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Combustion Process of Extracted Rapeseed by the Small Scale Stationary Fluidized Bed Combustor

The objectives of this paper are the experimental study on combustion of extracted rapeseed in a small scale stationary fluidized bed combustor (SFBC), measurement of exhaust gas component concentrations (e.g. O_2, CO, CO_2, NO, NO_x, and SO_2), investigation of the effect of a bed heat exchanger in the FBC focusing on the reduction of NO_x. The results show that the denitrification of NO_x-emissions in the flue gas by the combined heat exchanger in FBC was successful. The "reduced" NO_x- concentration of the emissions in operating point 4 was lower than the allowable limit value of German TA Luft-(2002). At this point the maximum of the heat-decoupling from the heat exchanger (99.8 kW) and the minimum of the O_{2dr}-concentration (3.9 Vol. %) were found. This study furthermore represents a small-scale test for the abundant biomass residue resources in Vietnam (rice husk, bagasse, and cassava residues etc., which show similar chemical compositions as for extracted rapeseed).

Keywords

Extracted rapeseed, exhaust emissions, heat exchanger, heating surface

Abstract

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Heat and electricity generation with biomass substitutes fossil fuels, thereby reducing greenhouse gases and increasing agricultural, silvicultural and energy sector sustainability [8]. Vietnam has abundant agricultural biomass residues such as rice husk, rice straw, bagasse, cassava residue, coconut shell, rubber wood and coffee husk [1,2,5,8]. Over 50 million tons are generated annually, but only 30-40% currently energetically utilized [3,4,8], mostly for cooking [8] or in cane sugar production mills (app. 150 MWth [1,8]). In the present German study extracted rapeseed is investigated. Its properties are similar to the Vietnamese biomass sources described above. The extracted rapeseed chemical composition and calorific value is analysed and its combustion characteristics in a stationary fluidized bed reactor are assessed. The emission levels and possibility for energy generation are studied.

Materials and methods

Fuel: Test fuel is extracted rapeseed (ER). It can be easily supplied by a screw feeder in the reactor. According to [6], ER is highly contained of fuel-nitrogen **(Tab. 1)**. Therewith high concentrations NO_x-emission in flue gas are expected. From [6] follows: Thermal NO_x escapes due to low temperature fluidized bed (TFB), prompt NO_x escapes due to of „no/not flame" combustion guidance (condition). From the fuel can be NO_x formed (maked), it will investigate/probe/test whether the NO_x-emissions of primary methods for the reduction of emissions can be influenced.

Method: The trial/test runs with a heat exchanger in (at the) „bed" from the combustion chamber to extract heat energy (takes away heat energy). The combustion process in the SFBC performs no flame (flameless) burning. The process is with flameless SFBC-combustion in connection with preselected maximum temperature to operated/control. It was here that the TFB of the trial/test period kept constant at around 850° C. The aim/objective of the investigations was elected in the combustion temperature to avoid any melting (sintering) of fuel "ashes". All important process parameters during the tests were kept approximately constant [8].

Results and discussion

As the results, the chemical composition and the net calorific value (NCV) of fuel sources is given in **table 1**. It shows that almost fuels are similar in the chemical compositions except ash. The ash composition in rice husk is highest. Probably it contains much more inorganic com-

Table 1

Chemical compositions (kg/kg) and the net calorific value (kJ/kg) of various biomasses

	(c)	(h)	(o)	(n)	(s)	(a)	(w)	(NCV)
Extracted rapeseed[1)]	0.4670	0.0633	0.2177	0.0575	0.0001	0.0693	0.1251	18086
Rice husk[2)]	0.3979	0.0523	0.3863	0.0013	-	0.1392	0.0230	15196
Bagasse[2)]	0.4638	0.0576	0.4519	-	-	0.0074	0.0193	16686
Coconut shells[2)]	0.4622	0.0520	0.4163	0.0026	-	0.0300	0.0369	17408
Cassava residue[2)]	0.4434	0.0576	0.4237	0.0065	-	0.0450	0.0238	15942
Coffee husk[(2)]	0.4488	0.0620	0.3600	0.0096	-	0.0310	0.0887	16217

1) Fuel of German origin; 2) Fuels of Vietnamese origin; S = "-" stands for an sulphur content below detection limit

pounds which can affect combustion process, quality of exhaust emission and the receivable thermal efficiency.

The **figure 1** shows the full diagram of the test process. There were 5 different operating points (OP) carried out (performed), which had run about constant volume flows of combustion air. The operating point 5 was processed without heat extraction. To heat extraction (OP 1 to OP 4) the heat exchanger were with different various high-pressure air volume flows through **(table 2)**.

To realize an adjustable heat extraction from the bed to allow the heat exchanger was with compressed air through. The heat extraction is altered by the cooling air throughput changed. For existing heat extraction was registered in the reactor quantity/mass of fuel increased to the chosen reaction temperature. With given heat extraction the feed supply was increased to hold the adjusted reaction temperature. Thereby the for combustion available oxygen concentration in the flue gas emissions was reduced.

The results are shown in **table 2** as well as **figure 1**. The concentration of exhausted emissions were based on the limits of the German Emissions Limit (GEL) ("TA Luft 2002" [7]) (with concentration of O_{2dr} = 11 Vol. %) rated **(Fig. 1)**.

Table 2

The main test results

Operating point			1	2	3	4	5
	Symbol	Unit	Value				
Operating parameters							
Fuel mass flow	m'_{Fuel}	kg/h	25.7	25.1	33.1	38.8	17.1
Fuel capacity	Q'_{Fuel}	kW	128.5	125.6	165.5	193.8	85.3
Combustion capacity FB	$Q'_{Combust}$	kW	131.2	128.0	167.5	226.3	87.7
Whirl current air volume	V'_{WA}	m^3/h	148.5	142.0	140.6	156.7	141.9
Air supply heat exchanger	-	-	blower	blower	1 Comp.	2 Comp.	not
Air flow heat exchanger (HE)	$V'_{Air, HE}$	m^3/h	54.2	74.1	179.2	333.6	0.0
Heat capacity HE	Q'_{HE}	**kW**	**16.1**	**22.4**	**54.4**	**99.8**	**0.0**
Coupling efficiency	η	%	12.5	17.8	32.9	51.5	0.0
Emissions							
Concentration	O_{2dry}	**%**	**10.2**	**9.6**	**5.0**	**3.9**	**12.6**
Carbon monoxide ($O_{2\,Basis}$ = 11 Vol. %)	CO	$mg/m^3(N)$	70	63	31	35	73
Nitrogen oxides ($O_{2\,Basis}$ = 11 Vol. %)	NO_x	$mg/m^3(N)$	334	270	98	61	480
Sulfur dioxide ($O_{2\,Basis}$ = 11 Vol. %)	SO_2	$mg/m^3(N)$	924	966	1145	1062	776

Figure 1 shows the state/conditions during the combustion without heat extraction at high O_{2dr}-concentration. It was observed a high NO_x- production.

Table 2 shows that in OP1 to OP4 by increasing the fuel mass flow higher combustion capacity has been achieved. While OP1 to OP4 there was an increase in cooling air flow in the heat exchanger. The lowest combustion capacity was in OP5. At the chosen operation points were elected a heat capacity combined in a range of 0 kW (OP5) to 99.8 kW (OP4) **(Tab. 2)**. The heat output achieved/reached the highest value in OP4 (with O_{2dr}-concentration = 3.9 Vol. %).

The **figure 1** and **table 2** show that, when a high heat extraction is reached/ achieved, it will be low O_{2dr}-concentration in the exhaust. Therewith for NO_x- production is much less oxygen available and explains the low NO_x- concentrations in the exhaust (OP4).

The concentration of O_{2dr} decreased from 10.2 Vol. % (OP1) to 3.9 Vol. % (OP4), while the amount of cooling air at the entrance/inflow of heat exchanger in the SFBC increased from OP1 to OP4 **(table 2)**.

Figure 1 and **table 2** show the effect of lowering the O_{2dr}-concentration in the exhaust through the heat capacity extraction to the NO_x- concentration. At the lowest oxygen concentration (highest heat extraction) were measured also the lowest O_{2dr}- concentrations in the exhaust (e.g. OP4).

Conclusions

The experimental results showed that the „reduced“ NO_x- concentration of the emissions in OP4 was lower than the allowable value of GEL. At this point was the maximum (99.8 kW) of the heat extraction from the heat exchangers and the minimum of the O_{2dr}-concentration was about 3.9 Vol. %. However, the SO_2- concentration was on this point higher. It was higher than the limit of GEL. Therefore in further experiments the proven methods to reduce SO_2- concentration must be applied. Using these methods the SO_2 concentration in the flue gas can safely remain below the limits of GEL. The result of the heat extraction can be used for plants in Vietnam, which have the heat energy consumption, such as: for a combined heat and power plant/ thermal power station, for the processing plant of cassava starch and /or for the simultaneous drying of other agricultural products. This technology should be very good in developing countries as Vietnam applied.

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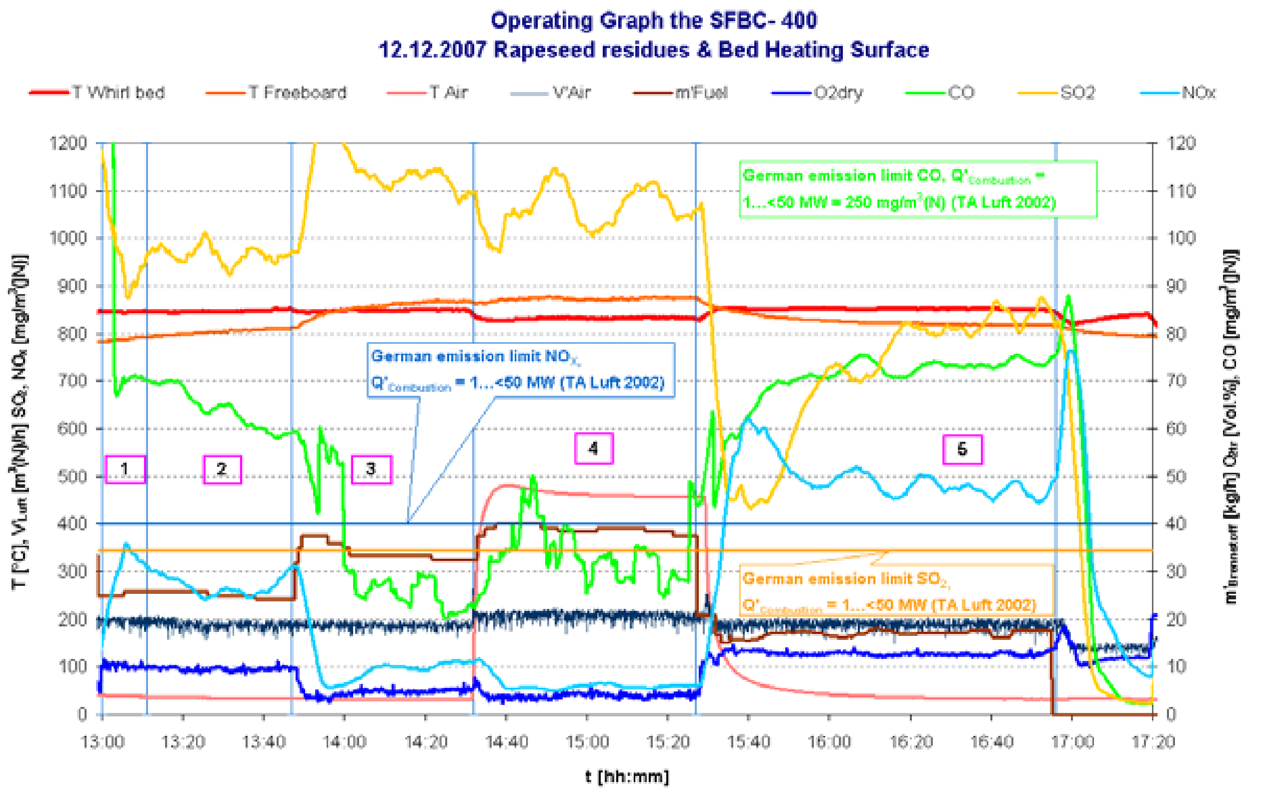
Fig. 1



Fluctuation of measured parameters during 260 experimental minutes

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