

*Experimental study of self-heating phenomenon at the reactor-scale.
Safety assessment of a fixed-bed filled with torrefied wood chips*

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In order to circumvent the weak fuel properties of raw biomass, pretreatments are commonly applied. For example, the thermochemical process called torrefaction upgrades these weaknesses [1] and helps the large scale development of the biomass-to-energy sector. However, the production scale up of torrefied materials rises hazard and risk issues related to self-heating. Indeed, it can lead to self-ignition if thermal runaway occurs. Self-ignition of torrefied materials has been suspected at the industrial scale [2] and experienced in laboratories. The objective of this paper is to study the self-heating of torrefied wood in a fixed bed reactor and evaluate the influence of the torrefaction severity, the velocity and the oxygen content of the heat transfer fluid.

Self-heatings without thermal runaway were generated by introducing air between 100 and 140°C at 30 NL.min⁻¹. When the anhydrous weight loss of torrefaction (AWL) goes from 10 to 24% the self-heating speed is more than quadrupled. At 140°C, the mildly and severely torrefied packed beds consume 30 and 150 NmL.min⁻¹.kg⁻¹ of oxygen and produce 15 and 30 NmL.min⁻¹.kg⁻¹ of carbon oxides, respectively. Thermal runaway occurs at 160 and 150°C for mildly and severely torrefied packed beds, respectively. During this phenomenon, the self-heating speed, the consumption of oxygen and the production of carbon oxides increase sharply.

The exothermic reaction consumes more oxygen than it produces carbon oxides on a molar basis, which suggests an adsorption mechanism pathway. We bring evidence that the severity of torrefaction enhances self-heating and self-ignition propensity. We suppose that the thermal degradation of crystalline cellulose provides new available sites for oxygen adsorption and steps up the exothermic reaction rate. Surprisingly, the ratio between oxygen consumed and carbon oxides produced rises from 2 to 5 when the torrefaction severity increase. We assume that the oxygen-wood complexes formed are more thermally stable with severely torrefied wood.

1. Koppejan, J., and al, Status overview of torrefaction technologies. IEA Bioenergy Task 32. 2012.
2. Verhoeff, F., J. Kiel, and R. Zwart, ECN's moving bed torrefaction technology in light of desired product qualities. 2012. p. 18–21.

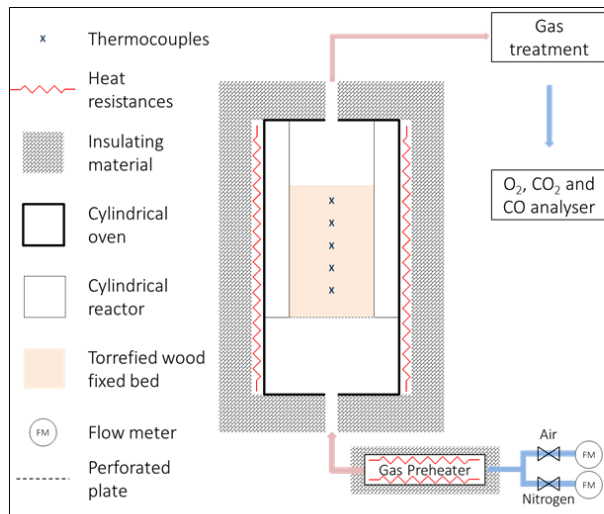


Figure 1a: experimental device sets up to study the self-heating of torrefied wood chips bed crossed by an upward air flow

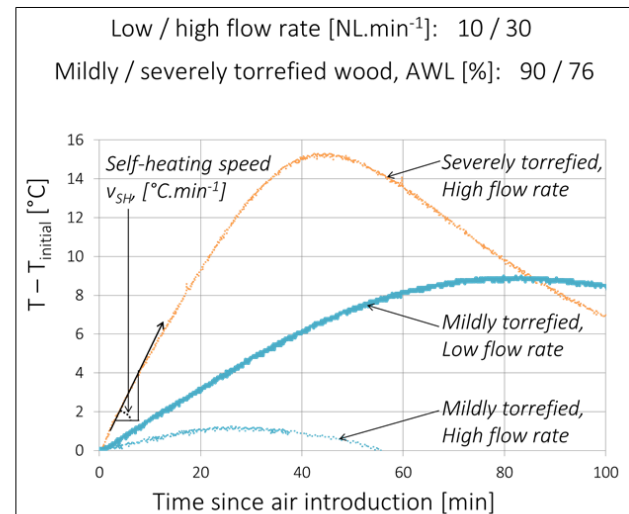


Figure 1b: self-heating generated by the isothermal introduction of air in the reactor at 140 $^{\circ}\text{C}$