5.2	2.39
H (dry) [%]	5.64	4.9	5.7	4.5	7.9	4.88
N (dry) [%]	1.28	0.69	0.13	0.4-0.78	0.74	3.2
S (dry) [%]	0.94	0.39	0.05	0.05-0.11	0.25	1.1
Cl (dry) [%]	0.128	< 0.1	< 0.1	0.4-0.73	0.82	< 0.1
O (dry) [%]	11.1	13	45	40.4	31.3	27.69
Ash melting point [°C]	1250	1050	1200	1050	1120	1200

3. EXPERIMENTAL RESULTS CONCENRING THE WASTE CO-COMBUSTION

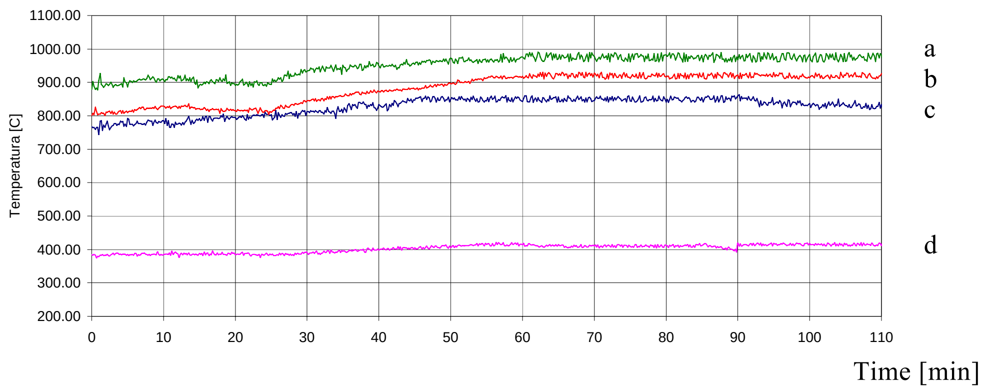
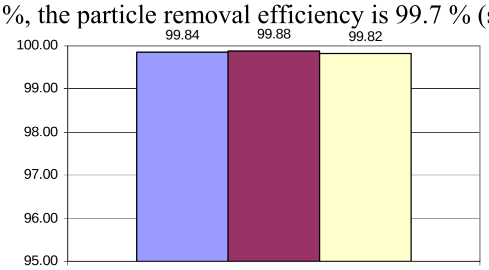


Figure 2. Temperatures variation for tests running with waste corncob and pit coal.
a-furnace middle, b-convective case inlet, c-furnace inferior, d-convective case outlet.

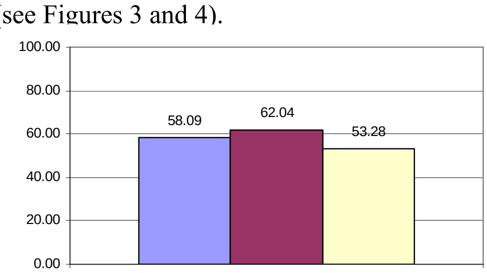
In Romania the biomass combustion is referred to 10 % O_2, the coal to 6 % by volume; thus, in accordance to the input of the fuels, a value of 8.03 % by vol. for $O_{2reference}$ is used. Temperatures, pressure losses and flow capacities have been recorded on line, with the help of a data acquisition system [12]. The values of pollutants concentration were measured with two simultaneous working gas analysers, placed before and after the flue gas cleaning system. Main stable average results are given in the Figures 2, for one case, the others being similar. The particles were retained in the cyclone with an efficiency of over 99 %. For reducing the pollutant concentrations in exhaust, mainly NO_x & SO_2, alkali solution with 2.5 % sodium hydroxide to 1 liter spraying liquid/m^3 gas flow rate was dosed. The de-nitrification efficiency is over 50 %, the desulphurization over 99 %, the particle removal efficiency is 99.7 % (see Figures 3 and 4).



A B C

A – Corncob + pit coal
B – Maize + pit coal
C – Sunflower seed + pit coal

Figure 3: SO_2 retention efficiency for different fuels mixtures



A B C

A – Corncob + pit coal
B – Maize + pit coal
C – Sunflower seed + pit coal

Figure 4: NO_x retention factor the different fuels mixtures

4. RESUMATIVE RESULTS CONCERNING NUMERICAL SIMULATION

The main above presented results have been partially demonstrated also by using numerical modeling. It was accomplished using the GAMBIT 2 code, part of the FLUENT 6.2 package [17, 18]. As main conclusions one remarks the profiles of temperature, main greenhouse gases and CO pollutant (as indicated by Figures 5-8) that are in satisfactory correlation with experimental results. One analysed 3 main cases, consisting of mixtures of coal with specific municipal waste fractions (Timisoara, Bucuresti, Piatra Neamt).

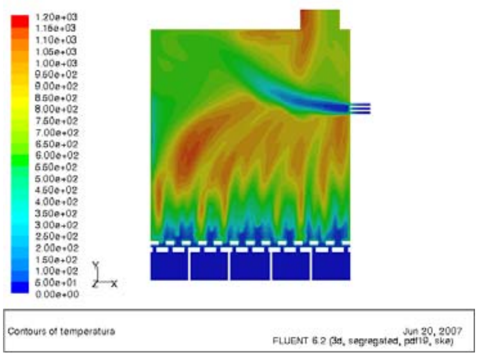


Figure 5: Temperature profiles [°C].

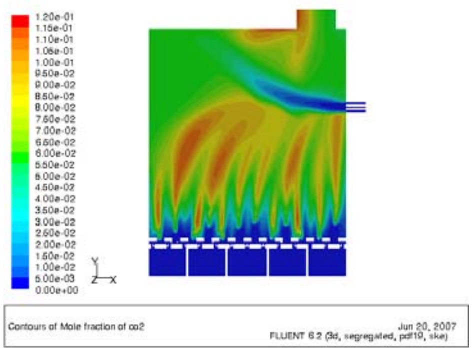


Figure 6: CO_2 concentation profiles.

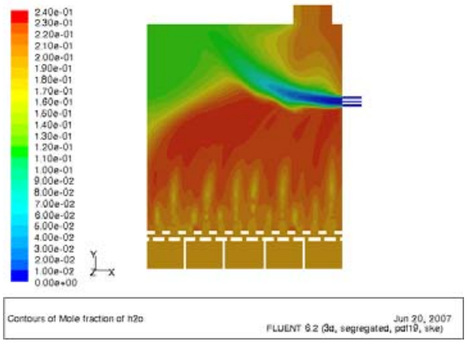


Figure 7: H_2O concentrations.

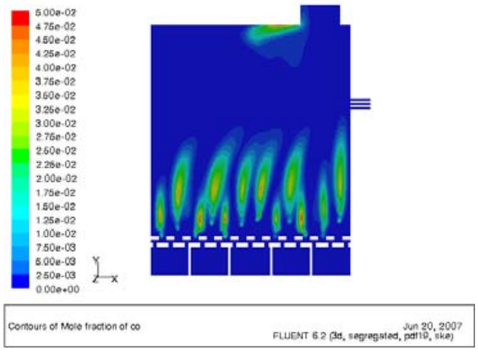


Figure 8: CO concentrations.

5.CONCLUSIONS

The proposed test rig and technology described are offering a lot of *benefits* concerning the flue gas cleaning and meets necessary standards. Similar conclusions were found in [16]:

- The fuel cost under these circumstances is lower in comparison to alone fossil fuel utilisation.
- No special deposit problems have been registered. Corrosion problems related to alkali metals and chlorine are major problems but still under control.
- Carbon burnout is reasonable as well.
- Gaseous emissions of SO_2 and NO_x were reduced because the applied combustion technology as well as because of the fuels (waste with no S). Additional denitrification and desulphurisation is activated on the flue gases, before exhaust. N_2O and SO_2 concentrations are reduced considerably with increase in residue share.
- In order to generate a total CO_2 lean global process by CO_2 absorption (through scrubbing with monomethanolamine-amine MEA), the CO_2 emission might be also reduced and controlled, of course by paying the price for the supplementary technology.
- Combustion efficiency increases with co-firing but remains constant around 96 - 98 % for all tests irrespective of biomass share.
- Increasing waste share in fuel blend determines slightly higher freeboard temperatures.
- O_2 and CO_2 concentrations are not sensitive to increase in biomass share. CO concentrations increase with increasing residue share. NO_x concentrations are not affected by the change in the olive residue share in fuel blend.
- Addition of biomass agricultural residue results in lower SiO_2 and Al_2O_3 and higher CaO concentrations in bottom, cyclone and filter ashes.
- The process represents a near-term, low-risk and low-cost, sustainable, renewable energy option that promises reduction in CO_2, NO_x and SO_2, and other social benefits.

Further research is needed for:

- Optimisation of the cyclone function and its efficiency of particles' retention and special concern for PAH, HCl and heavy metal should continue;
- Electronic control and automatisation of the combustion process;
- Larger testing campaigns with more various qualities and mass ratio of waste-mixture;
- Research concerning ash utilisation.
- Further controll of HC, PAH&soot, HCl, PCDD/F,heavy metals (Pb, Zn, Cd) emissions.

- Calculus of the financial gain by CO_2 reduction, accounted in green certificates trading.

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