PROCESS CHEMISTRY CENTRE

ÅBO AKADEMI UNIVERSITY

Biomass char oxidation kinetics in IPFR (Isothermal Plug Flow Reactor)

Host organization:
International Flame Research Foundation (IFRF)
Dates of visit: 1.10 – 16.10 2012

Oskar Karlström

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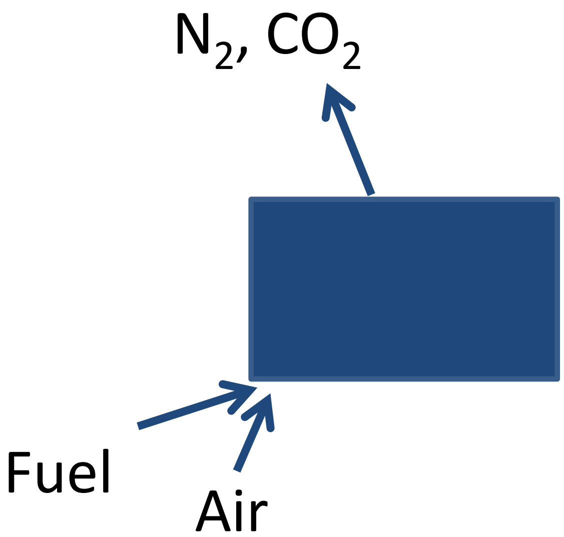
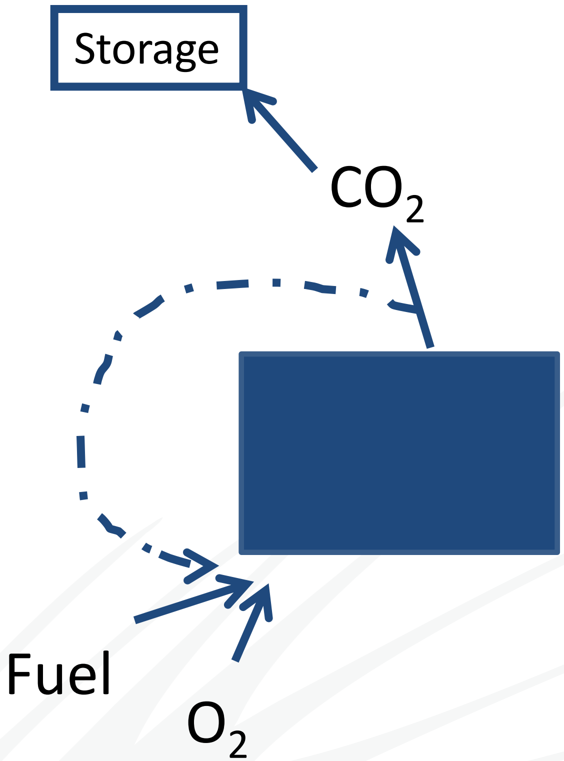
Background (1/3)

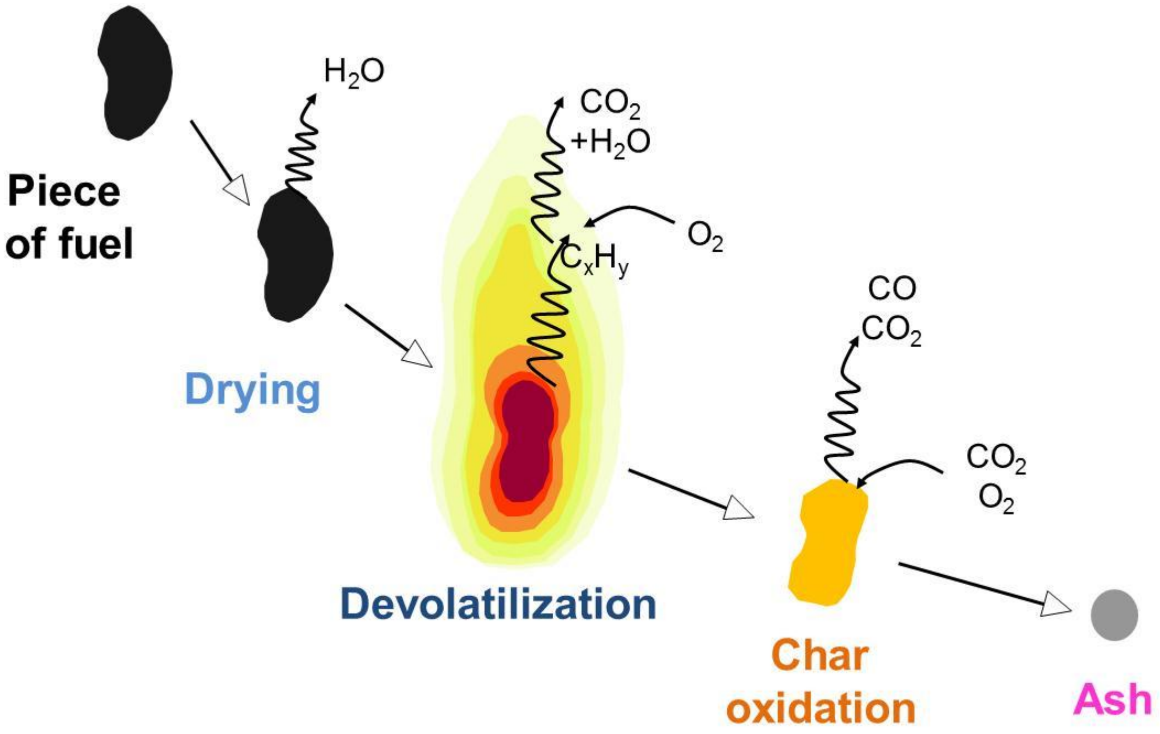
Combustion



Oxy-combustion

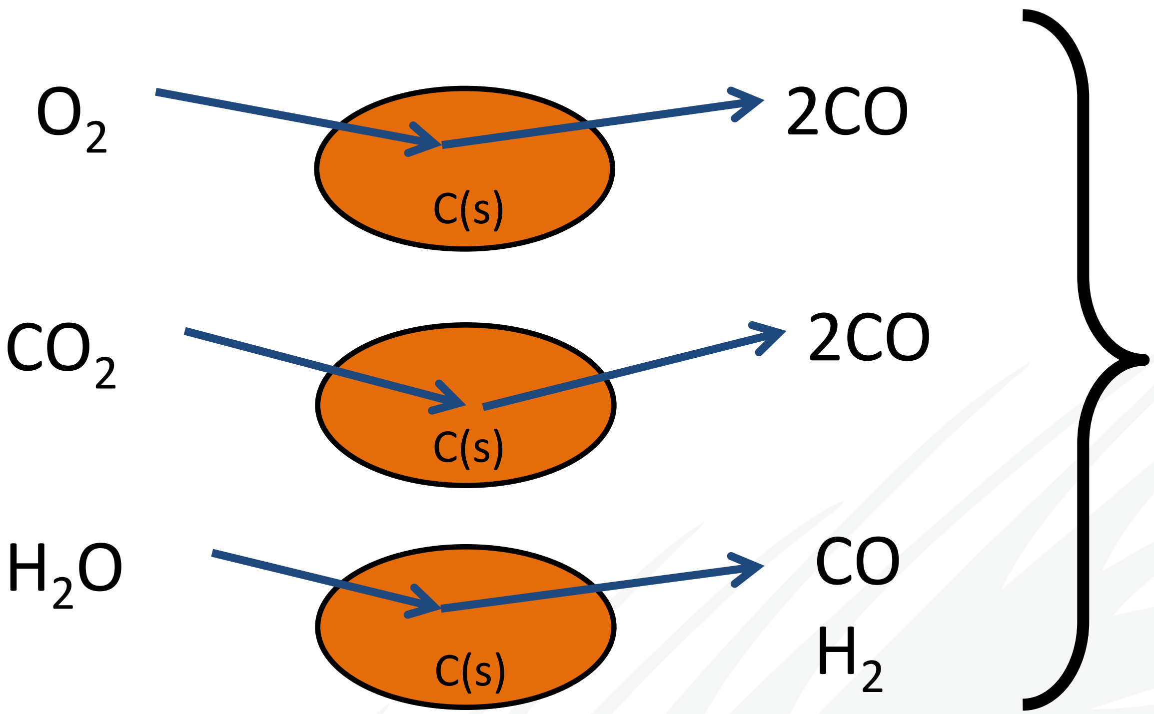


Background (2/3)



Background (3/3)

- Char reacts with O_2, CO_2, H_2O



Influence of CO_2, H_2O often neglected

Objectives

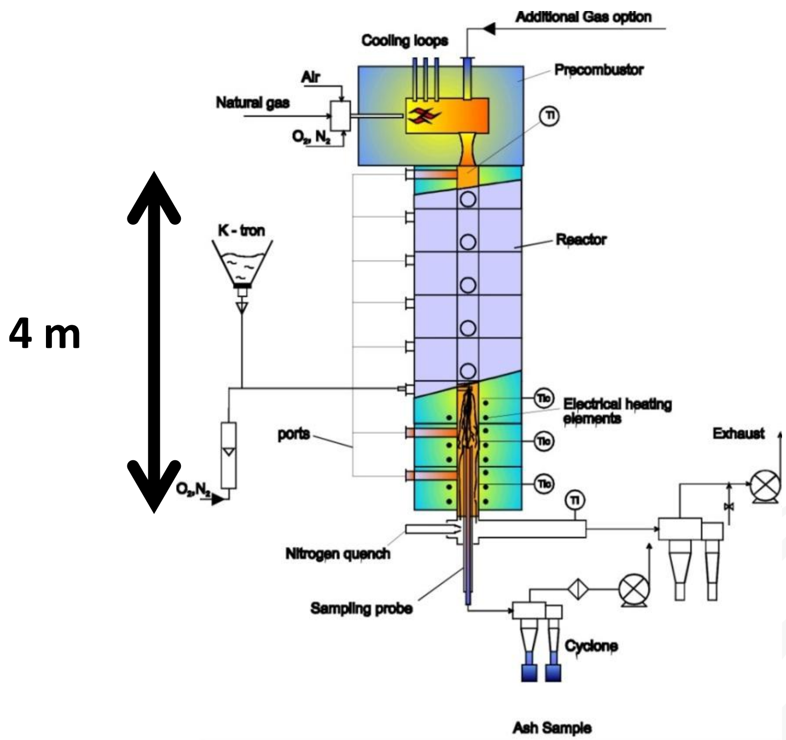
- Gain better understanding of biomass char gasification at high temperatures
- Characterize char gasification kinetics of pulverized biomass particles at high temperatures

Biomass

- Char residue from Danish straw
- Char residue produced at 900 °C in IPFR
- Average diameter of char particles = 0.22 mm

Experiments

- IFRF drop tube reactor



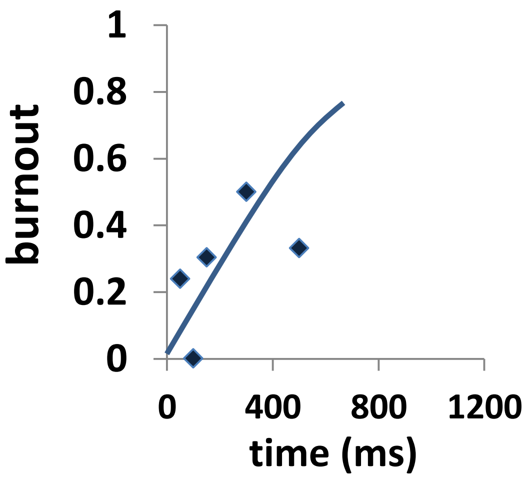
Straw char:

1200 °C

0 % O_2

13% CO_2

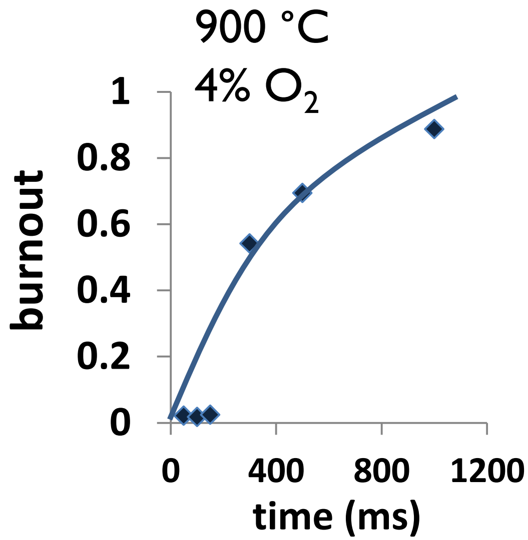
26% H_2O

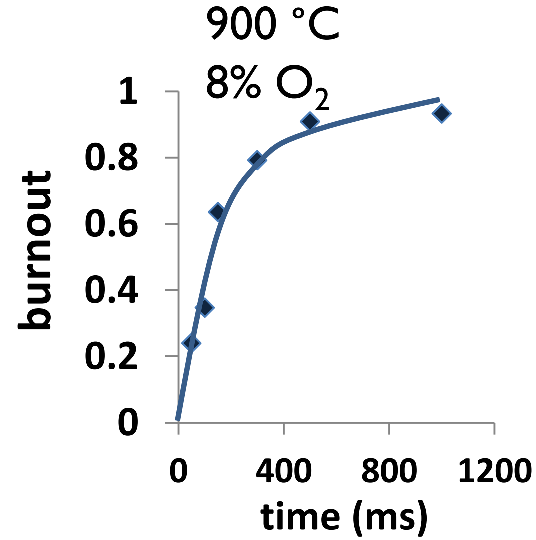


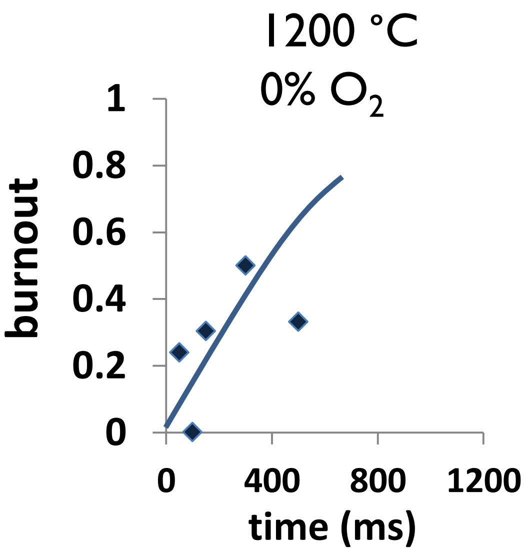
Experimental char tests

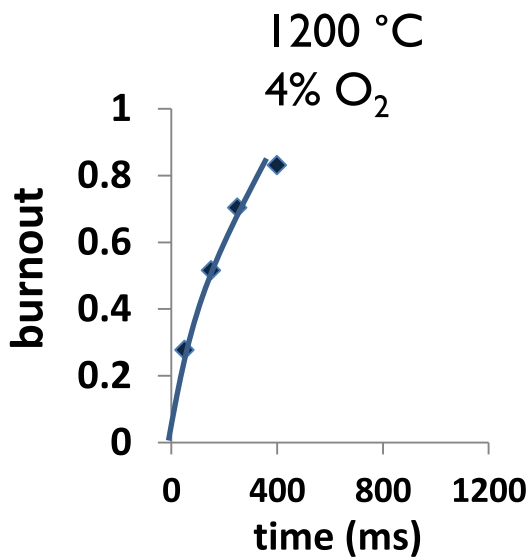
T (°C)	O_2	CO_2	H_2O	N_2
900	4 %	10 %	20 %	66 %
900	8 %	8 %	15 %	69 %
1050	4 %	11 %	22 %	63 %
1200	0 %	13 %	26 %	61 %
1200	4 %	10 %	21 %	65 %
1200	8 %	7 %	15 %	70 %

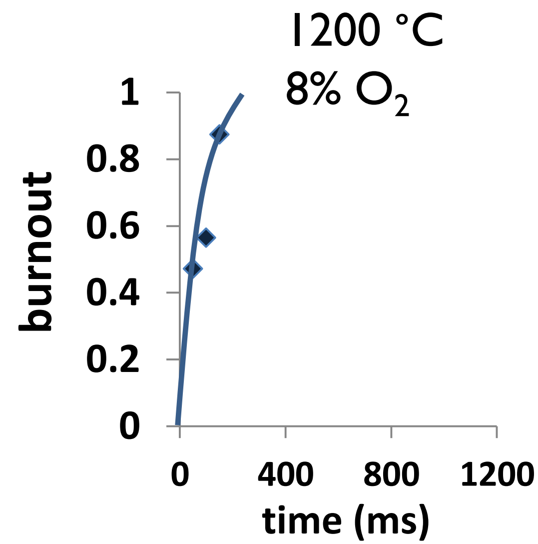
Experimental results











Model

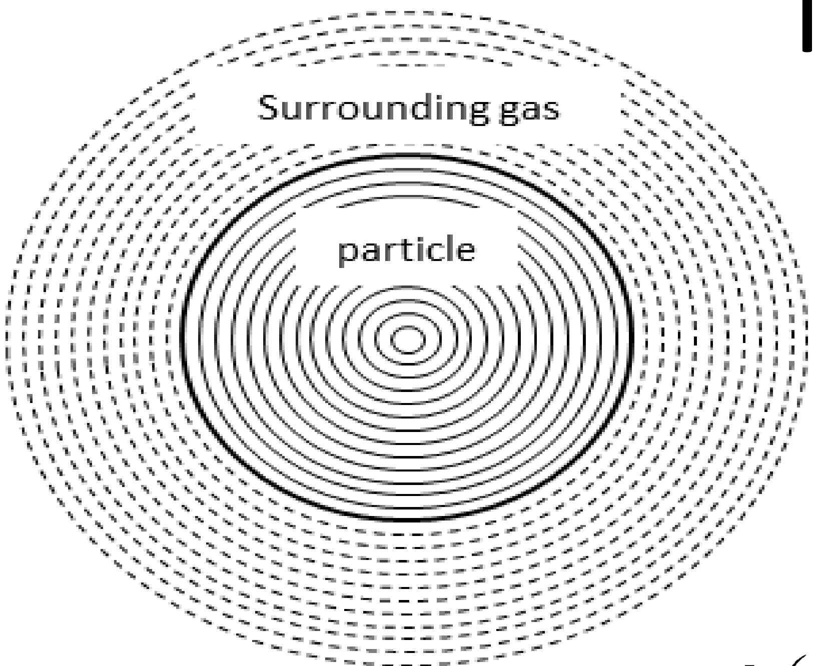
$2C(s) + O_2(g)$	$\rightarrow CO(g)$	(R1)
$C(s) + CO_2(g)$	$\rightarrow 2CO(g)$	(R2)
$C(s) + H_2O\ (g)$	$\rightarrow CO(g) + H_2(g)$	(R3)
$2CO(g) + O_2\ (g)$	$\rightarrow 2CO_2\ (g)$	(R4)
$CO(g) + H_2O\ (g)$	$\rightarrow CO_2\ (g) + H_2\ (g)$	(R5)
$2H_2(g) + O_2\ (g)$	$\rightarrow 2H_2O\ (g)$	(R6)

$$K_{O_2} = c_{O_2} k_{ads,O_2} \frac{1}{1 + \frac{k_{ads,O_2}}{k_{des,O_2}} c_{O_2} + \frac{k_{ads,CO_2}}{k_{des,CO_2}} c_{CO_2} + \frac{k_{ads,H_2O}}{k_{des,H_2O}} c_{H_2O}}$$

$$K_{CO_2} = c_{CO_2} k_{ads,CO_2} \frac{1}{1 + \frac{k_{ads,O_2}}{k_{des,O_2}} c_{O_2} + \frac{k_{ads,CO_2}}{k_{des,CO_2}} c_{CO_2} + \frac{k_{ads,H_2O}}{k_{des,H_2O}} c_{H_2O}}$$

$$K_{H_2O} = c_{H_2O} k_{ads,H_2O} \frac{1}{1 + \frac{k_{ads,O_2}}{k_{des,O_2}} c_{O_2} + \frac{k_{ads,CO_2}}{k_{des,CO_2}} c_{CO_2} + \frac{k_{ads,H_2O}}{k_{des,H_2O}} c_{H_2O}}$$

Model*



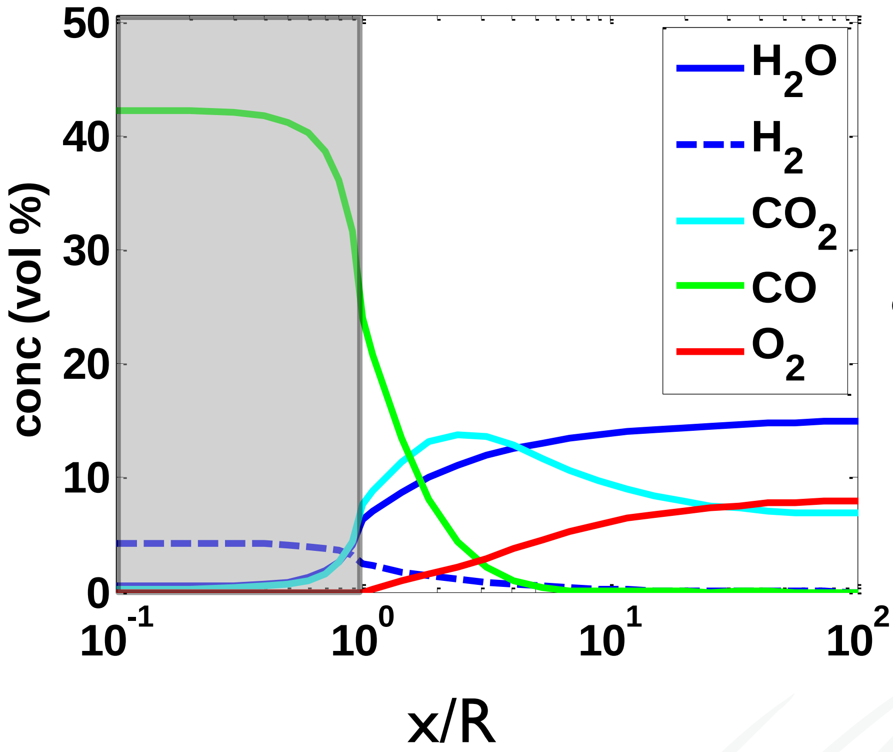
$$\dot{n}'''_{C,w,i} = -\Omega f_i(X_w) K_i$$

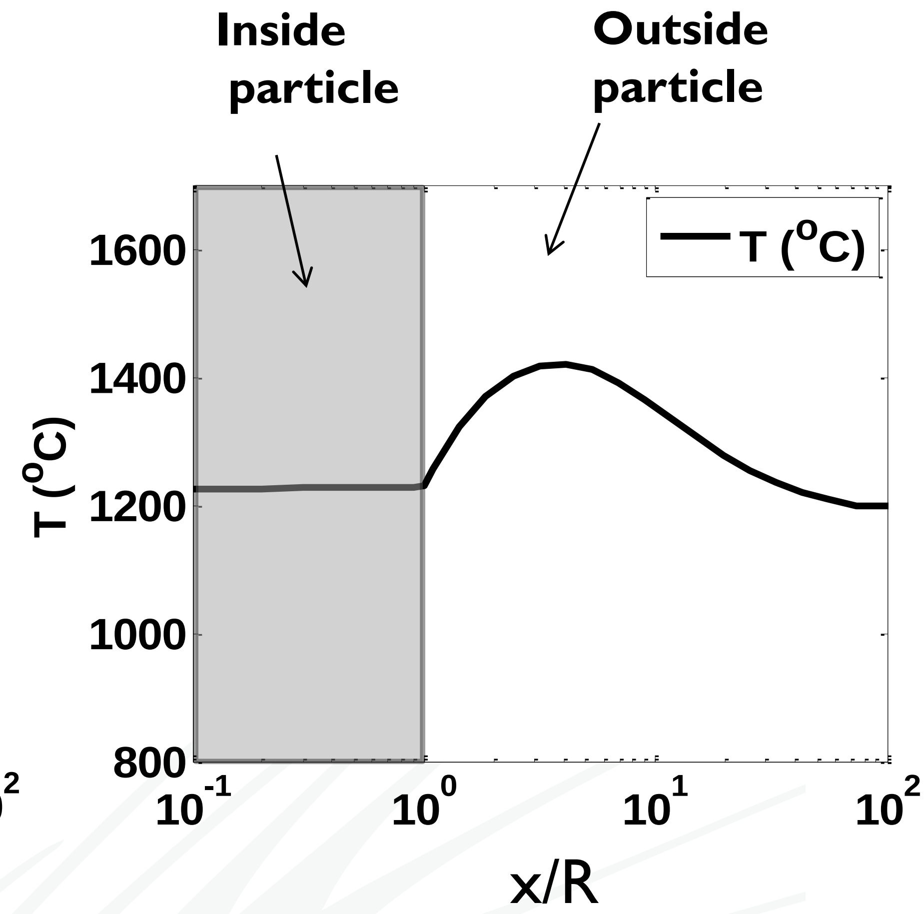
$$\frac{1}{S(r)}\frac{d}{dr}\left(S(r) D_j \frac{dc_j}{dr} + S(r)\sum_{j=1}^{j_{max}} x_j D_j \frac{dc_j}{dr} \right) = \dot{n}'''_j$$

$$\frac{1}{S(r)}\frac{d}{dr}\left(S(r)\lambda \frac{dT}{dr} \right) + \frac{1}{S(r)}\frac{d}{dr}\left(\sum_{j=1}^{j_{max}} \dot{n}_j H_j \right) = \sum_{j=1}^{j_{max}} \dot{n}'''_j H_j$$

*Oskar Karlström et al.
Combustion and Flame 2015

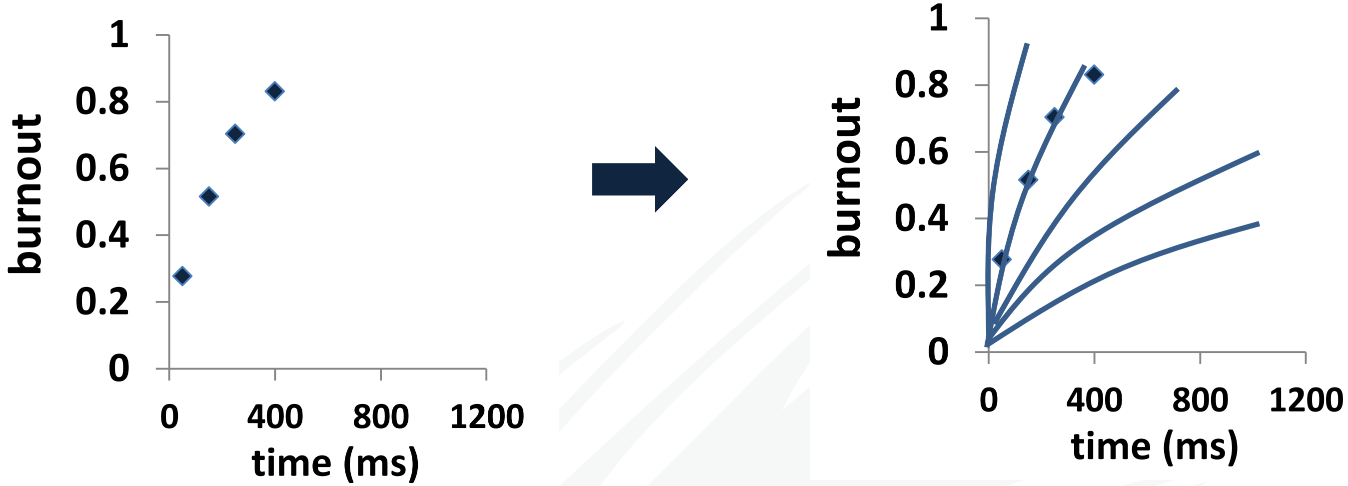
Model: 1200 °C with 8% O_2





kinetic parameters

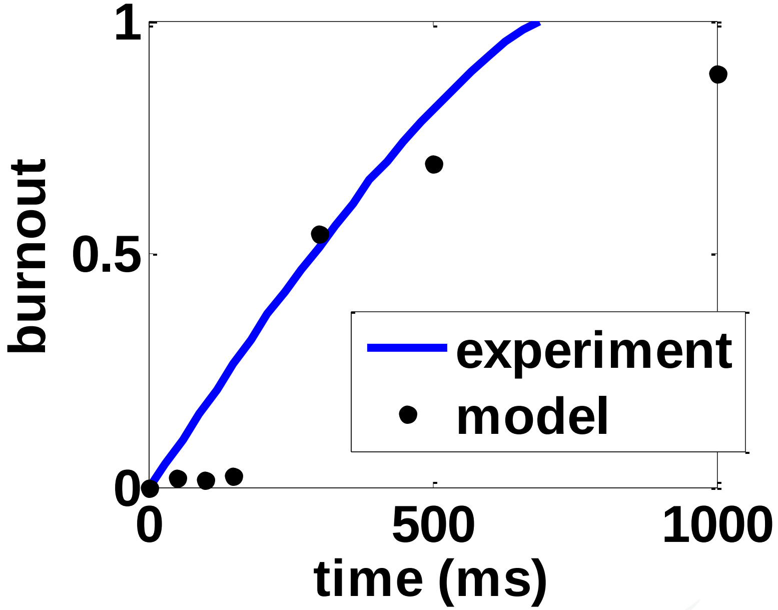
- Determined by using a multivariable optimization method* in which modeled char conversion are fitted to experimental char conversion



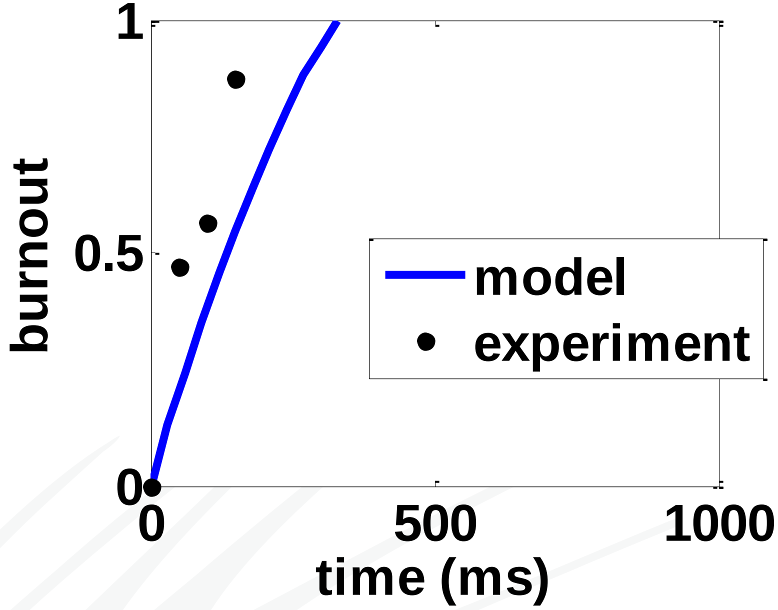
*Oskar Karlström et al.
Combustion and Flame 2011

Model and experimental results

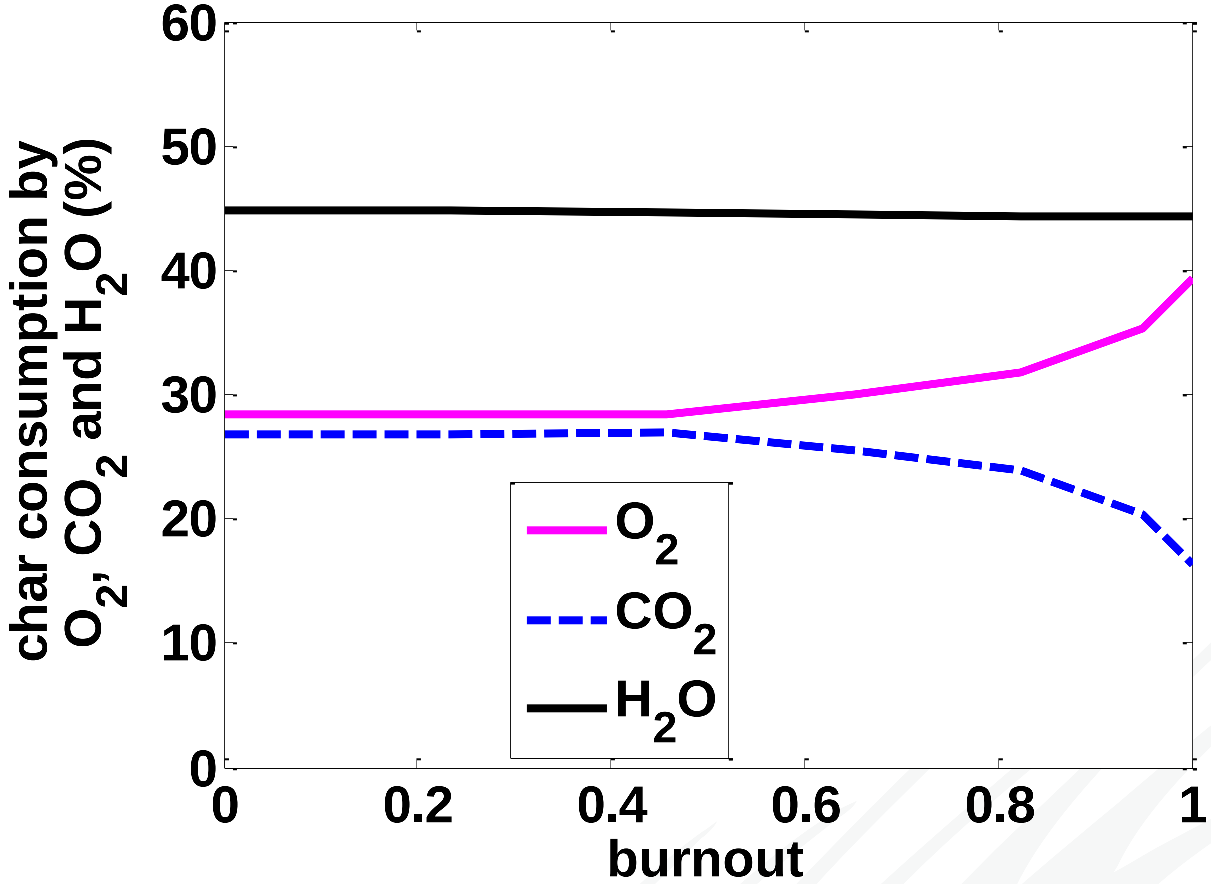
900 °C
4% O_2



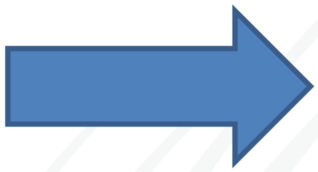
1200 °C
8% O_2



How much of char consumed by O_2, CO_2 and H_2O?



1200 °C
8% O_2
7% CO_2
15% H_2O



Gasification extremely important!!!

Conclusions

- Kinetic parameters are available in BRISK report
- In pf combustion of biomass, more than 60% of the char gasified already at 1200 °C
- Perhaps biomass char reactions with O_2 are unimportant in industrial pf combustion?
- Results to be published (could not be done previously because no suitable model existed)