EXPERIMENTAL RESEARCH ON CO-COMBUSTION PROCESS OF PIT COAL WITH AGRICULTURAL BIOMASS

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The research presented in this paper is part of several national research grants and mainly supported by a European network consortium and focuses on a facility, the experimental results, interpretation and future plans concerning the co-combustion of biomass with coal in a fluidized bed combustion pilot rig.

Keywords: Agricultural biomass, co-firing, pit-coal, fluidized bed.

1. Introduction

The recent EU membership of Romania and the research directives in Europe and all over the world bring a new opportunity for the development of biomass co-firing, due to the coal combustion infrastructure already installed, the land availability for energy crops and the current dependency on imported fossil fuels. According to the EU resolution on renewable energies of May 1998, the share of biomass has to be increased from 3.1 % in 1995 up to 8.5 % in 2010, a target which will not be met unless a unified approach of biomass co-firing in the European level comes into play.

Biomass co-firing represents, compared to other renewable sources, a technically feasible option with the potential of contributing to the EU energy supply meanwhile ensuring sustainable development. Co-firing of biomass with coal offers several advantages, such as the utilization of large quantities at low combustion rates in the current combustion systems, lower investments and higher conversion efficiencies compared to systems fired exclusively with biomass.

The EU has recognized the need of promoting the use of biomass co-firing in order to comply with the Kyoto Protocol which implies a reduction of 8% of the greenhouse emissions between 2006 and 2012. In spite of numerous successful experiences achieved in Europe, this technology still deserves attention in order to find solutions for technical problems as well as to improve efficiency, reduce costs and emission levels.

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Co-firing of biomass is a promising short-term technology to use secondary fuels, consisting on the simultaneous combustion with a primary fuel in plants originally designed and optimized for the combustion of coal. Therefore, biomass co-firing activities, both in retrofit and new plants, are expected to expand significantly world-wide within the next years contributing to the overall target of the Kyoto protocol.

2. Experimental setup

According to the promising biomass potential available for heat and electricity production in Romania from the stock of wood and from agriculture, researches has been started in order to utilize different qualities of biomass (low price in comparison to coal, for an acceptable and comparative energy offer), as fuels for the co-combustion facility.

The following sorts of agricultural biomass and coal were used as fuels for co-combustion facility: corn cob, maize, sunflower seeds and pit coal from Valea Jiului basin.

Next tables (tables 1 to 4) give the elementary analysis and information for pit coal and for several used types of agricultural biomass.

Table 1

Elementary analysis for pit coal - Sample 1

Characteristics in reference to humid probe	Symbol	IS unit	Value
Carbon	C^i	%	37.20
Hydrogen	H^i	%	2.43
Sulfur	S^i	%	1.10
Oxygen	O^i	%	9.00
Nitrogen	N^i	%	1.00
Ash	A^i	%	40.30
Humidity	W^i	%	8.97
Inferior heating value	H_i^i	kJ/kg	15.894

Table 2

Elementary analysis for corn cob – Sample 2

Characteristics in reference to humid probe	Symbol	IS unit	Value
Carbon	C^i	%	47.79
Hydrogen	H^i	%	5.64
Sulfur	S^i	%	0.01
Oxygen	$(O)_{by\ dif.}$	%	44.71
Nitrogen	N^i	%	0.44
Ash	A^i	%	1.20
Chlorine	Cl^i	%	0.21
Inferior heating value	H_i^i	kJ/kg	16.755

Table 3

Elementary analysis for maize - Sample 3

Characteristics in reference to humid probe	Symbol	IS unit	Value
Carbon	C^i	%	44.62
Hydrogen	H^i	%	5.37
Sulfur	S^i	%	0.05
Oxygen	$(O)_{by\ dif.}$	%	39.57
Nitrogen	N^i	%	0.41
Ash	A^i	%	8.50
Chlorine	Cl^i	%	1.48
Inferior heating value	H_i^i	kJ/kg	16.509

Table 4

Elementary analysis for sunflower seed - Sample 4

Characteristics in reference to humid probe	Symbol	IS unit	Value
Carbon	C^i	%	50.92
Hydrogen	H^i	%	6.31
Sulfur	S^i	%	0.17
Oxygen	$(O)_{by\ dif.}$	%	37.82
Nitrogen	N^i	%	1.12
Ash	A^i	%	3.62
Chlorine	Cl^i	%	0.04
Inferior heating value	H_i^i	kJ/kg	19.300

The co-combustion system contains the following parts (figure 1):

The main burning subassembly / system components are:

- furnace, parallelepipedic shape with truncated pyramid base
- air distributor, air nozzles for injection of fluidization/main burning air
- air feeding system – air blower, adapting pieces
- fuel bunkers, starting/post combustion burner working with natural gas
- furnace connection – heat transfer system (convective case)
- measuring equipment (temperatures, pressures) and observation holes

The heat transfer subassembly / system components are:

- convective case, parallelepipedic-shaped
- convective case connection with furnace and dust collecting system
- heat transfer – serpentine cooler and water pump
- measuring equipment

The flue gases dedusting subassembly / system components are:

- cyclone dust separator, cylindrical body in vertical position
- convective case connection, tangential upside encased cyclone
- powder measuring socket, thermocouple and siphon gauge-cyclone inlet
- socket/appliance for flue gas analysis and powder/dust sampling, thermocouple/ thermometer, manometer – cyclone outlet

The flue gases cleaning subassembly / system components are:

- scrubbing tower with Raschig rings, cylindrical body in vertical position with a cone-shaped base
- neutralization reactor with Raschig rings, cylindrical body in vertical position with a cone-shaped base
- demister, parallelepipedic-shaped with division wall, in vertical position
- reagents circulation pumps

The main characteristics of the functional facility are:

- Thermal energy:	0.21- 0.42 MJ
- Electrical power consumption:	2 - 4 kWh
- Flow of the water system:	2 - 4 m^3/h
- Flow of combustion/fluidization air:	200-300 m^3/h
- Flow of compressed air for flue gases cleaning pumps:	0.5 - 1 m^3N/h
- Flow of natural gas for the start:	2 - 5 m^3st/h
- Mass flow of coal:	25 - 50 kg/h
- Mass flow of biomass:	15 - 30 kg/h
- Flow of the washing liquid (p = 2 bar):	0.2 - 0.6 m^3/h

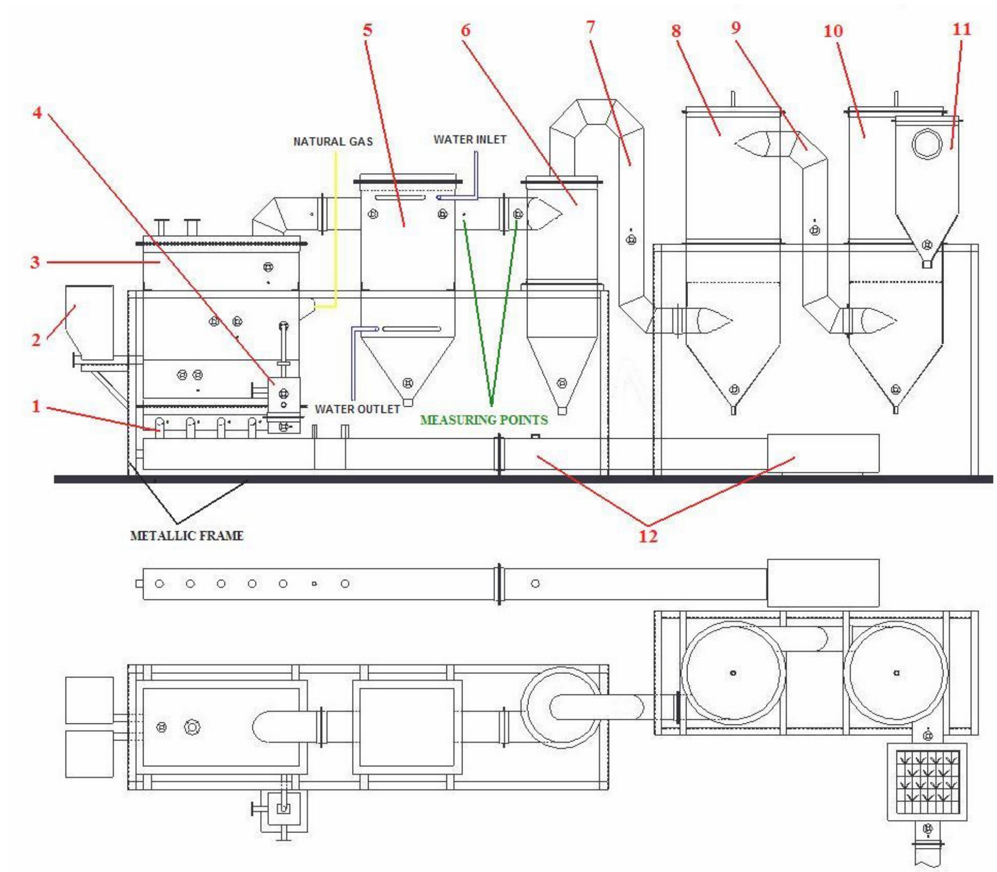

Fig. 1. Design of the co-combustion facility in fluidized bed
1.Air distributor 2.Fuel feeding system 3.Furnace 4.Ash cooler 5.Convective case 6.Cyclone dust separator 7.Cyclone-scrubber connection piping 8.Scrubbing tower 9.Scrubber-reactor connection piping 10.Neutralization reactor 11.Demister 12.Air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

3. Results & Conclusions

The biomass participation into combustion had a share of maximum 40% from the total thermal power input. The facility using fluidized bed combustion technology is adaptable to different sorts of biomass, by only taking sure that first a drying process and a grinding suitable for fluidized bed combustion are accomplished. These data are mostly needed in order to depict the reference oxygen content for including the combustion results into the maximum admitted values for stack emissions. The biomass combustion is referred to 10 % oxygen, the coal to 6 %, by volume; thus, in accordance to the thermal input of the both fuels, a value of 8.03 % by volume for O_{2ref} is calculated. In several points the temperatures, pressure losses and flow capacities have been recorded on line, with the help of a data acquisition system. The values of pollutants concentration were measured with two simultaneous working gas analyzers, placed before and after the flue gas cleaning system. Main results representing average values obtained during operation in a stabilized regime are given in the next figures (Fig. 2, 3, 4).

Temperature profiles demonstrate that the process is stable and achieves the presumed characteristics.

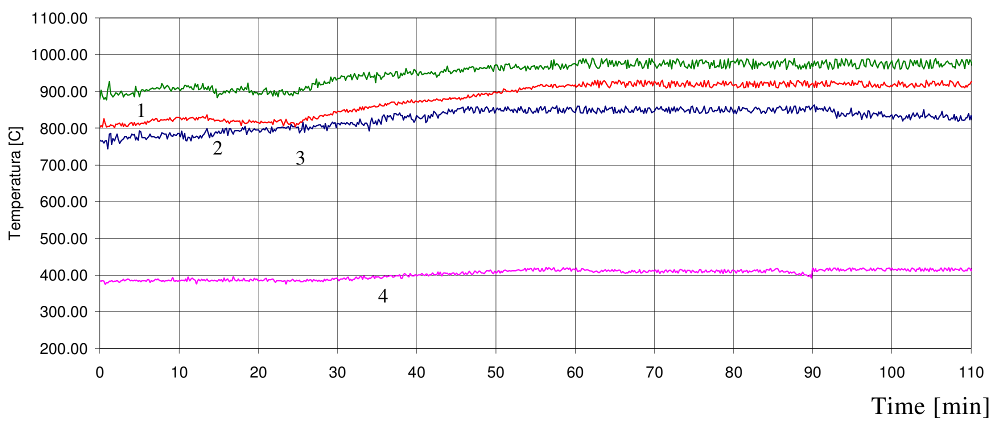

Fig. 2. Temperatures variation in furnace and convective case for approx. 2 hours of running with corncob and pit coal
1-furnace (middle), 2-convective case inlet, 3-furnace (inferior), 4-convective case outlet

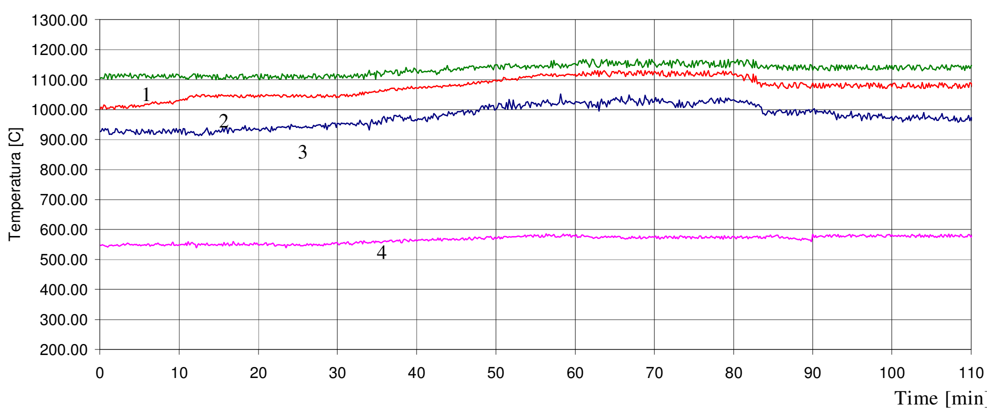

Fig. 3. Temperatures variation in furnace and convective case for approx. 2 hours of running with maize and pit coal
1-furnace (middle), 2-convective case inlet, 3-furnace (inferior), 4-convective case outlet

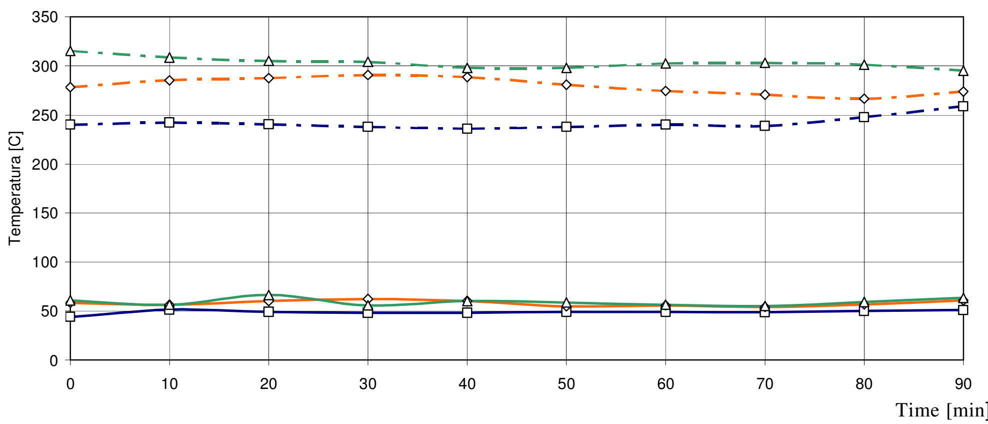

Fig. 4. Temperatures variation before and after the flue gas cleaning system (FGCS) for the 3 types of fuel (agricultural biomass with pit coal)

Δ - Sunflower seed ◊ - Maize □ - Corn cob - - before FGCS — after FGCS

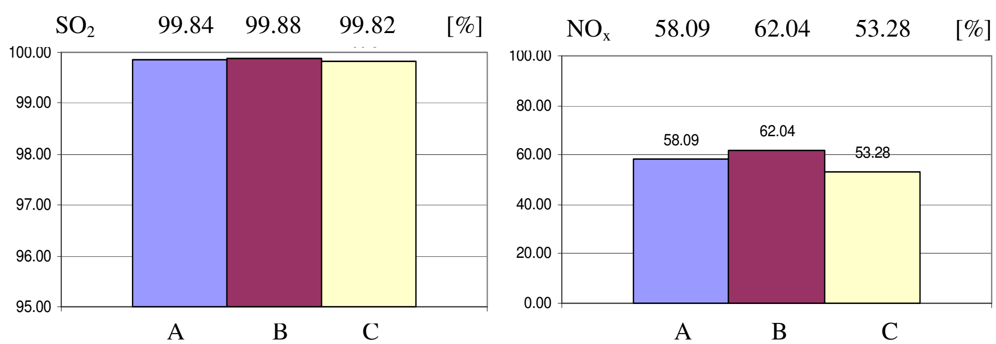

Fig. 5. SO_2 and NO_x retention factor for the 3 types of fuel (agricultural biomass with pit coal)
A – Corncob + pit coal, B – Maize + pit coal, C – Sunflower seed + pit coal

In order to reduce the pollutant concentrations in the flue gases, especially NO_x and SO_2, in correspondence, reagent proportioning was made as follow: alkali solution with 2.5 % sodium hydroxide and ammonia solution with 15 % NH_3, with 1l spraying liquid/m^3 gas flow rate using a dosing pump. The achieved desulphurization efficiency is over 99 %, the denitrification over 50 % (see figures 5). The particles were retained in the cyclone with an efficiency of over 99 %.

The proposed test rig and the technology described are offering a lot of *benefits* concerning the flue gas cleaning and meet necessary standards:

○ The fuel cost under these circumstances is lower as in comparison to alone fossil fuel utilisation.

○ By blending agricultural waste with coal a maximum level of approx 0.17 – 0.20 kg (potassium&sodium)/GJ is achieved, thus enabling less risk.

○ No special deposit problems have been registered according to the special design of the fluid bed combustor.

○ 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 both because the applied combustion technology and fuels.

○ Additional denitrification and desulphurisation is activated on the flue gases, before exhaust.

○ In order to generate a total CO_2 lean global process by CO_2 absorption (through scrubbing with monomethanol-amine MEA), the CO_2 emission might be also reduced and controlled, of course by paying the price for the supplementary technology.

○ CO, HC, PAH and soot, HCl, PCDD/F and heavy metals (Pb, Zn, Cd, others) emissions are still under research. The residence time and the temperature profile along the combustion chamber, as well the final additional burner introduced at the end of the furnace assure the reduction of the dioxins and furans, both in gaseous form or bounded on particles.

○ This 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 (such as energy dependency on national resources).

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