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Ash reduction in waste wood combustion

Reducing downtime with additives in large-scale biomass combustion

Wels, 28th February

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Content

- Introduction and objectives
- Methodology
- Results
  - Deposit formation
  - Gaseous emissions
  - Dust emissions
  - Reducing downtime
- Summary and conclusion

Introduction and objectives

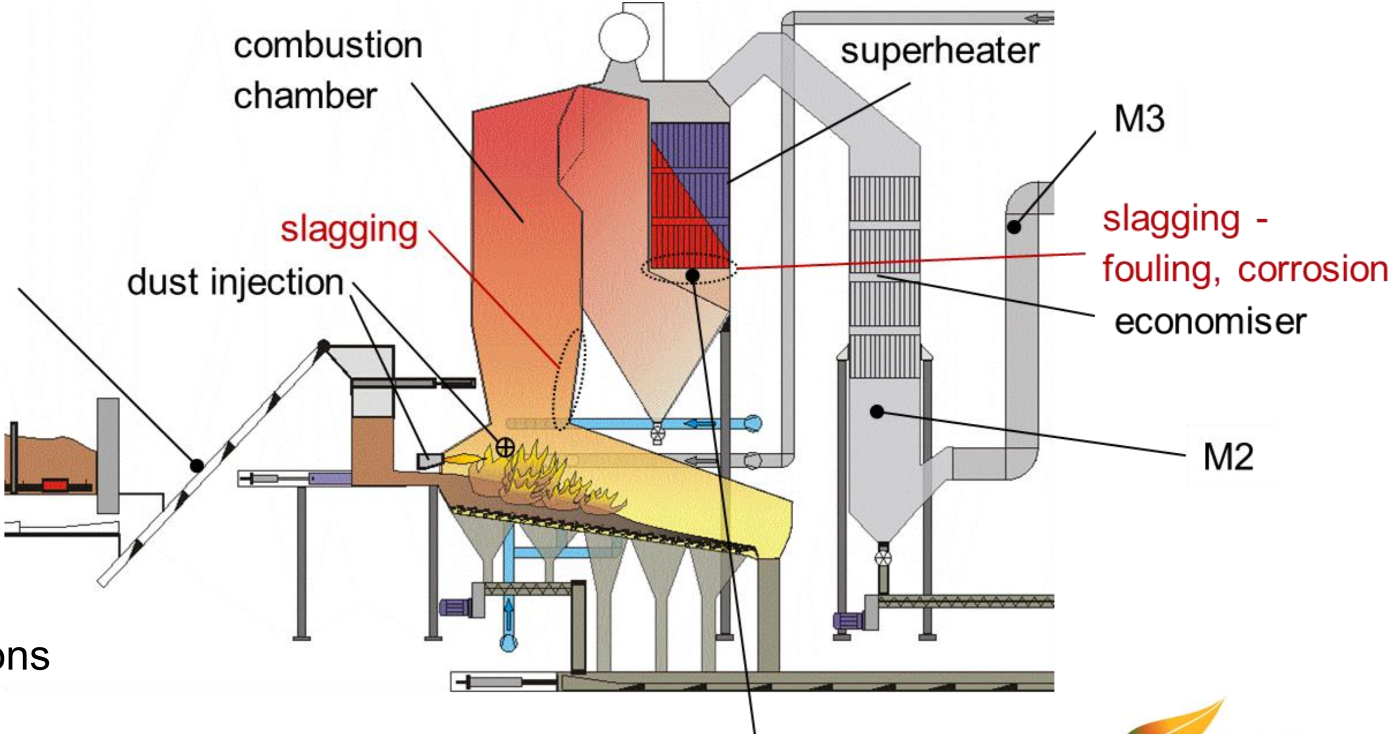
- **Slagging and fouling in biomass boilers leads to shutdowns → Removement of these deposits**
  - **Downtime** of the boiler is associated with **enormous costs.**
- **In order to minimise the slagging tendency, inexpensive additives are to be used.**
  - Additives and favourable additive rates were first tested on laboratory scale.
  - Aim: Testing of suitable additives in a large-scale biomass combustion system.

Introduction and objectives

Plant investigated

- 40 MW_{th} grate furnace equipped with 3 dust injectors; production of superheated steam
- Fuel: grate: forest wood chips, bark and waste wood
  dust burner: dust fractions from the manufacturing process
- Problems: slagging in the combustion chamber, slagging and fouling at the heat exchanger, corrosion

Introduction and objectives - Scheme of the biomass CHP plant



Measurement and sampling points:

FS … fuel sampling
M1 … deposition probe
M2 … flue gas analysis
M3 … total dust emissions

M1: 3.pass (upstream superheater)

Introduction and objectives - Photos of problems in the biomass boiler

Protective evaporator from below (in the flow direction, luv) after a system operation of **9 weeks**

Rear wall of the 2^{nd} duct against the flow direction in the direction of the 1^{st} duct photographed

Methodology

- **Additive injection close to the right dust burner**
- **Measurements**
  - Deposit formation
    - Deposit probe simulating a heat exchanger tube
    - Determination of built-up rate
    - SEM/EDX analysis for composition of deposits
  - Emissions
    - Gaseous emissions (SO_2, HCl, NO_x, CO); total dust
    - Chemical analysis: fuel, bottom ash and total dust

Methodology - Additive investigations

Additive application

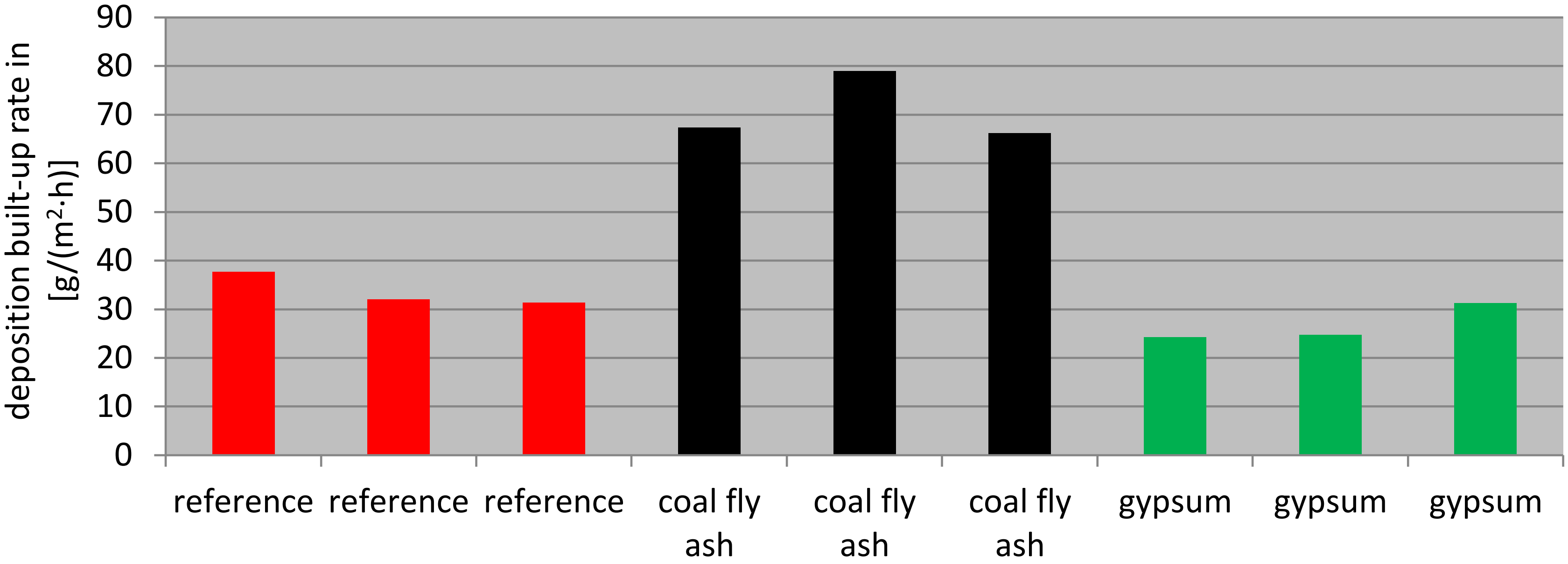
- Reference without additive
- Coal fly ash
- Gypsum

Amounts of additive provided to the combustion system

Additive	Addition in wt.% related to dry fuel	Addition in kg/min
Coal fly ash	3	3.92
Gypsum	2	2.61

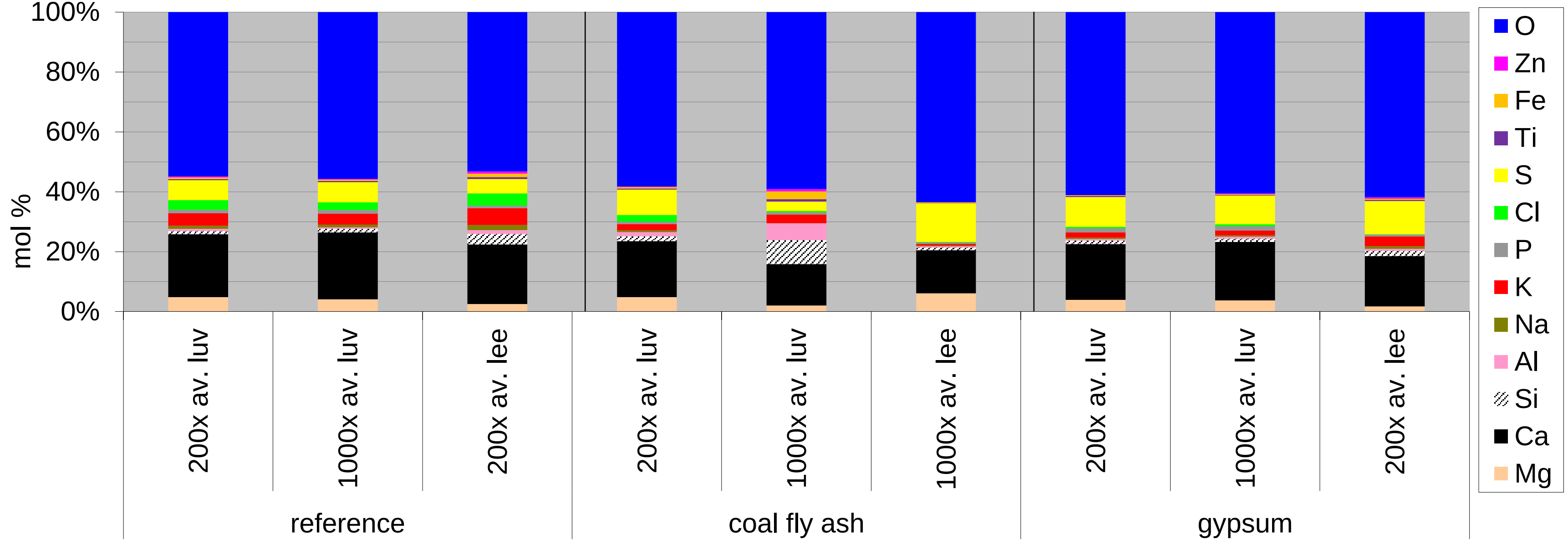
Results - Deposit formation - Built-up rate

Deposition built-up



- Highest deposition built-up rate for coal fly ash addition

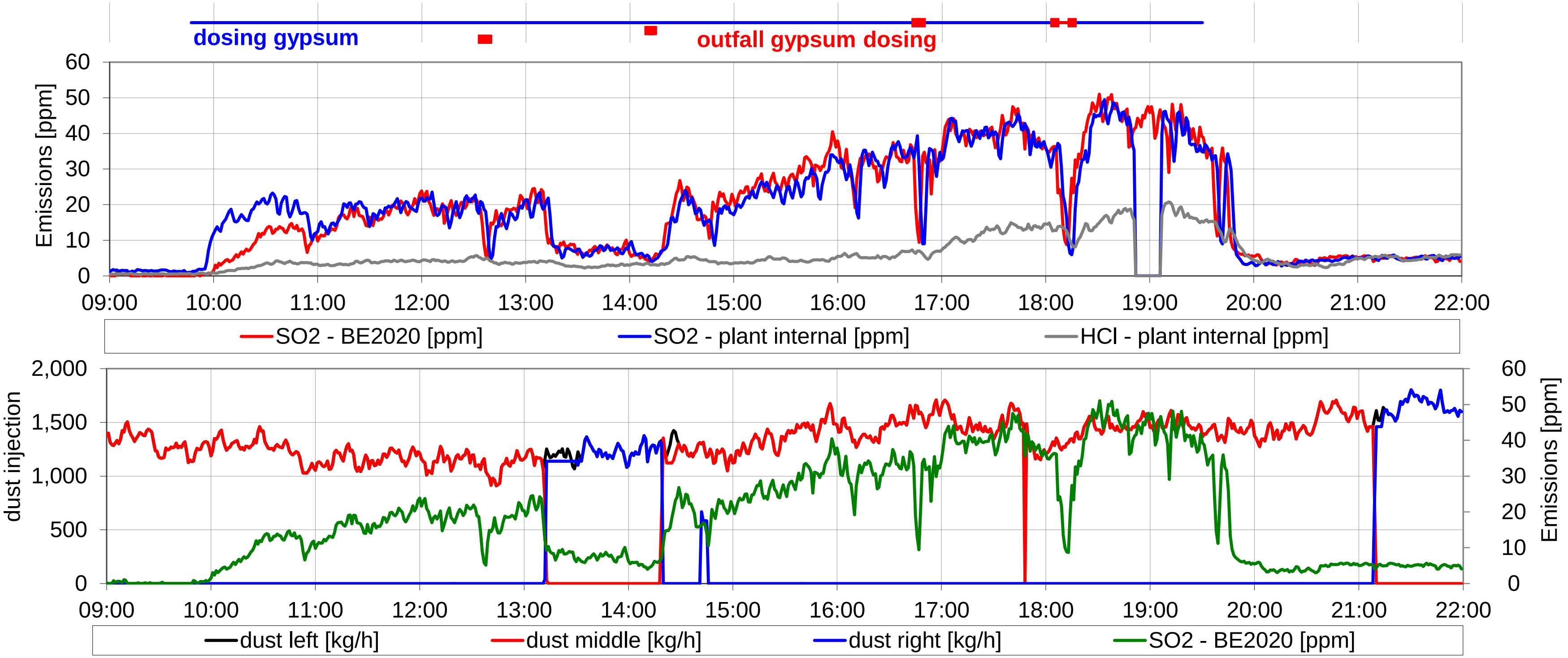
Result - Deposit formation - SEM-EDX analysis



- Inhomogeneous element distribution for coal fly ash
- Higher S concentrations by gypsum → sulphation → lower Cl concentration

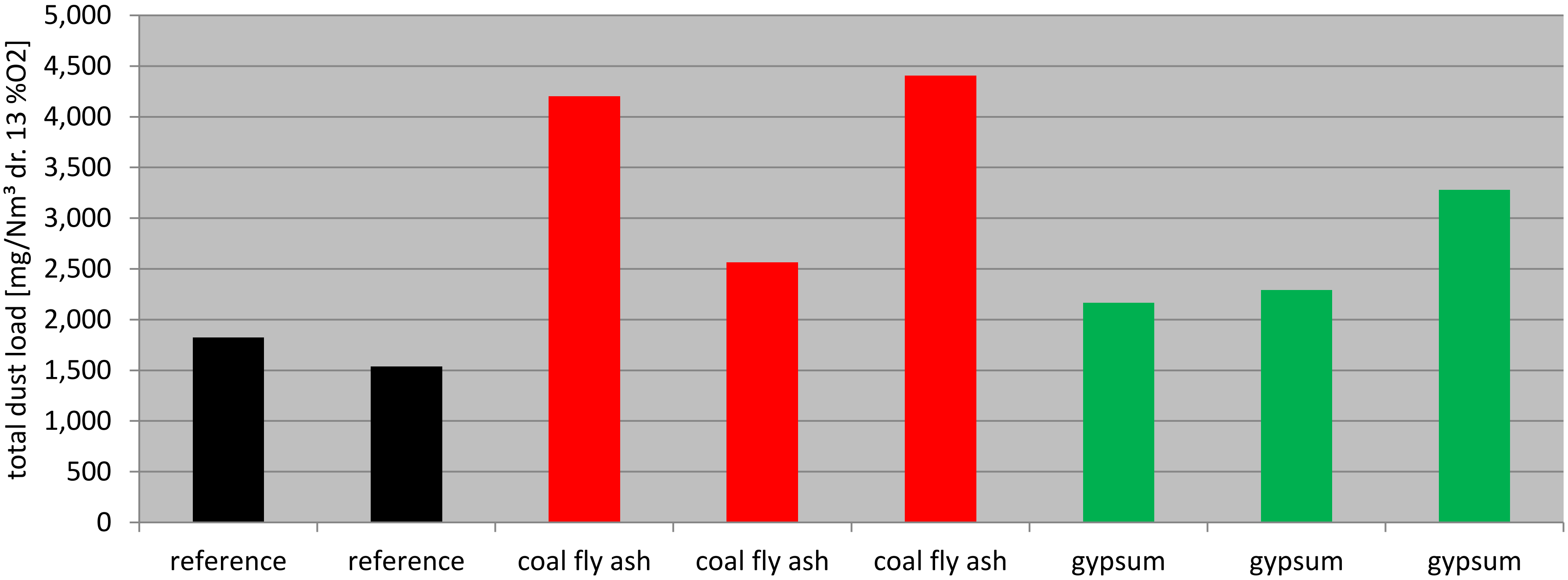
Results - Gaseous emissions - Gypsum addition

- Influence of fuel dust injection on precipitation of the additive



Results - Total dust emissions

- **Total dust in the flue gas**



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Results - Total dust emissions

- **Total dust in the flue gas – chemical composition**
  - **Higher Al** und **lower K and Zn** concentration for coal fly ash addition compared to the reference case without additive.
    - Coal fly ash contains high amounts of Al and reduces the release of K and partly of Zn
  - Significantly **higher S** concentrations and **lower Cl** concentrations for gypsum addition compared to the reference case without additive and for coal fly ash addition
    - Degradation of gypsum in the combustion chamber
    - Formation of SO_2 → preferable formation of sulphates

Results - Reducing downtime

- **Indices based upon the chemical composition of ash forming elements.**
- **The molar (Si+K+P)/(Ca+Mg) and (Si+K+P)/(Ca+Mg+Al) ratio can predict the potential regarding ash melting or slagging.**
  - Si in combination with K decreases the ash melting temperatures
  - CaO and MgO increase the ash sintering temperature; K_2O and P_2O_5 decrease the sintering temperature
    - Based on ternary phase diagrams

[Sommersacher, P.; Brunner, T.; Obernberger, I. Energy Fuels 2012, 26, 380−390.]
[Sommersacher, P.; Brunner, T.; Obernberger, I. Proceedings of the Conference Impacts of Fuel Quality on Power Production and Environment, Sept 23−27, 2012, Puchberg, Austria]

Results - Reducing downtime

- **Modification of the molar (Si+K+P)/(Ca+Mg) and (Si+K+P)/(Ca+Mg+Al) ratio to estimate the reduced downtime of the combustion system.**
  - Si content is not considered since the ashes are Ca dominated.
  - The molar **(K+P)/(Ca+Mg)** and **(K+P)/(Ca+Mg+Al)** ratios are used for a prediction concerning the slagging of deposits formed (SODF). → **SODF is the reason for downtime of the boiler.**

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Results - Reducing downtime

- Lower values for the molar (K+P)/(Ca+Mg) and (K+P)/(Ca+Mg+Al) ratio (minimisation of SODF) is linearly proportional to the reduction of downtime which are necessary because of SODF.
- Assumption: Only about 50% of the improvements of the index values have a real effect concerning reduction of downtime in the combustion system.

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Results - Reducing downtime

- **Estimating the minimisation of SODF for chemical composition of total dust.**

		reference	coal fly ash	gypsum
(K+P)/(Ca+Mg)	mol/mol	0.25	0.24	0.17
(K+P)/(Ca+Mg+Al)	mol/mol	0.20	0.15	0.13
[(K+P)/(Ca+Mg)]*0.5	%		3	17
[(K+P)/(Ca+Mg+Al)]*0.5	%		13	18

- **Concerning SODF an improvement of about 13% and 17% for coal fly ash and gypsum respectively can be assumed → Reduced downtime in % of the combustion system.**

Summary and conclusions

- **Position of additive injection and prevailing boundary conditions in the boiler (dust injection close to the additive injection) influences the precipitation of the additive in the boiler.**
  - Additive application must be individually tailored out to each specific combustion system.
- **Degradation of gypsum in the combustion chamber successful**
  - Formation of SO_2 → preferable formation of sulfates
- **Increased total dust emissions for coal fly ash addition.**
  - Higher Al und lower K and Zn concentration for coal fly ash addition compared to the reference case without additive.
- **A reduced downtime of the combustion system of about 13% and 17% for coal fly ash and gypsum respectively can be assumed.**

Thank you for your attention!

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