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Biomass conversion with a fluidized bed-fired Stirling engine in a micro-scale CHP plant

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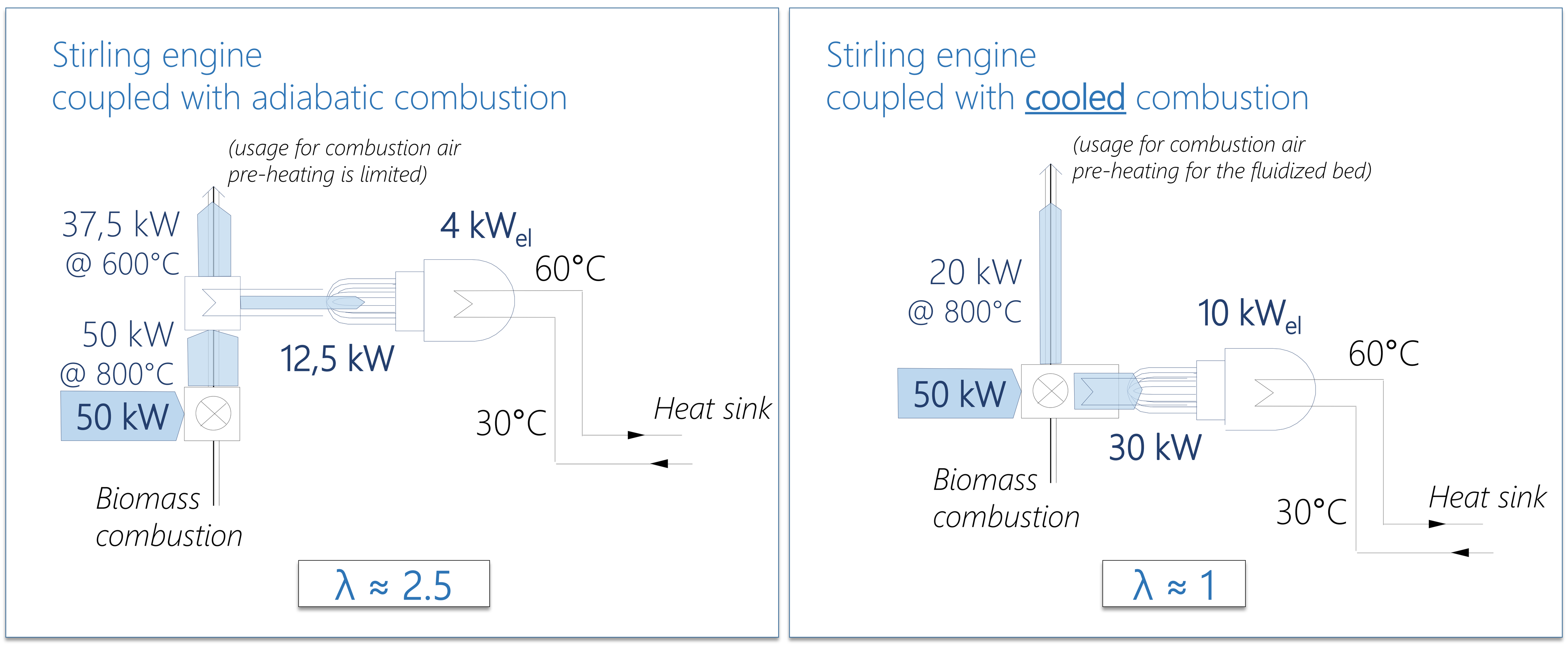

Figure 1: Energy flow charts for a Stirling engine coupled with an adiabatic (left) and a cooled (right) combustion

Micro-CHP with solid biofuels

Up to now, high amounts of solid biofuels and residues are still unexploited for small-scale power generation, since they cause severe problems in conventional grate furnaces. The reason for that is primarily the desired high combustion temperature, which causes slagging and fouling of heat exchanger surfaces.

Concept

To face this issue, the authors suggest an adaption of fluidized bed combustion for mini or micro-scale CHP concepts. In this way, an efficient cooling of the combustion zone through an in-bed heat exchanger (e.g. a Stirling engine) gets possible without exceeding ash melting temperatures. This goes along with another main advantage – namely the fuel flexibility of fluidized bed combustion (see Figure 1).

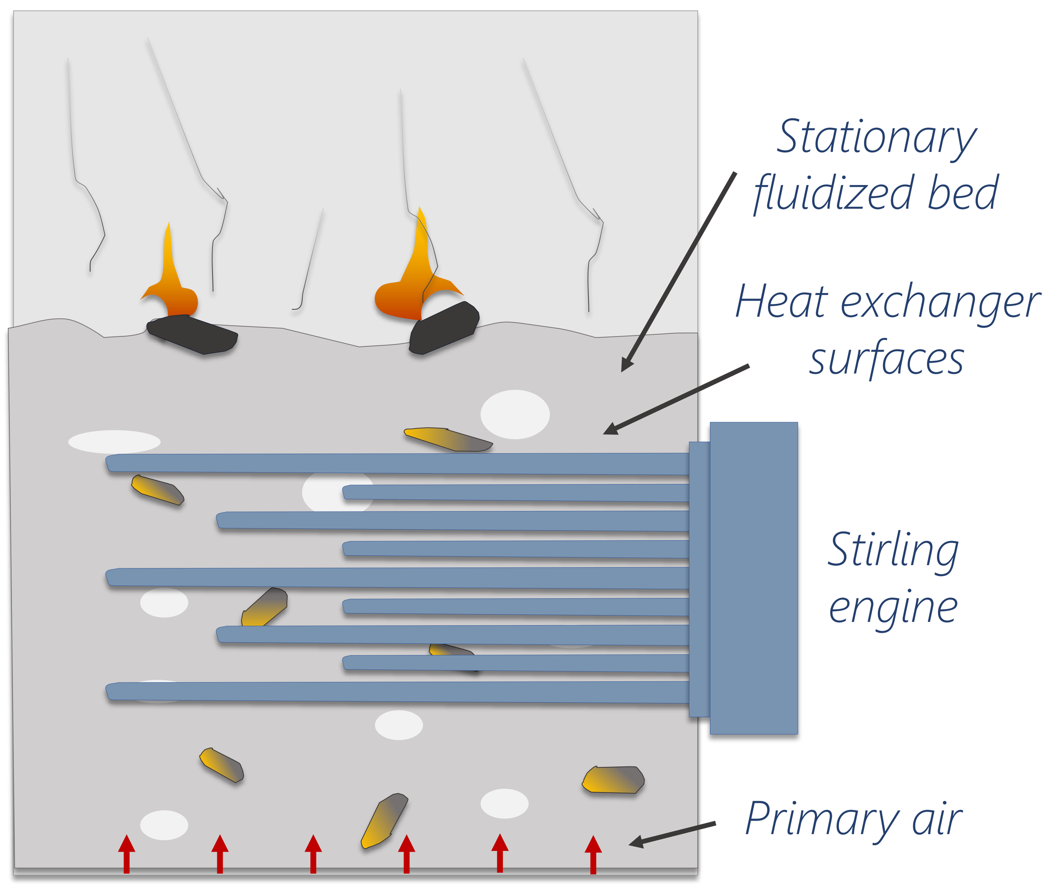

Figure 2: Scheme for integrating the Stirling engine as an in-bed heat exchanger for fluidized bed combustion

Results from lab tests

For lab-scale experiments a 30 kW_{th} fluidized bed combustion chamber with an integrated 3 kW_{el} Sunmachine Stirling engine was developed at the Chair of Energy Process Engineering, Friedrich-Alexander University Erlangen-Nürnberg (concept see Figure 2) during the last years. For efficient particle separation of entrained bed material and ash, it features an integrated horizontal cyclone.

First tests with wood pellets resulted in electric efficiencies of about 10 %. Furthermore, the measured carbon-monoxide and dust emissions were significantly low and met easily the limits according to 1. German Federal Emission Protection Directive (1. BImSchV, see Figure 3)

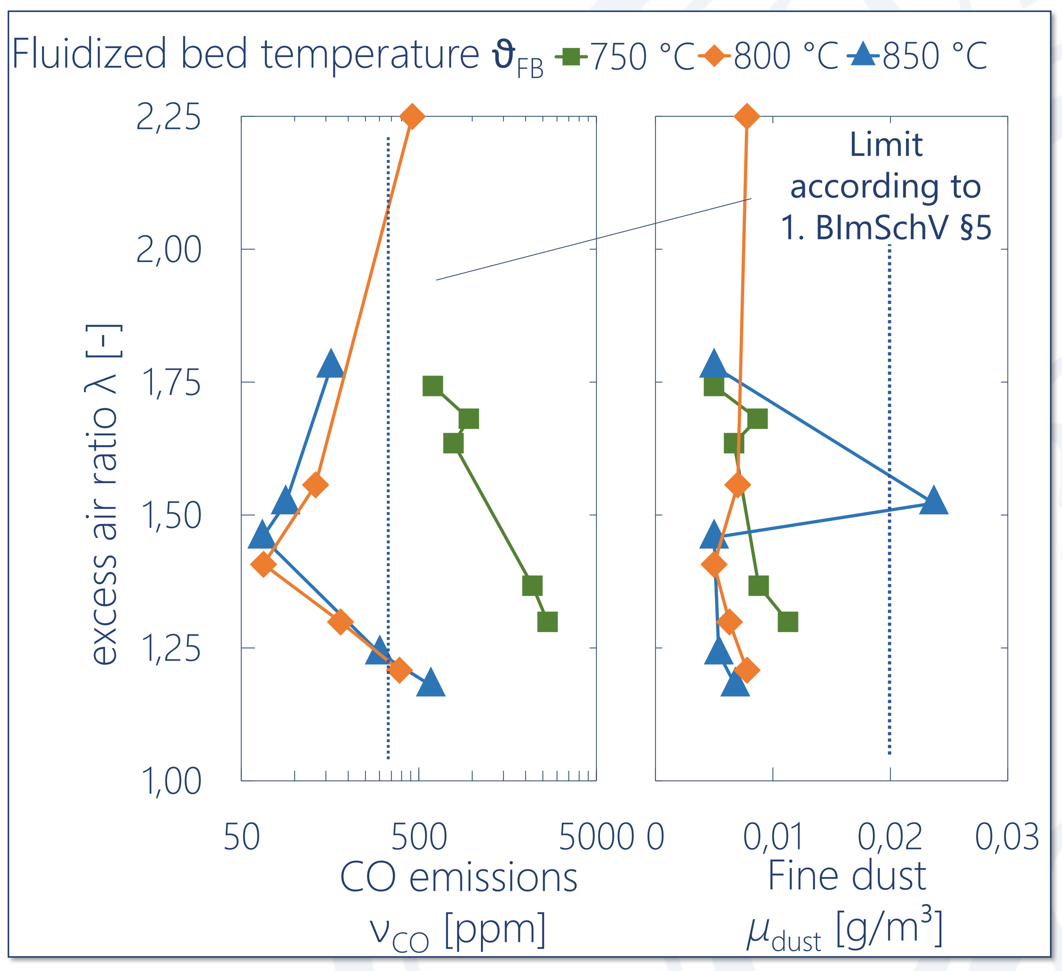

Figure 3: CO and fine dust emissions as a function of the bed temperature and the fuel-to-air ratio λ (wood pellets, fuel input: 15 kW_{th})

Project "BioWasteStirling"

Based on these results, the objective of the recently started project "BioWasteStirling" is the development and field testing of this highly efficient, fuel-flexible pilot CHP-system. For this purpose, EVT will provide a similar designed 45 kW_{th} fluidized bed combustion chamber which will be linked to a 5 kW_{el} Stirling engine prototype by Frauscher Thermal Motors (see Figure 4).

Afterwards, SWW Wunsiedel as an operator of different bioenergy plants will install this pilot plant in one of their production sites for long-term tests. They will focus on the operation performance during tests with different woody biomass and further challenging biogenic residues, like for example hay or straw pellets.

Figure 4: Setup of the pilot plant with a 45 kW_{th} fluidized bed combustion, horizontal cyclone and a 5 kW_{el} Stirling engine (illustration without Stirling engine, instrumentation and insulation)

Additionally, dedicated experiments concerning the erosion behaviour of the heat exchanger surfaces in the fluidized bed depending on bed material and material design will follow. Previous operation and simulations did not identify any exposed areas, however an appropriate material selection will be mandatory.

Moreover, CFD simulations and associated experiments should serve to postulate a general design specification for the particle separation in a horizontal cyclone.

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