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COMBINED COMBUSTION COAL AND WASTE WOOD

KOMBINOVANÉ SPALOVÁNÍ UHLÍ A ODPADNÍHO DŘEVA

Abstract

This work was focused to the comparison of various fuels (lignite and wood waste materials) combustion from the environmental point of view in circulating fluidised-bed power station in Štětí. It was concluded that the waste wood combustion produces lower amount of environmentally-hazardous pollutants than fossil fuel combustion.

Abstrakt

Tato práce byla zaměřena na srovnání spalování různých paliv (hnědého uhlí a materiálů na bázi dřevních odpadů) z hlediska ochrany životního prostředí ve fluidním kotli s cirkulující fluidní vrstvou v elektrárně Štětí. Dospělo se k závěru, že spalování odpadního dřeva produkuje menší množství environmentálně nebezpečných znečišťujících látek, než spalování fosilních paliv.

1. INTRODUCTION

Worldwide, there is a growing interest in the use of biofuels for energy purposes. There are many reasons for this utilization, such as political benefits (the reduction of the dependency on imported oil etc.), employment creation (biomass fuels create up to 20 times more employment than coal and oil) or environmental benefits [1-4]. Even though the environmental impacts of air pollution from most biomass combustion today are far from negligible, compared to fossil fuel combustion applications there are several advantages. Biomass is considered as being CO_2 neutral with respect to the greenhouse gas balance. Reduction of acid rain and soil improvements are another benefits. Moreover, as a renewable fuel biomass will be available for heat and power production in substantial amounts after the fossil fuel resources have diminished [5-7].

In the Czech Republic fluidised-bed combustion is preferred as a modern and ecological combustion technology. A general feature of fluidized bed systems is their flexibility in the kind of fuel combusted, which makes them suitable for co-combustion of different kind of fuels. Moreover, circulating type of fluidized bed systems has better carbon burnout efficiencies and is efficient also in absorbing acid gases [7]. This is the reason why this work was focussed to evaluation of environmental impact of fluidised-bed combustion of different fossil and biomass fuels. Particular attention was paid to the comparison of the release of environmentally the most significant species – amount of solid coal combustion products and their leaching behaviour or emissions of sulphur and carbon dioxide.

2. COMBINED COMBUSTION

The experimental measurements and completed the operating hours of boilers burning coal and biomass in the Czech Republic has very important findings, especially the issue of atypical properties of coal [8]:

- Highly abrasive ash,
- high moisture fuels,
- the proportions of clay processing and distribution of fuel,

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- increased content of foreign substances in the raw fuel (gravel, wood, metal),
- the problems of removal of the ashes of fluid layers, the subsequent cooling and manipulation
- sintering particle fluidized bed and temperature below 900 ° C.

Advantages of fluidized combustion can be summarized as follows**:**

- Combustion able types of fuels, coal, or lignite, or mixtures, the fuel with high sulfur and ash content,
- the possibility of combustion the essential fuels and biofuels, or "waste",
- high combustion efficiency, appropriate technology which can be reached on the content of unburned compounds in solid residues after combustion under 1%,
- use relatively inexpensive limestone desulphurization methods, which also guarantees high sulphurous fuel efficiency desulphurization,
- low combustion temperature (850 ÷ 900 °C) has a positive influence on the emissions of NO and NO_2, which are below 200 $mg.m^{3N}$, at 6% O_2,
- minimum as well as emissions of chlorine and fluorine ions F, which bind to the ash and calcium,
- due to a higher degree of recognition in the hearth ash and larger particles of ash granulometry is the separation of solid particles partially simpler than conventional granulation boilers,
- fluidized bed boilers have a strong regulatory power range (30 ÷ 110 %), which is a big advantage especially for heat source.

Disadvantages of fluidized bed combustion can be generalized in the following sections:

- Fluidized combustion technology is significantly more complex, than conventional granulation boilers. Boilers require a series of complex mechanical parts working in corrosive environment, and often at temperatures of 800 ÷ 900 °C ,
- specific electric energy consumption per unit of electrical power is due to the large consumption of fluid air and compressed air for pneumatic transport of ash needs more than conventional boilers,
- maintenance of equipment is more sophisticated than conventional boilers,
- hours running the boiler from cold is longer than the granulation boilers,
- problems with disposal of fly ash with high calcium content of various compounds.

3. EXPERIMENTAL TESTS

The power company Mondi Packaging Paper Steti were performed three combustion tests (modes V to VII). It was a common combustion experiments with coal woods matter at boiler K11 with circulating fluidized-bed at a temperature of about 870 ° C.. Coal and wood fuel are continuously fed into the fluidized boiler, which supports the full circulation of intense mixing and burning fuel.

Fluidized air is supplied to fire guns placed in the bottom of the grate boiler, while secondary air is supplied to the fireplace wall at different height levels, thereby achieving a "tiered" combustion without formation of excess NOx. [10]. After leaving the combustion chamber flue gas passes through the cyclone, which separates the coarse fraction of fly ash, which returns back to the bed. Finer fractions of fly ash from flue gases are then capture in electrostatic precipitators.

Simplified diagram prepared so as to clearly show the place of collection of fuel and ash samples are shown in Fig. 1. The boiler K11 in normal operation burned most brown coal with wood waste as a matter arising from the production of cellulose (paper). Usually the ratio between the weight of incoming coal and wood is approximately 10:1.

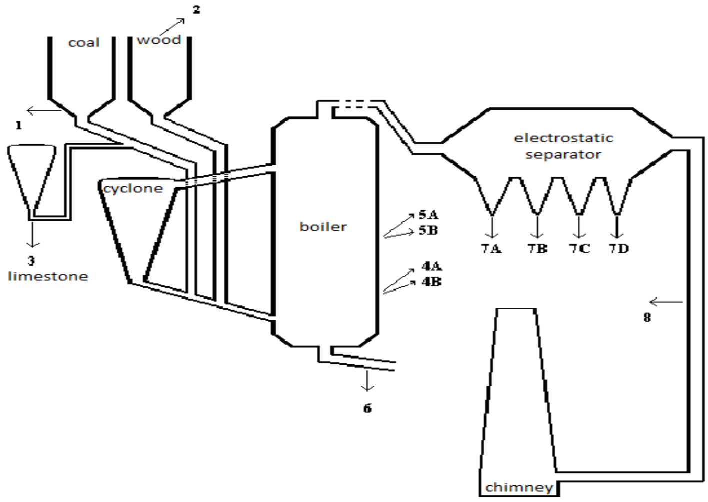

Fig. 1 Total simplified diagram of boiler K11 and place of collection of samples

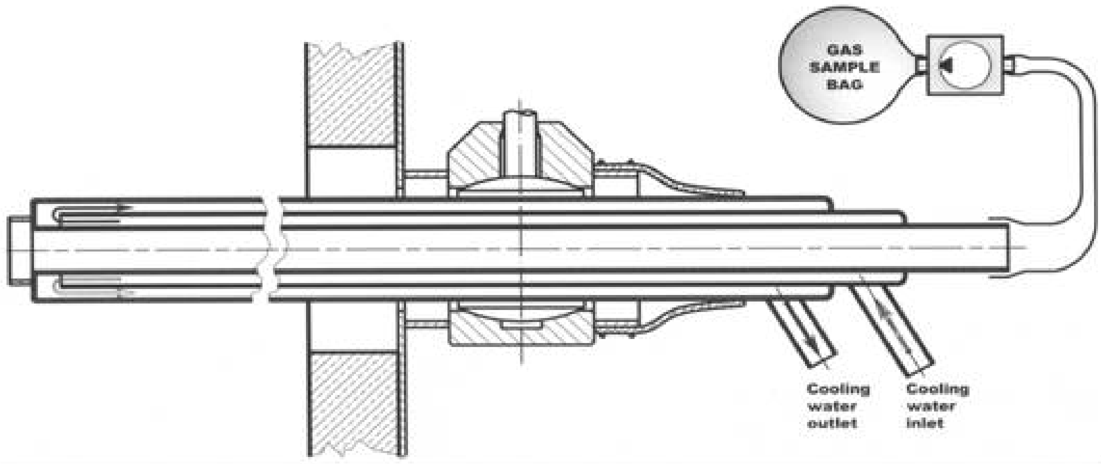

Fig.2 Probe for flue gas sampling from fluid layer

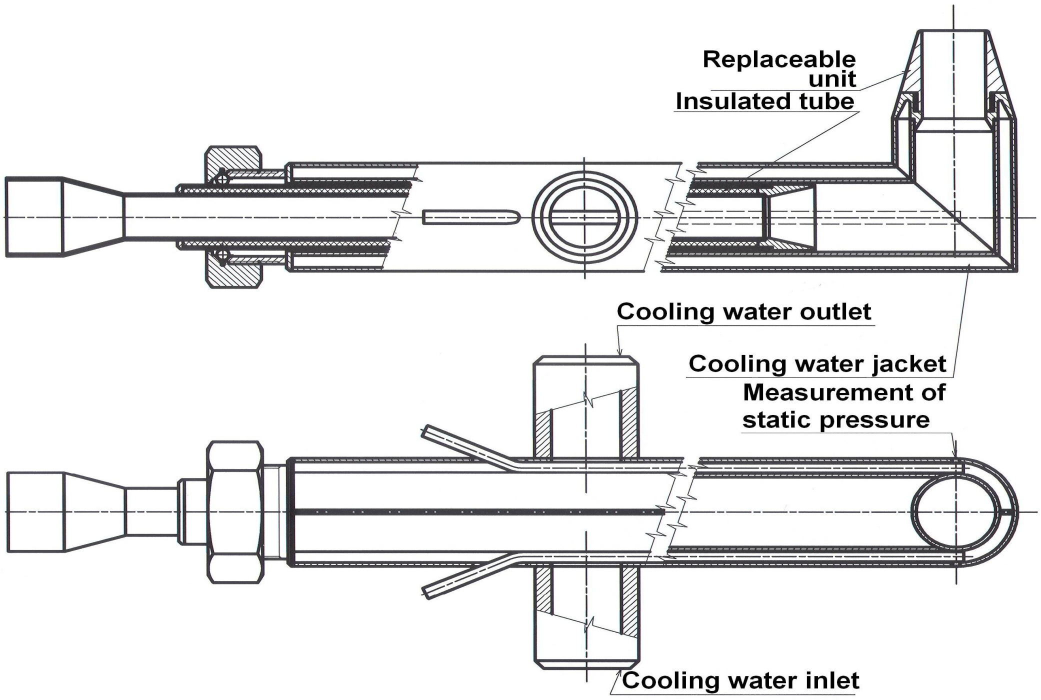

Fig. 3 Diagram of cooled sampling probe

In the boiler K11 is located in the mantle four holes into the combustion chamber (Fig. 1). Using these holes as progressive sliping thermocouples to measure temperatures in the fluidized bed height different levels through the holes 5A and 5B, where it was plugged probe, through which the probe positions in three samples of gaseous emissions and ash from the fluidized bed directly. [11].

Sliping probe of 0.5 meter horizontal distance was measured temperatures in the fluidized bed at the inlets (5A, 5B). During all combustion regimes were sampled from storage tanks of fuel (instead of 1 - coal bin, instead of 2 - stack of wood, instead of 3 - limestone reservoir), the removal of ash bed combustion chamber (instead of 6) and all four sections of the electrostatic precipitator (places 7A - 7D). Furthermore, continuous measurement of emissions of NOx, CO, SO_2 in the flue gases (see Fig.1).

Fig. 2. illustrates a cooled sampling probe that might be used to take flue gases samples. The probe has an identical construction to that used for temperature measuring. During exhaustion gas is rapidly cooled down (from 800 ^oC to approx. 30 ^oC in cooled probe) so that there is no reaction with any other flammable waste gases. Gas is then sampled to be analyzed in the mobile laboratory. It is always recommended to use a cooled probe to take samples from the furnace , cyclone and cyclone linking channels. Fig. 3. illustrates the cooled sampling probe for solid particle isokinetic sampling.

The balance of fuel and combustible waste, the mass flow, moisture content and ash, as well as the mass flow bed ash (BA) and fly ash (FA), the volume and flow sensing gaseous emissions (VE, g), the quantity of solid emissions (me with), can be evaluated following table.

Tab. 1 Mass flow of inorganic materials

Mode	**Input (t/h)**							**Output (t/h)**		
	Coal	**Limestone**	**Sawdust**	**Bark**	**Wood**	**Chips**	**M_{inp}**	**FA**	**BA**	**M_{out}**
V	4,743	1,733	-	-	-	-	6,476	3,210	3,210	6,420
VI	1,989	0,640	0,033	0,750			3,412	1,360	2,020	3,380
VII	-	-	0,015	-	0,037	0,155	0,207	0,386	0,004	0,390

Values of mass flows, ash content, respectively, loss on ignition can be found in tab. 1. The summary of calculated values is obvious a very good match between the input (m_{inp}) and exit (m_{out}) data. The difference between the weights of the input current m_{inp} and output current m_{out} under mode VII can be explained so that the fluid in the boiler was not "running" the whole mode VII cleaned ash from coal combustion, and therefore part of the ash has gone into the output stream and the weight is greater than the output current m_{vyst}.

Tab. 2 Calculation of the incoming flow of inorganic materials for 1 GW of power boilers.

Regime	**m_{output}/Q_{output} (kg.hr^{-1}.GW^{-1})**
V	28
VI	12
VII	0.7

Tab. 3 Input mass flow of carbon converted to carbon dioxide (CO_2).

Mode	**Input CO_2 (t/h)**							**$m_{CO2,out}/Q_p$ (t.h^{-1}.GW^{-1})**
	Carbon	**Limestone**	**Sawdust**	**Bark**	**Wood**	**Chips**	**$m_{CO2,inp}$**	
V	45,46	0,90	-	-	-	-	46,36	0,20
VI	20,74	0,33	6,43	15,70	-	-	43,20	0,16
VII	-	-	3,73	-	21,74	18,01	43,48	0,14

In Tab. 3, where the index corresponds to the C carbon in coal . Are then calculated given all the input flows of carbon converted CO_2. For simplicity we assume that all the carbon is burned and transferred to the emissions in the form of CO_2. The results confirm that burning wood is actually produced per unit of energy input to the atmosphere less CO_2 than the burning of brown coal.

Tab. 4 Sulphur input mass flows

Regime	**Input flows (kg/hr)**						
	C	**L**	**S**	**B**	**W**	**Ch**	$m_{S,input}$
V	194	3.6		-	-	-	197.6
VI	98	1.3	0.7	1.8	-	-	101.8
VII	-	-	0.4	-	0.9	6.3	7.6

Tab. 5 Output flows of sulfur (S).

Mode	**Output (kg/h)**				**% $S_{E,g}$**	**$m_{s,E}/Q_p$ (kg/h.GW)**
	FA	**BA**	**$m_{s,E}$**	**$m_{s,out}$**		
V	102	59	29,6	190,6	15,5	0,13
VI	39.0	58.8	27,3	125,5	21,8	0,10
VII	13,9	0,1	5,5	19,5	28,2	0,018

The data listed in Tab. 4, 5 show that the minimum content of SO_2 emissions (% S_E,g) is the combustion of coal with limestone (mode V). Absolute numbers of sulphur contained in the mass emissions ($m_{s,E}$), however, clearly demonstrate that the burning of wood is the amount of sulphur that gets in the emissions into the atmosphere about 10 times smaller than that of burning coal. This parameter is much more favourable for burning wood. Will lay it to the GW energy produced.

4 CONCLUSION

This work was focused to the comparison of various fuels (lignite and wood waste materials) combustion from the environmental point of view in circulating fluidised-bed power station in Štětí. Three combustion tests were conducted using the following input materials: in regimeV lignite and limestone were combusted, in regime VI it was lignite, limestone, sawdust and tree-bark and in regime VII wood, sawdust and wood chips were used as fuels. For the three tests the most significant characteristics were evaluated and recalculated for transparent comparison to 1 GW boiler output – mass of ash produced, mass of CO_2 and S released into atmosphere and toxicity of the ash leachate, which is important e.g. in relation to land-filling.

The most significant results are summarized below:

1. Mass balance calculations suggest that mass flow of inorganic matter produced per 1 GW of boiler output has dropped from 28 kg $.hr^{-1}.GW^{-1}$ for lignite combustion to 0.7 $kg.hr^{-1}.GW^{-1}$ when wood wastes were combusted.
2. Mass flow of CO_2 produced during the combustion was related to 1 GW boiler output as well – 0.20 $t.hr^{-1}.GW^{-1}$ was obtained for lignite combustion and it has dropped to 0.14 $t.hr^{-1}.GW^{-1}$ released when wood wastes were combusted.
3. Sulphur emissions were also recalculated to 1 GW boiler output - sulphur emission flow calculated for lignite combustion ($0.13 kg.hr^{-1}.GW^{-1}$) was considerably higher than that obtained for wood wastes combustion ($0.01 kg.hr^{-1}.GW^{-1}$).
4. This observation is a source of many advantages relating to ash land-filling – e.g. decreasing amount of ashes produced during the combustion process will consequently result in decreased amount of toxic leachates, above all sulphates, and also significant increase of pH (due to high amount of Ca-bearing minerals present in coal ash) will be diminished.

Results described above unambiguously suggest the conclusion that the waste wood combustion produces lower amount of environmentally-hazardous pollutants relating to fossil fuel combustion, even if combusted with Ca-bearing additives.

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