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Bed Material Quality
Operating Conditions
Agglomeration Behavior
in Fluidized Bed Combustion Systems

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Background & Motivation

- Fluidized bed technology is suitable for combustion as well as gasification of various solid fuels.
- Stabile fluidization is essential for the conversion process; therefore the choice of the bed material is of high importance.
- Testing the fluidization behavior of different bed materials
- Testing the agglomeration potential of selected materials by emergency shut-down experiments and by analytic measurements.
- Main goal: to find out which bed materials show best application behavior for a fluidized bed combustion system

Materials

Properties of investigated materials

*) no data available, #) varying shape and density

name	*particle density ρ_P [kg/m³]*	*particle size [µm]*		*composition(selection)[MA%]*						
		min.	*max.*	*SiO_2*	*MgO*	*Fe_2O_3*	*Al_2O_3*	*Cr_2O_3*	*NiO*	*K_2O*
sand A	2650	560	2000	95,05	<0,03	0,25	2,59	<0,03	*	1.82
sand B	2650	800	1600	99,25	<0,03	0,04	0,28	<0,03	*	0,08
olivine A	3300	250	800	41,5	49,7	7,3	0,49	0,3	0,32	*
olivine B	3300	800	2000	41,5	49,7	7,3	0,49	0,3	0,32	*
used bed material	2650	500	1800	bed material + ash, additives						
bituminous coal	*	around 5000								
paper-mill sludge	#	#	#							

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Materials

a. Silica sand

Sand A [560-2000] µm

Sand B [800-1600] µm

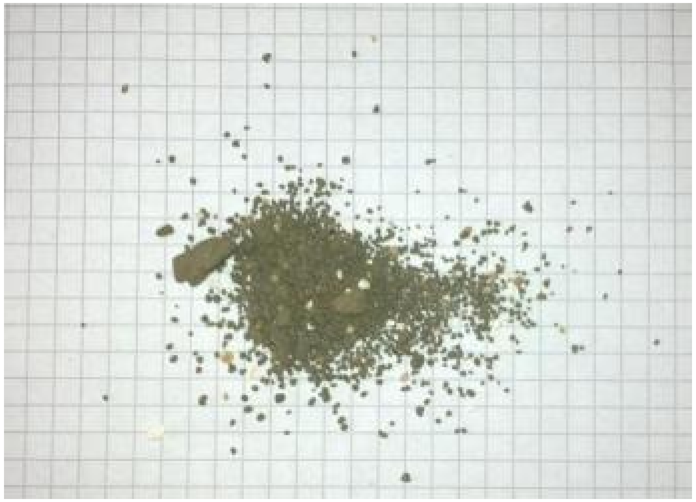
b. Olivine

Olivine A [250-800] µm

Olivine B [800-2000] µm

Materials & Fuels

Used bed material



originally from Sand A [560-2000] µm

bituminous coal

paper-mill sludge

Methods

- The fluidization- as well as agglomeration experiments were carried out in a laboratory-scale fluidized bed unit which is electrically heated up to 900° C.
- To simulate a scenario which shows high agglomeration potential, defluidization tests, like during an emergency shut-down of a combustor, were carried out.
- Analytical measurements on the pure and used sands, as well as the agglomerated particles were carried out by EDX methods. Optical investigations were carried out by using a microscope.
- Fluidization characteristics (e.g. U_{mf}) were calculated and compared to measurement data for monitoring.

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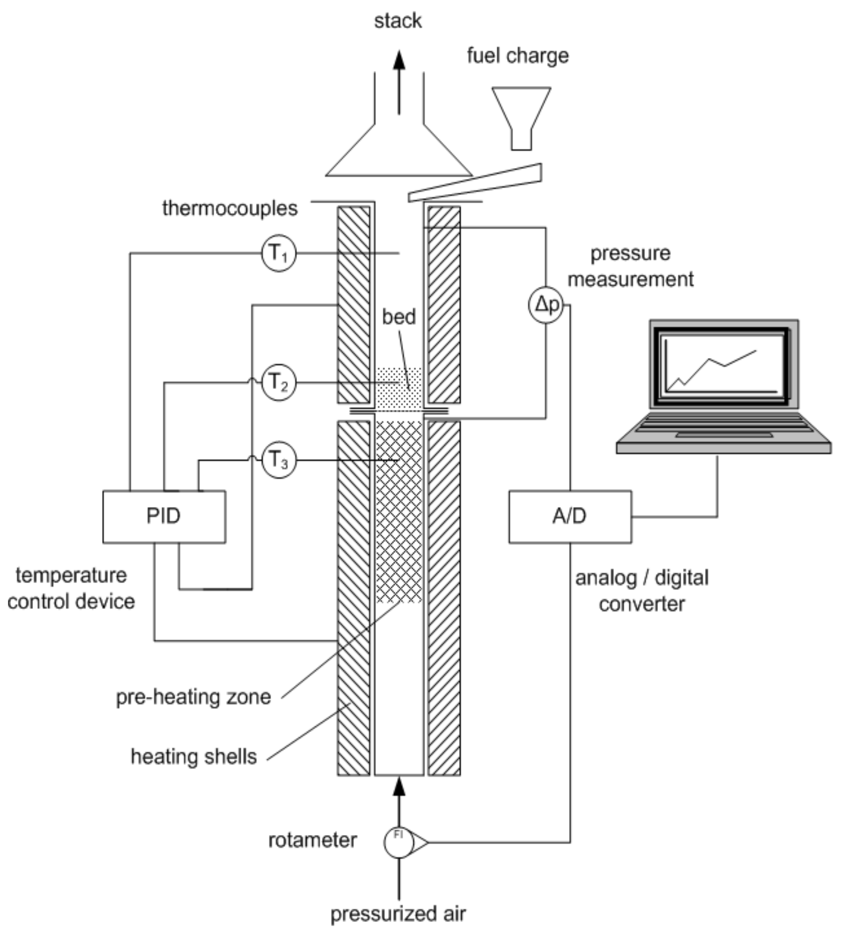
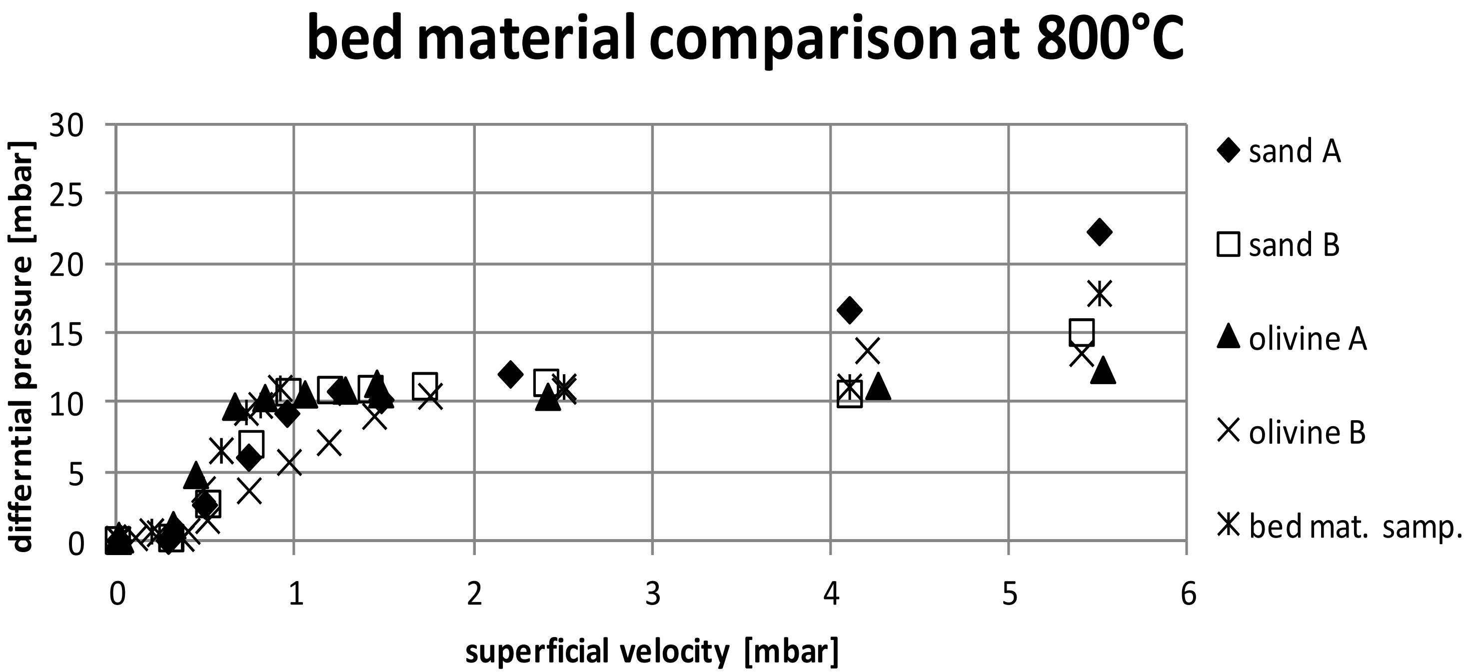
Methods

Hot-Fluidization Rig



Lab-scale fluidized bed reactor (reactor diameter: 70mm, height over bed: 850mm, maximum temperature: 900° C, maximum volume flow: 950 Nl/min, 450 g bed material, experimental fuel charge: coal, sludge, 2,6 g minute)

Results: Fluidization



- Sand B shows good properties for application as bed material in fluidized bed combustion plants.
- Wide fluidized bed region (about 1 to 4 m/s) and the sharp border to the fixed bed region and the fluidization region.

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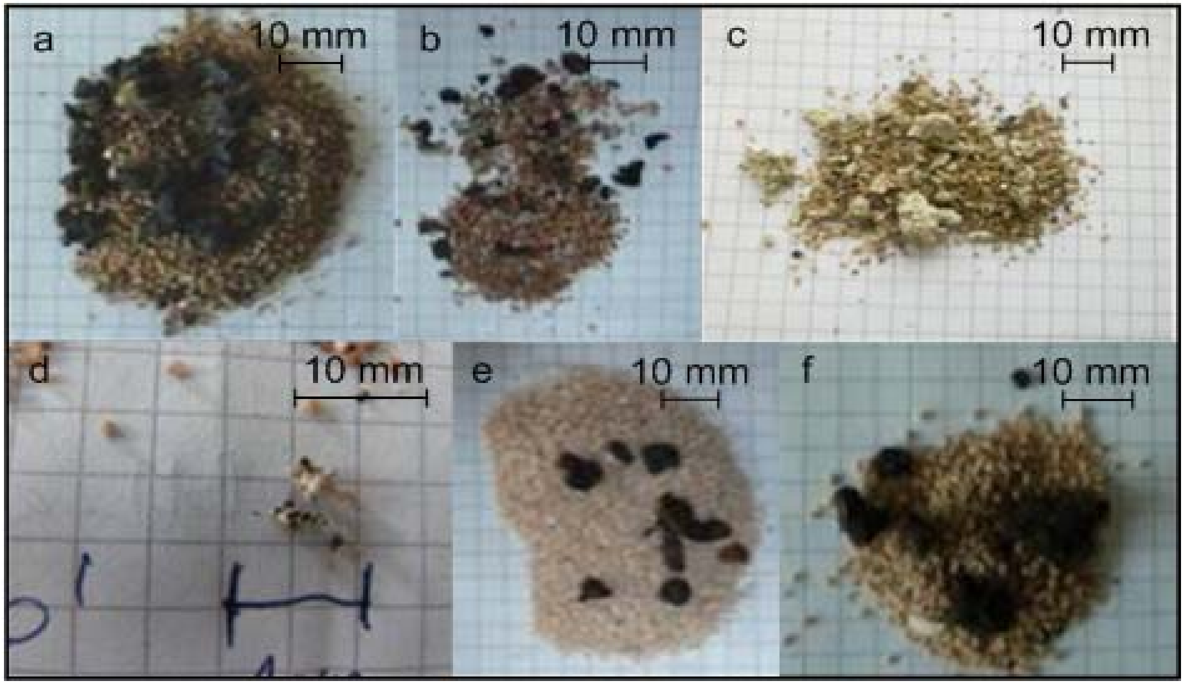
Results: Agglomeration tests



Agglomeration types generated during different experiments

bed material	agglomeration type		
time	10 min	30 min	60 min
sand A	none, coal-particles	ash-agglomerates	ash-agglomerates sand-agglomerates
sand B	none, coal-particles	ash-agglomerates	ash-agglomerates

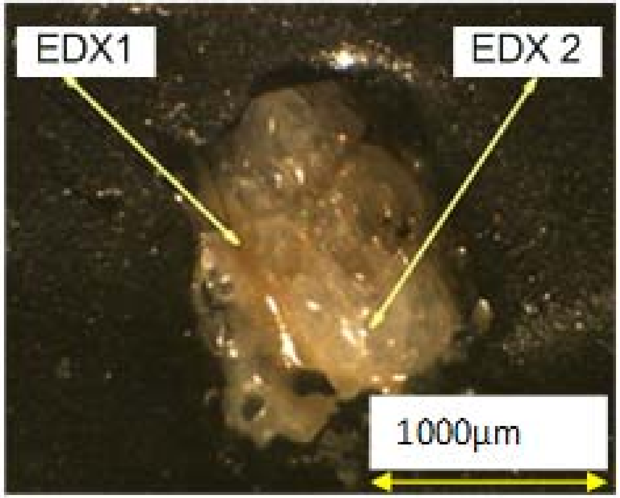
Results: Agglomerates formation

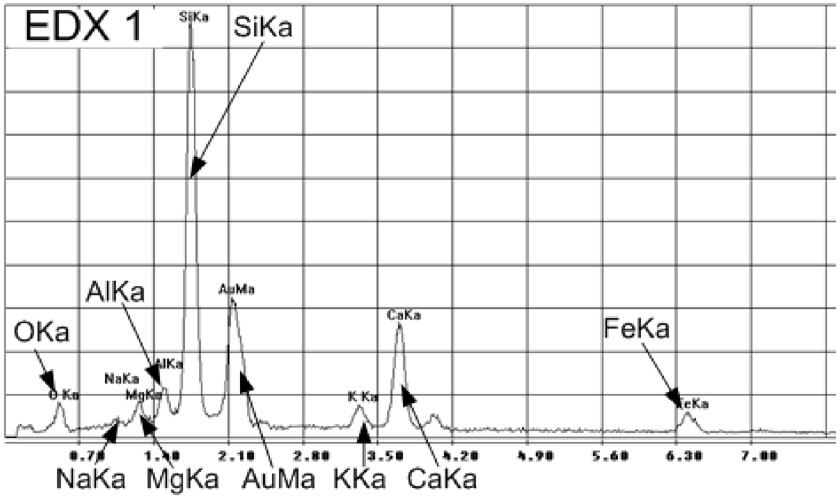
$$B = \frac{CaO + MgO}{SiO_2 + Al_2O_3}$$

	coal ashes	paper sludge ash	reaction product
basicity B	0,2-0,5	1,0	0,18 – 0,2
Na_2O+K_2O	2-4%	1,3%	1-1,5%

- Basicity and the alkali contents of fuel ashes and agglomerations (reaction product) can be seen as index for the agglomeration behavior.
- The high content allows the building of melting phases at comparable low temperatures of 950-1000°C in the combustion chamber.
- These can be characterized as silica-rich melt with high content of CaO, MgO, FeO, Fe_2O_3, Al_2O_3 and K_2O+Na_2O.
- The formation of glass or crystalline structures in the reaction product refers to cooling conditions.

Results: EDX analysis





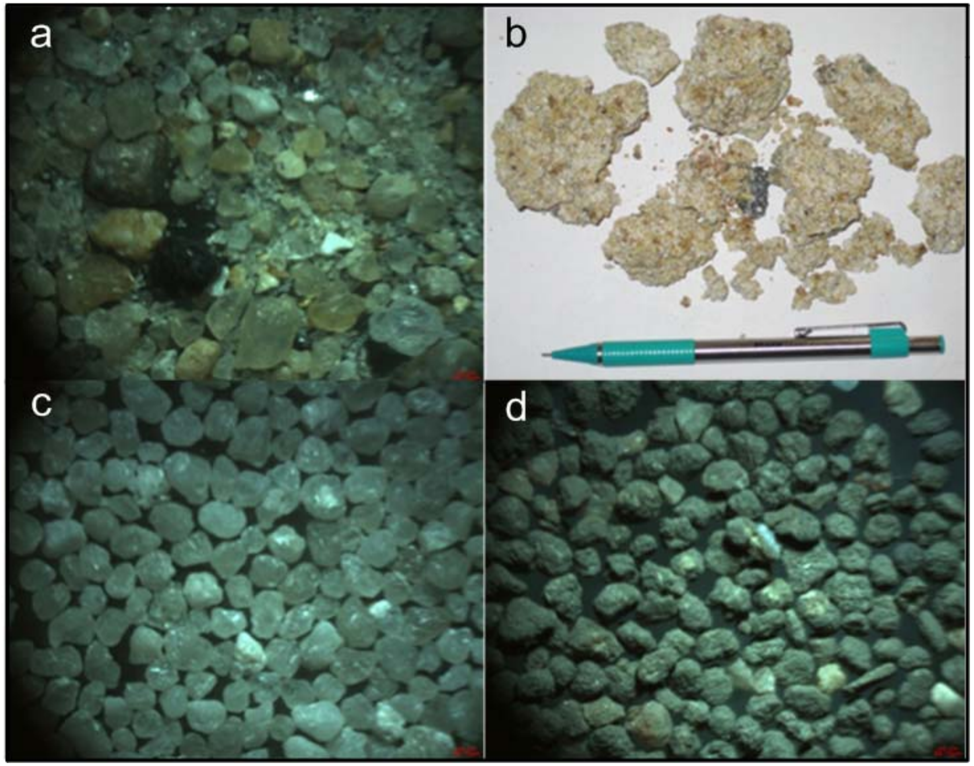
- Binocular view and an EDX analysis of melting phases and the reaction products.
- The deposit on the particle which is formed by the reaction products can be seen.
- EDX analyses on the right hand side ensured, that it consists of the chemical compounds CaO, MgO, FeO, Fe_2O_3, Al_2O_3 and K_2O+Na_2O.

Results: Reactor mass balance

	INPUT: total inorganic input to FBC						agglomeration formed out of bed material and „INPUT“			
MA% of input	0,5%	12,7%	6,1%	33,9%	44,8%	2,0%	**21%**	**79%**		
parameter [MA%]	coal ash A	coal ash B	coal ash C	fibre sludge ash	dolo-mite	hydrated lime	„INPUT“	bedmaterial	calculated	analysis
SiO_2	26,10	25,20	35,60	29,04	1,15	0,00	15,88	95,09	78,36	79,00
Al_2O_3	21,12	16,39	23,19	16,22	0,58	0,00	9,38	2,59	4,02	2,55
Fe_2O_3	18,97	23,10	15,77	2,20	0,24	0,00	4,85	0,25	1,22	0,97
CaO	10,22	12,47	6,81	44,96	58,60	100,00	45,50	0,05	9,65	10,55
MgO	7,02	7,62	5,24	2,85	39,01	0,00	19,76	0,00	4,17	5,20
K_2O	1,23	0,79	1,57	0,88	0,15	0,00	0,57	1,82	1,55	1,01
Na_2O	2,25	1,40	1,81	0,43	0,00	0,00	0,45	0,06	0,14	0,12
SO_3	10,90	11,73	8,15	1,03	0,17	0,00	2,47	0,00	0,52	0,44

- Not only fuel ashes are responsible for alkali-input.
- It is the bed material as the mass balance shows. Especially the content of K_2O in the pure sand is higher than the one inserted by the “INPUT”

Results: Microscope investigations



Pictures of different investigated sands; a: sand A used in FBC; b: agglomerates of sand A during FBC emergency shut-down; c: sand B, fresh; d: sand B used in FBC – no agglomerates

Results: Olivine

- Olivine used as bed material is said to be more agglomeration resistant. (De Geyter et al.)
- The molten ash layers formed on the particle during the combustion process are rich of Mg and poor of K
- These do not show the low melting eutectics like K - rich layers
- if the amount of K in the fluidized bed rises up the agglomeration behavior is quite similar to silica sand.
- the amount of K within the fresh bed material may raise the agglomeration potential of olivine as well.

Conclusions

- Bed material quality has a direct influence on the agglomeration potential during fluidized combustion processes.
- The material type (silica sand, olivine) itself shows different agglomeration behavior, a narrow grain size distribution offers stable fluidization conditions, which can prevent agglomeration.
- Agglomerates formation is reduced by the movement of the particles and is favored during defluidization.
- The analytical investigations of sand A and sand B showed, that the sand quality (e.g. purity, concentration of alkali metal oxides) is affecting the agglomeration behavior significantly.

Conclusions & Outlook

- The major influence is due to contaminations, especially with K, in the fresh bed material, these will increase agglomeration risk.
- Olivine used as bed material is more agglomeration resistant, however contaminations may rise the agglomeration potential.
- The quality of fresh bed material used for fluidized bed combustion is of major importance.

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Thank you for your attention!

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