LULEÅ UNIVERSITY OF TECHNOLOGY

Effect of fuel additives on the gasification process-

Prediction of important ash transformation processes

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Background

- The ash content and the composition of the ash forming elements in wood derived fuels can vary in wide ranges

- These differences in ash compositions will influence the:
  - slag formation characteristics
  - syngas composition (particles, HCl…..)
  - overall process performance

- Several authors have previously proposed the use of different mineral additives (eg. Si and/or Ca/Mg based) to combat ash related operational problems during biomass combustion

Example of fuel characteristics – ash forming main elements (wood derived fuels)

	Bark (Scots Pine)	Logging residues (Norway Spruce, stored)	Logging residues (Norway Spruce, fresh)	Sawdust (Scots Pine)
Ash content	1.9	6.4	2.2	0.31
S	0.03	0.03	0.03	<0.01
Cl	0.01	<0.01	0.01	<0.01
Si	0.13	1.86	0.18	0.011
Al	0.089	0.38	0.024	0.0031
Fe	0.016	0.15	0.024	0.0022
Ca	0.42	0.256	0.57	0.093
Mg	0.038	0.070	0.048	0.021
P	0.030	0.034	0.033	0.0093
Na	0.010	0.11	0.011	0.0001
K	0.13	0.29	0.19	0.045

Important ash transformation processes during gasification of a solid biomass particles

High temp zone (> 800 C)

Low temp zone (< 800 C)

Pyrolysis/Gasification

$(K/_{Na})OH$ (g), $(K/_{Na})Cl$ (g), $K/_{Na}$ (g)

fuel particle

Residual ash

entrained ash particles 10-50 µm

K-silicate melt ?

Other residual ash forming matter (e.g. Ca, Mg)

Condensation

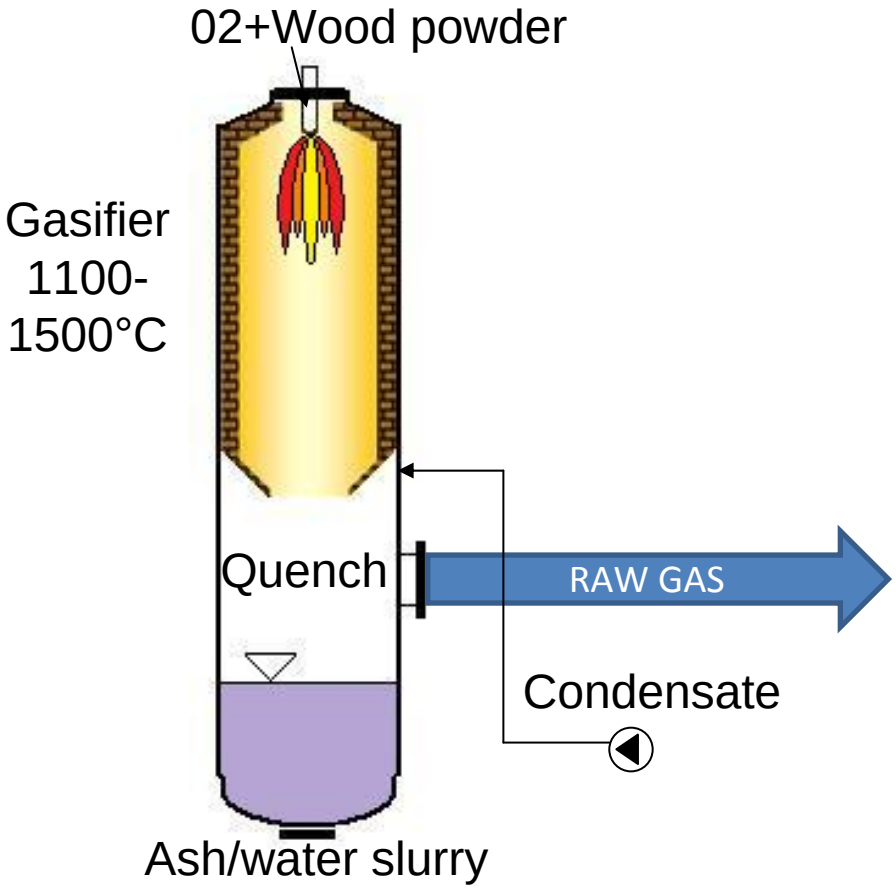
Producer gas/syngas

fine particles 0.1-1.0 µm

KCl (s)

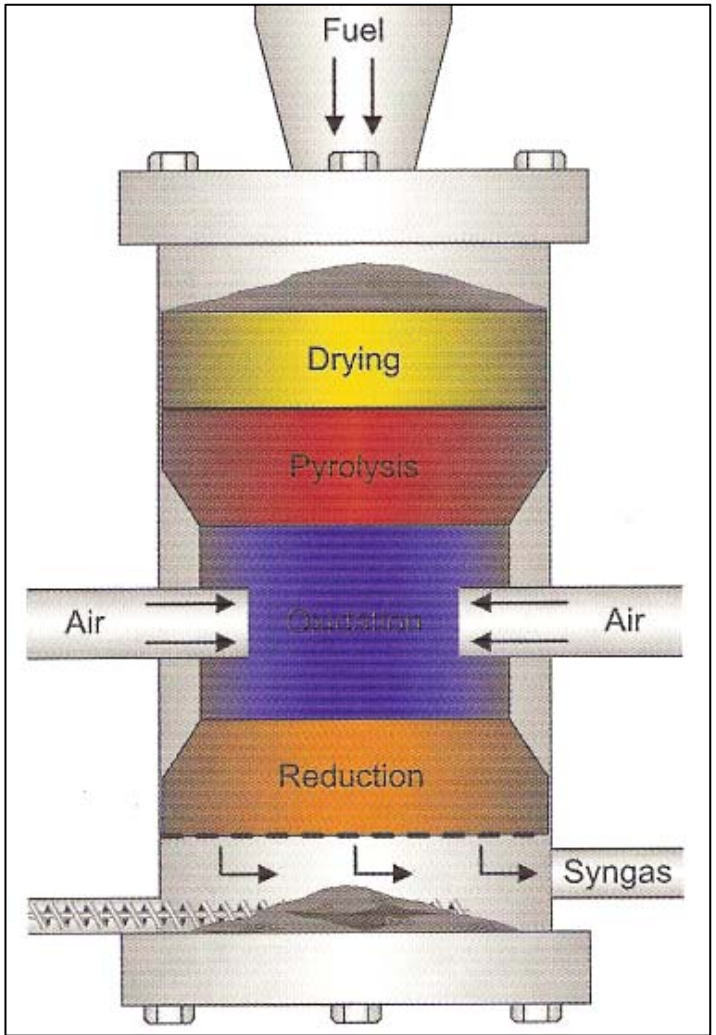
K2CO3 (s)……. Zn ? (s)

Important ash/slag behaviour in an Entrained Flow Biomass Slagging Gasifier



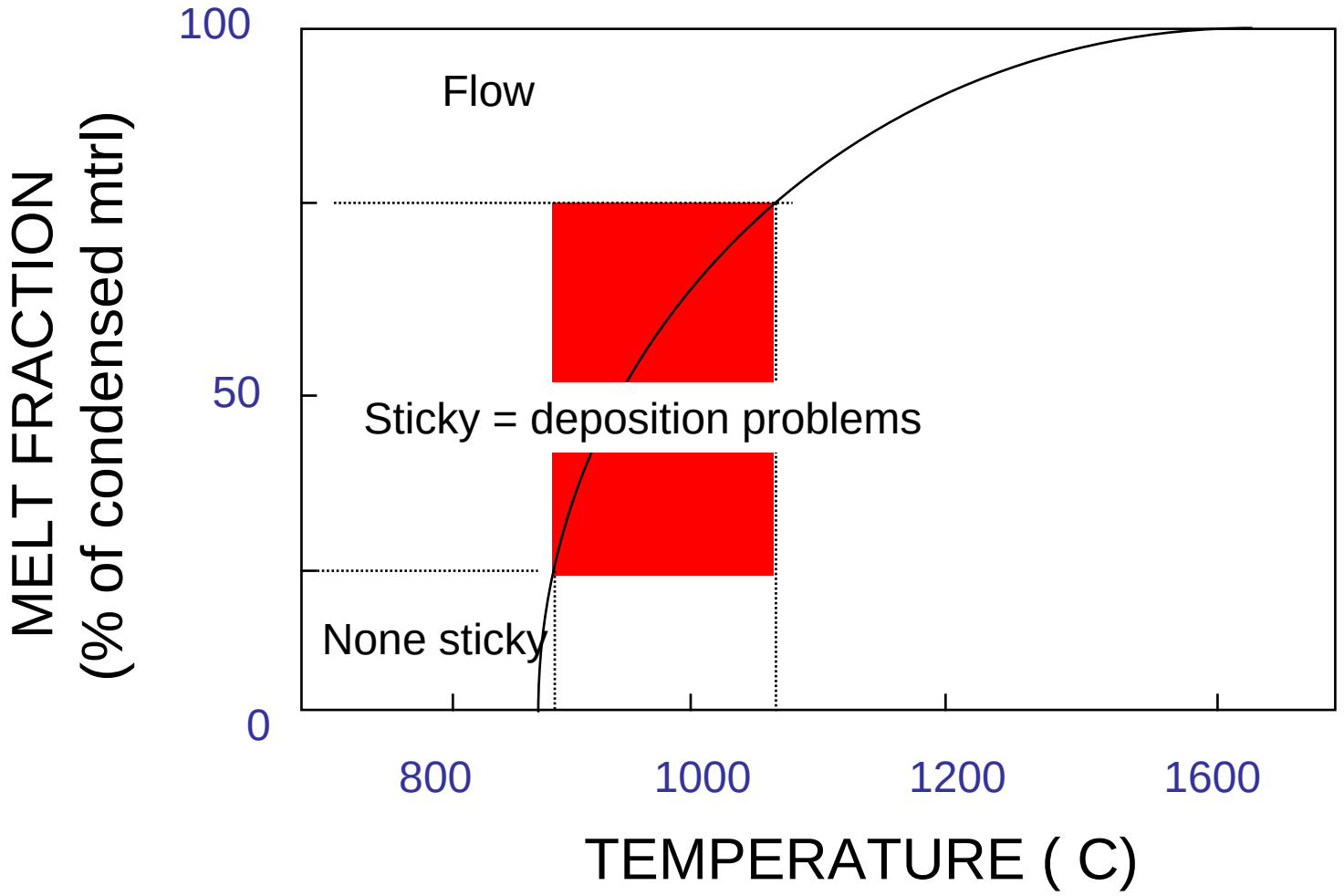
- Slagging gasifiers must operate above ash melting
- The slag must flow (i.e. not partially melted)
- Material stresses arise due to the corrosive slagging ash
- Effect of fuel additives?

Important ash/slag behaviour in a Down Draft Gasifier



- The gasifiers must operate below ash melting
- Effect of fuel additives?

Ash melting behaviour?



Objective

- To determine/predict the effect of different fuel additives on:
  - slagging characteristics of the produced ash (residual ash)
  - alkali (K+Na) release to the gas phase/producer gas (volatilization)

Method

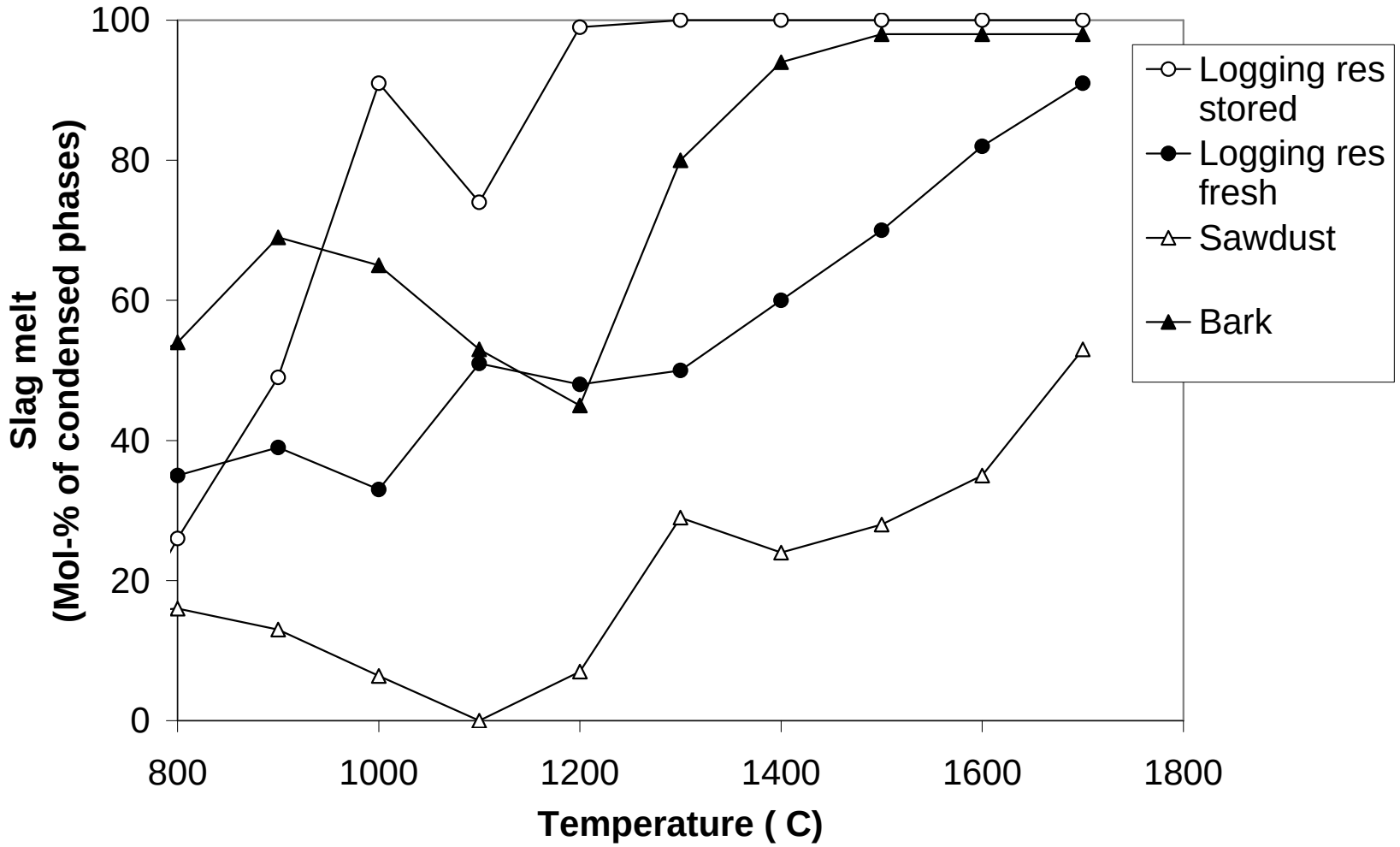
- Thermo chemical model calculations were performed using the software program FactSage 5.0
- The program uses the method of minimization of the total Gibb´s free energy of the system.
- Thermodynamic data includes stoichiometric data (gas species and condensed species) as well as non-ideal solid and liquid solution models.
- 4 fuel samples (Scots pine bark, logging residues (stored), logging residues (fresh) and softwood sawdust (Scots pine)
- Effect of Si- and Ca addition to sawdust and bark were studied
- Global approach for atmospheric pressure (1 bar) and an air-to-fuel ratio (λ) of 0.35 corresponding to typical global gasification conditions.
- The calculations were carried out covering a temperature range of 800 °C to 1700 °C.

Results (extracted from the calculations)

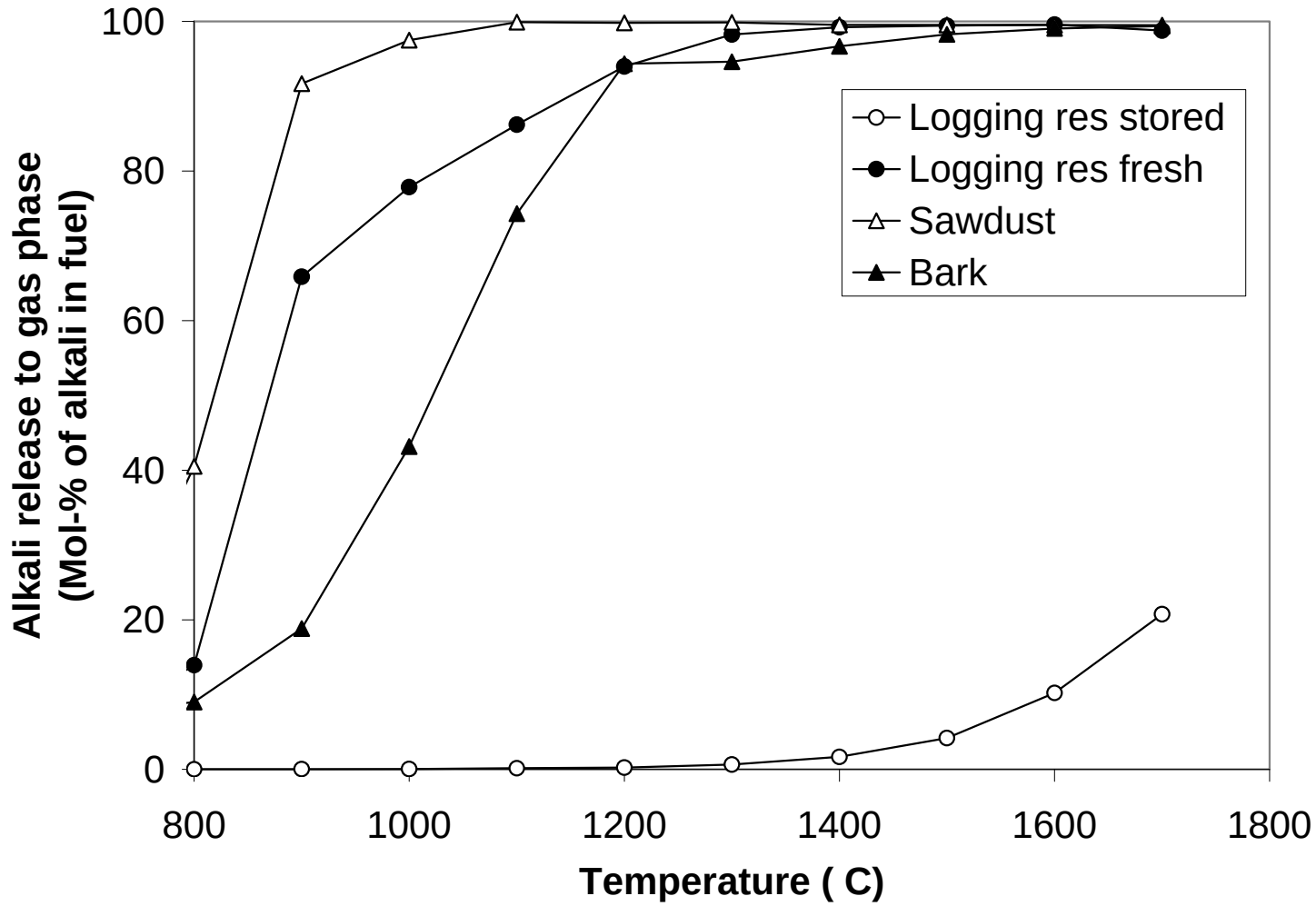
- Ash melting behavior of the produced residual ash as a function of the temperature
  - expressed as mol-% of condensed phases

- Alkali release to gas phase/producer gas (volatilization) as a function of the temperature
  - expressed as mol-% of alkali in the fuel

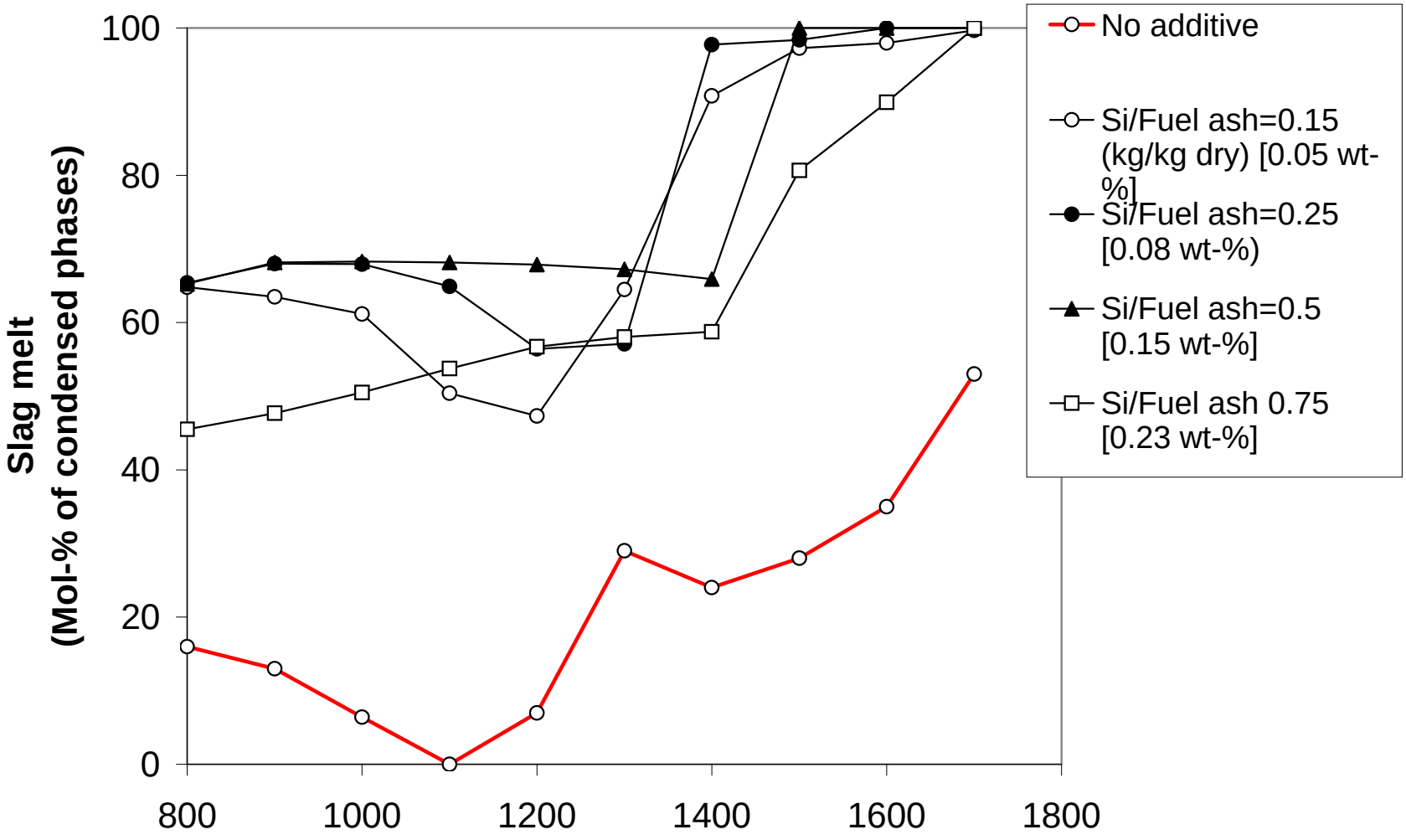
Melting behavior of the produced residual ash



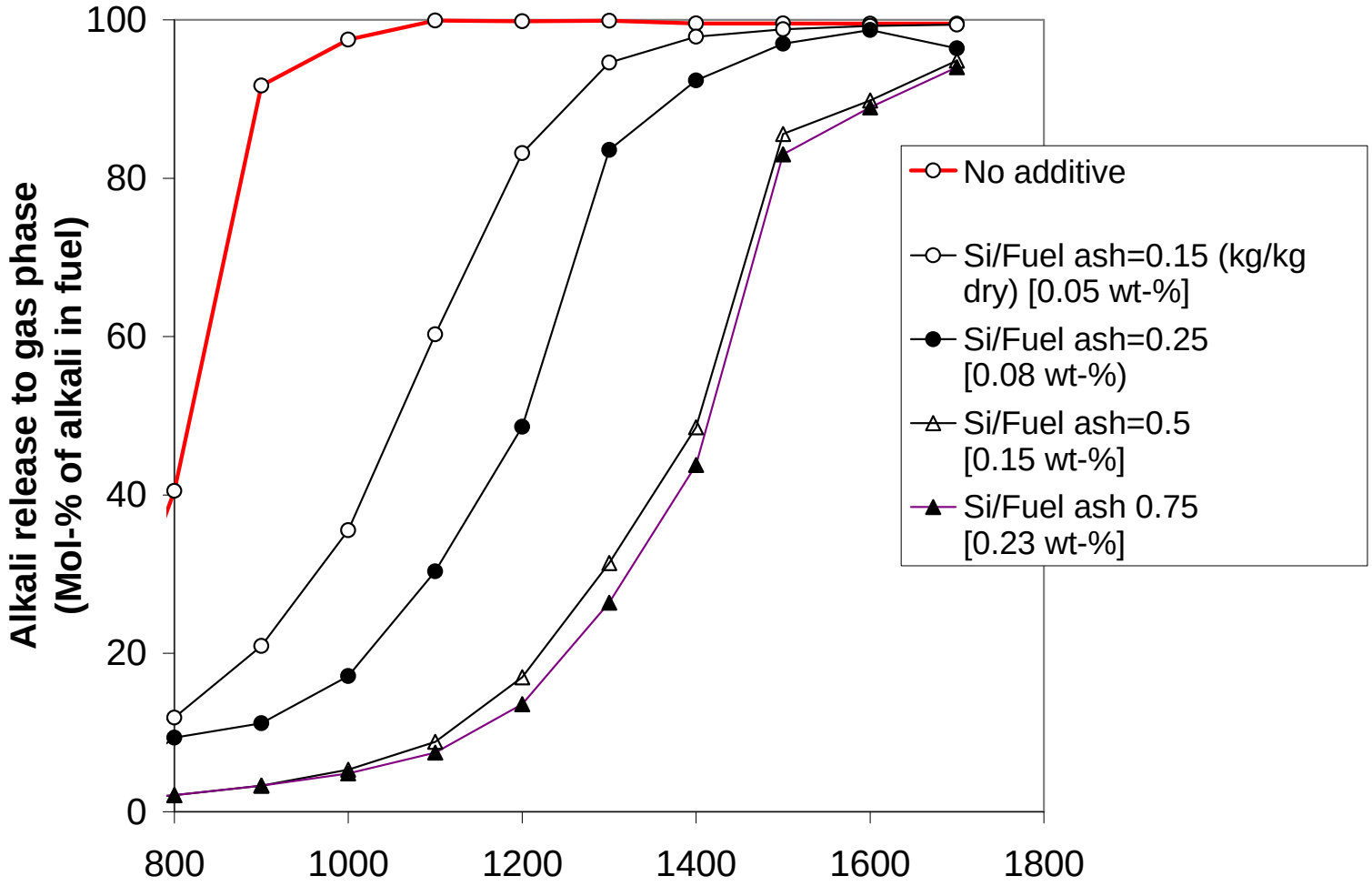
Alkali (K+Na) release to the gas phase (producer gas)



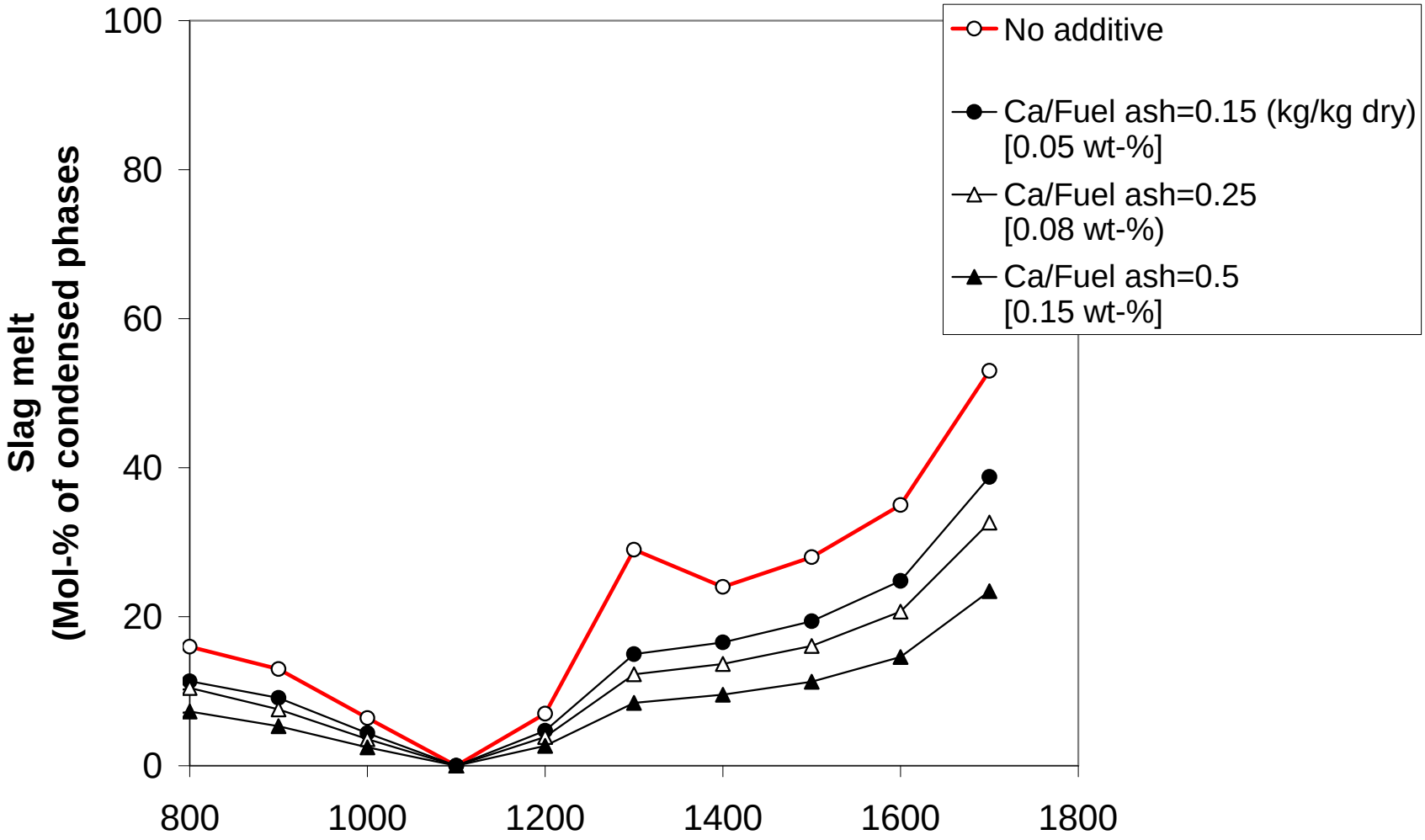
Effect of Si-addition on slagging behavior of sawdust



Effect of Si-addition on alkali release to the gas phase during sawdust gasification



Effect of Ca-addition on slagging behavior of sawdust



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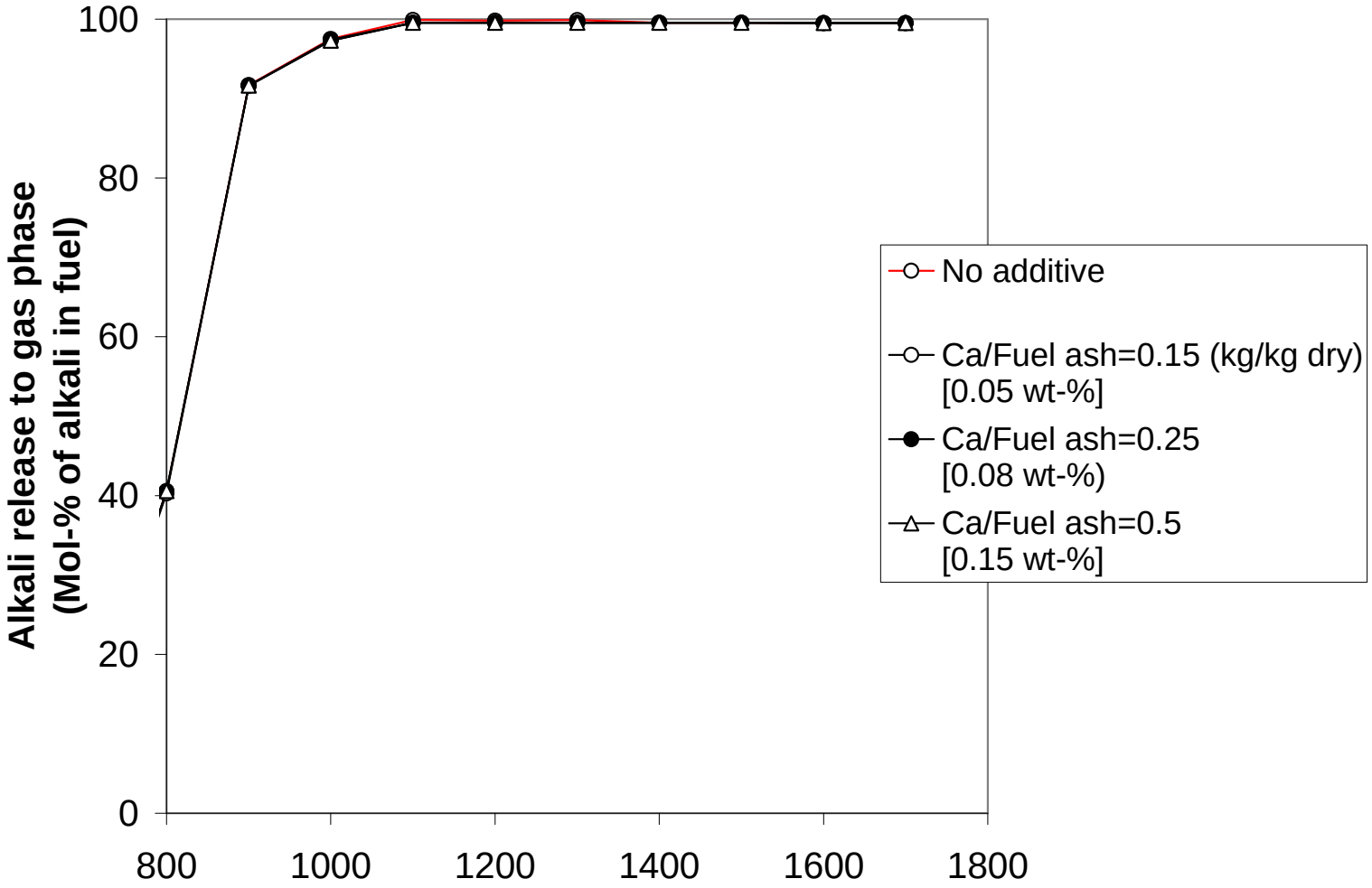
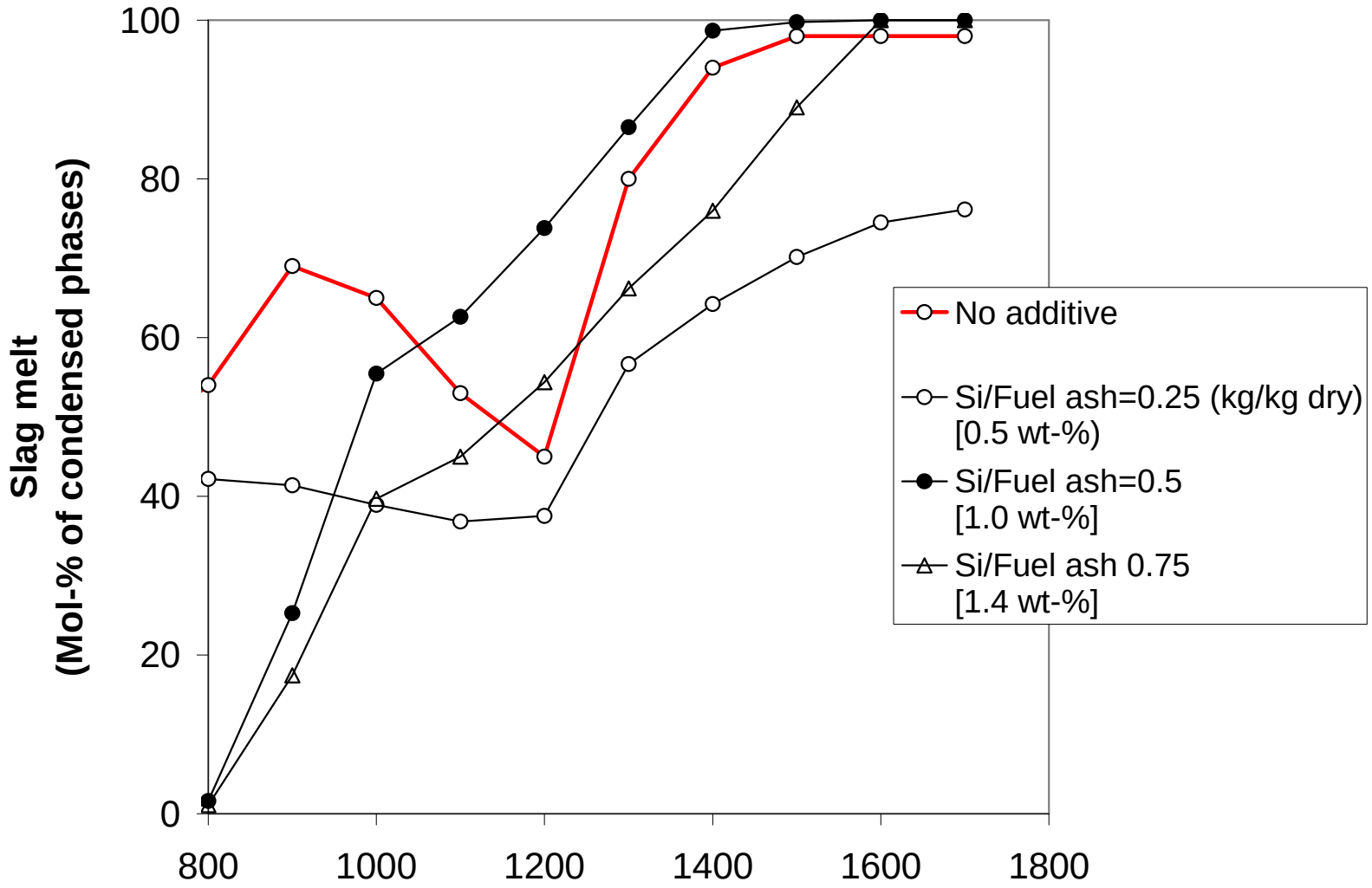
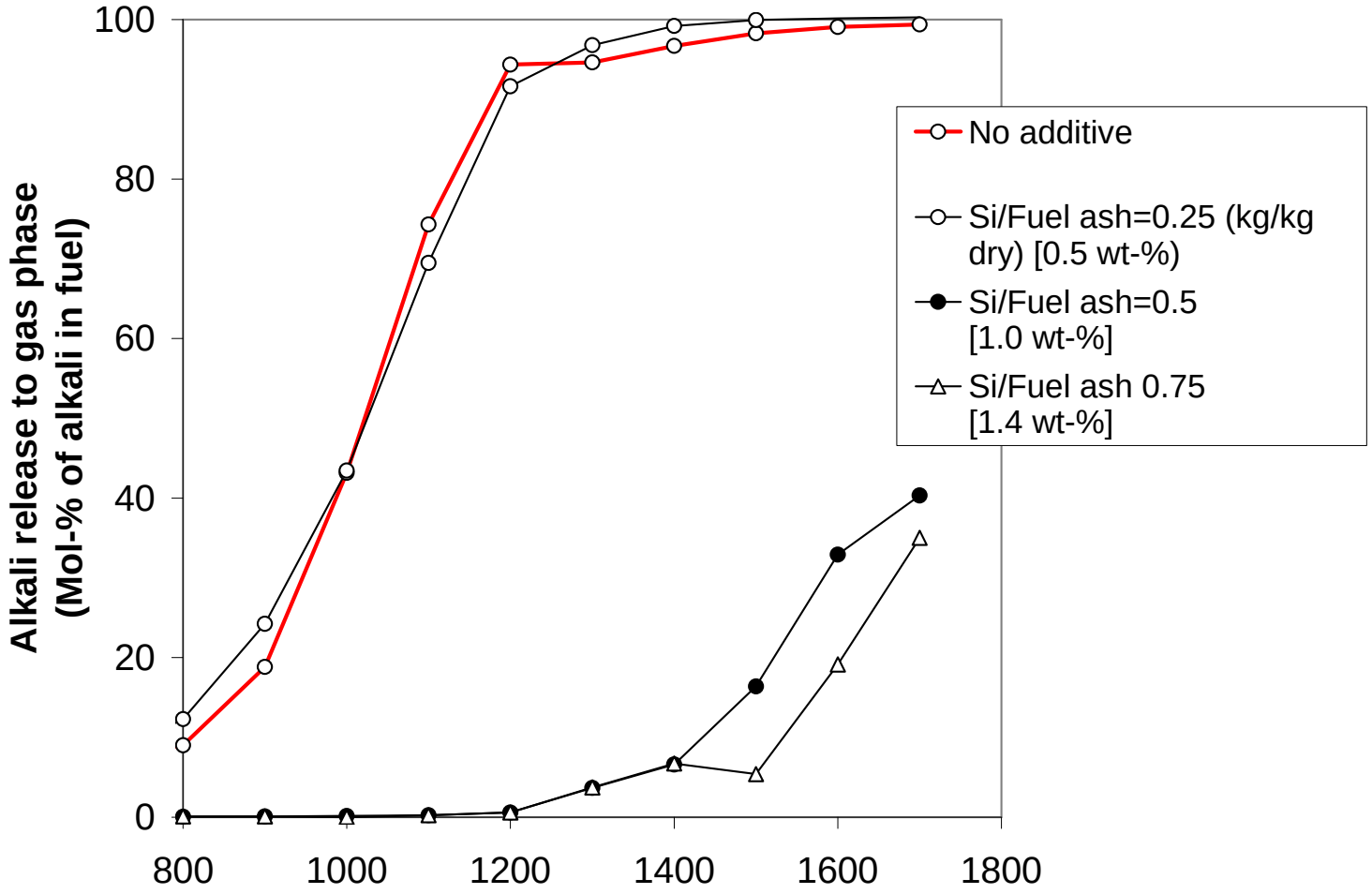


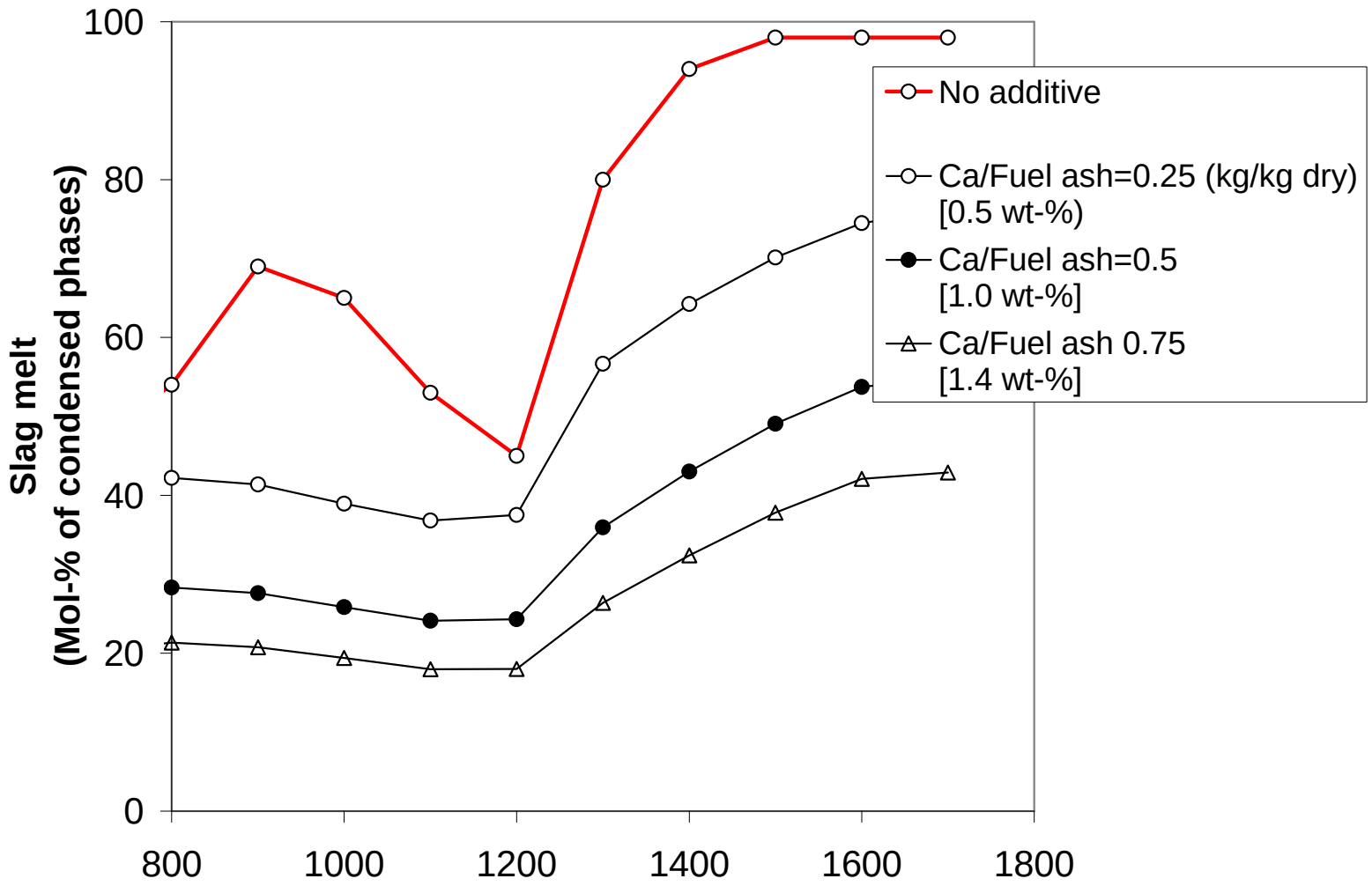
Effect of Si-addition on slagging behavior of bark



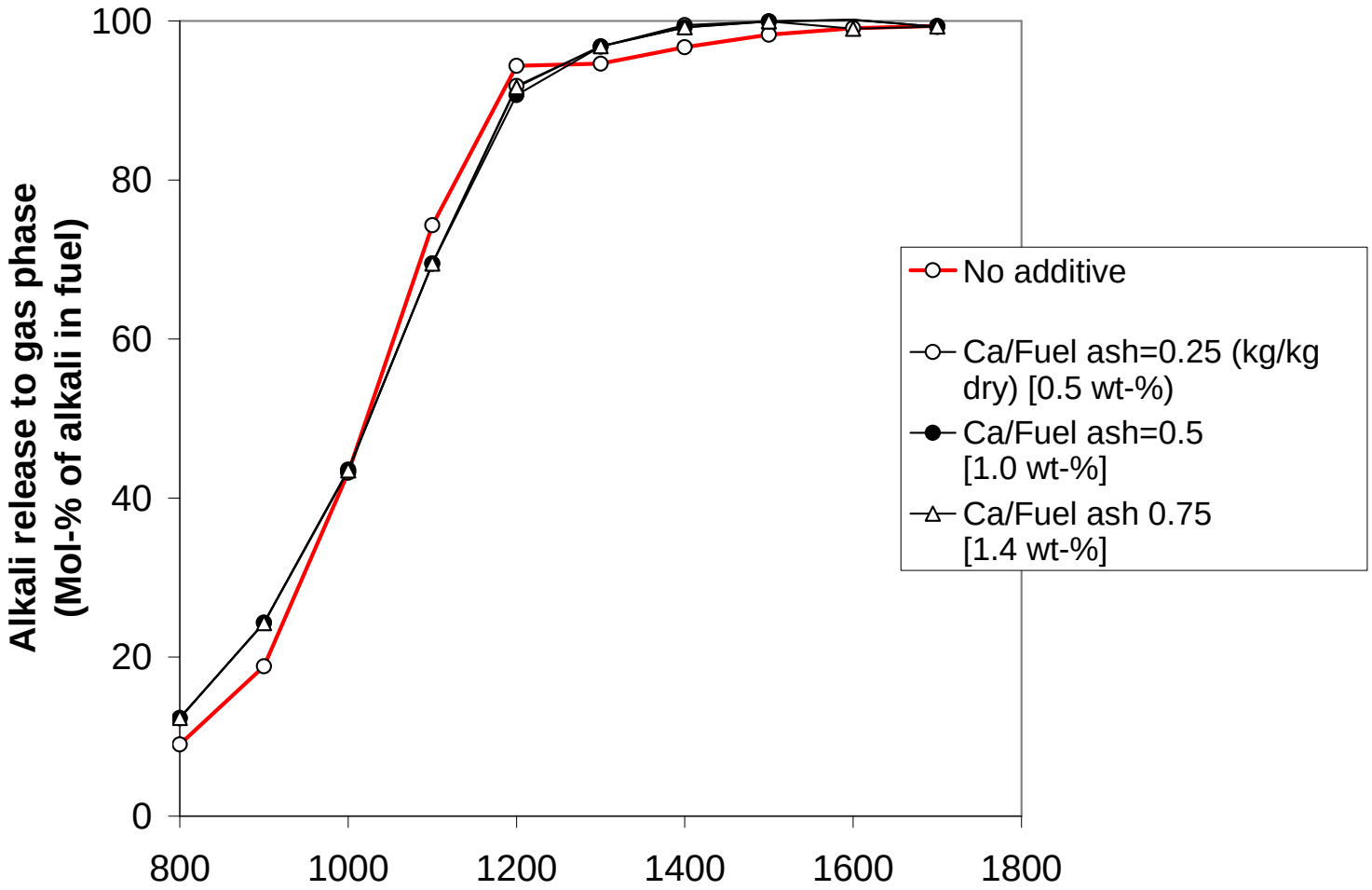
Effect of Si-addition on alkali release to the gas phase during bark gasification



Effect of Ca-addition on slagging behavior of bark



Effect of Ca-addition on alkali release to the gas phase during bark gasification



Conclusion

- Addition of Si-based fluxing agents (fuel additives) could be an interesting option to:
  - improve the slagging/ash behaviour during entrained flow biomass slagging gasification
  - Reduce the alkali volatilization (i.e. reduce fine particle formation/fouling of down stream equipments)

- Addition of Ca-based fuel additives could be an interesting option to reduce slag formation during fixed bed gasification

Further work

(Thermo-chemical modeling in WP 2 D3 and D2)

- More detailed studies (effect of different air to fuel ratios, more fuel samples/additives, pressured systems)
- Local equilibrium calculations
- Compare the results with actual gasification experiments/improve the models (e.g. add viscosity data/models)

Thank you for your attention!

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