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Reaction kinetics for biomass self-ignition at 150–230°C

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Replacing coal with pelletized biomass on pulverized-fuel CHP-plants has led to an increased fire risk in storages and processing facilities. Accurate models to predict this behavior are scarce, mainly owing to a lack of reaction kinetic data for low temperatures.

Mill fires in power plants – a case study in self-ignition
Mill fires consume fuel, may damage equipment and cause additional downtime, all detrimental to power plant operation. Fires are likely caused by settled dust beds that start to smolder. Such particle beds can easily accumulate in mills. Experience shows biomass to be more susceptible to spontaneous ignition than coal.

The challenge – reaction kinetic data for low temperature oxidation
Based on experiments, self-ignition is likely caused by thermal runaway of a heterogeneous oxidation reaction of the biomass. Thermal decomposition (pyrolysis) occurs simultaneously at a slightly lower rate.

Highlights:
- Biomass reaction kinetic data for oxidation and pyrolysis were determined at 150–230°C by TGA (top right).
- The data was used in a model combining the two reactions and heat transfer, with the aim of predicting thermal runaway (middle and right).
- The model was validated with lab-scale fixed bed experiments and was accurate within 15 K. (right).
- Production rates of CO and CO₂ could also be predicted, albeit with slightly lower accuracy. (bottom right)

Moving on: further developments
The reaction model (see TGA-data top right) is currently revised. More generalized pyrolysis models exist in the literature, but these are often optimized for temperatures above 200°C.

Relevant range for self-ignition
Pyrolysis conversion kinetics for pine as sum of cellulose, lignin and hemicellulose adapted from Areca-Couce et al., Combustion and Flame 159 (2012) 1708–1719.

Self-ignition (thermal runaway) in a lab-scale experiment and results from modelling this experiment.
The experiment shown was run with 12g samples of pine, ground to 50–200 µm particle size, and heated at 1kW/m² to 225°C (no runaway) and 230°C (runaway), respectively. A constant gas flow of 2.5 L/min with 20% O₂ was maintained (see setup design above). An idealized 1D, time- and space discrete model was programmed to simulate this experiment. Model calculations predict a slightly lower critical temperature for thermal runaway. None of the reaction kinetic or heat transfer modelling parameters were fit to oven experiments.

Data below shows measured and modelled gas release rates of CO and CO₂ from fixed bed experiments under 20% and 0% O₂. Sample sizes 10–40 g (species dependent), heating rate 1kW/m² to 300°C, gas flow 2.5 L/min.