Fluidized Bed Biomass Combustion Combined with Organic Rankine Cycle for Small-scale CHP

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Combined heat and power (CHP) is an interesting application in which low-grade waste heat from combustion can be used to drive a turbine to produce electrical power. The use of biomass, e.g. from waste or demolition wood, for power generation has large potential to mitigate CO_2 by replacing conventional fossil sources. Unfortunately the low operating temperatures of combustion have limited its use and efficiencies.

A simple model was developed in which combustion of biomass (i.e. demolition wood) in a 1.1 MW_{th} bubbling fluidized bed (BFB) is combined with an Organic Rankine Cycle (ORC) of 800 kW_{th} operating on toluene. A boiler efficiency of 84% and a total system efficiency of 10.2% is to be expected.

Design parameters

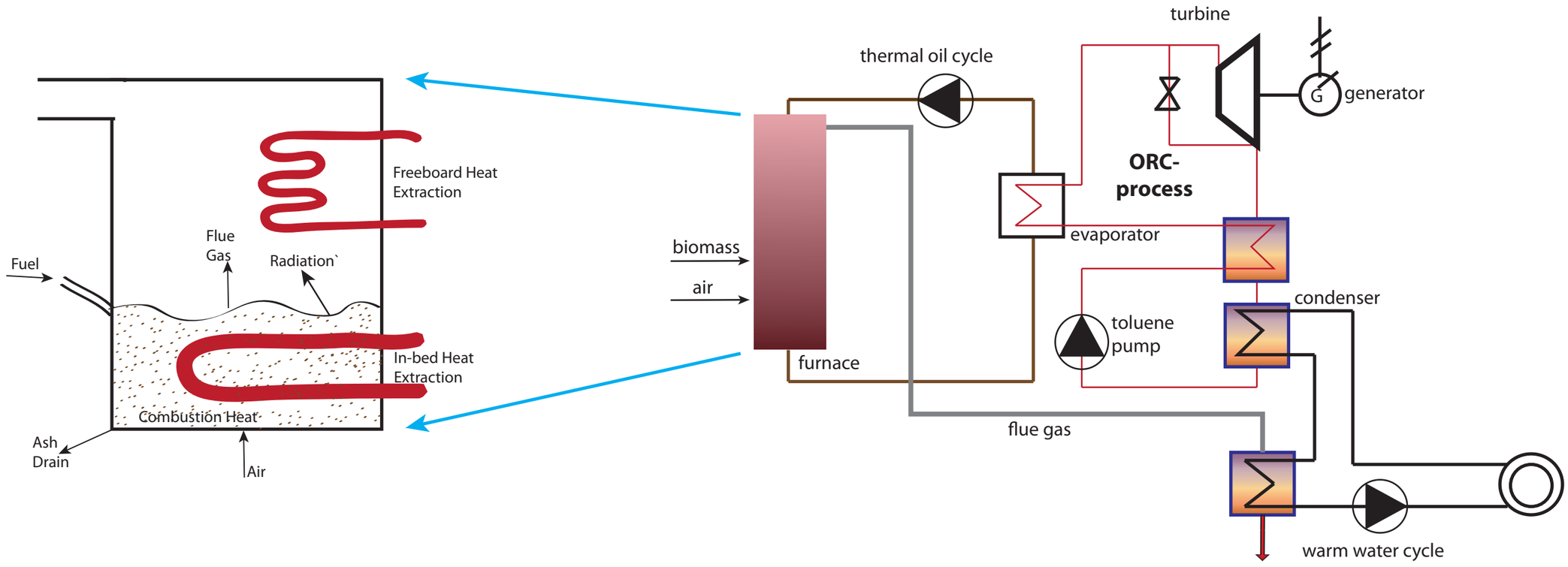
CRONE BFB (Bubbling Fluidized Bed Reactor)
- 1,1 MW thermal input
- Bed Operating Temp. 850 °C
- Square combustor 1,1m2
- Air at 20% excess

ORC electrical cycle
- 800 kW - thermal

Heat Transfer via Heat exchangers
- In bed
- Freeboard temperature max 350 °C

Advantages of ORC

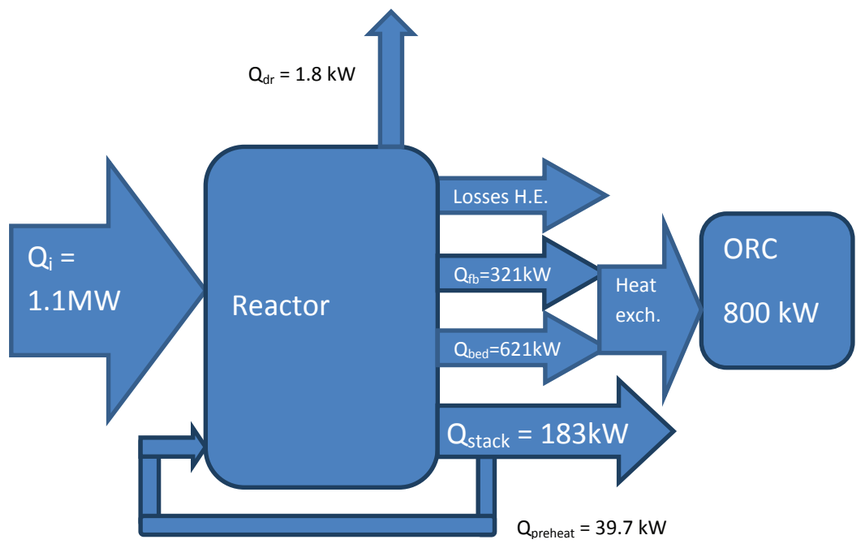
- Applicable to small systems with relatively low energy flows
- Possibility of using lower temperatures, including waste heat recovery and biomass combustion
- Low temperatures inhibit NOx production
- Toluene as ORC fluid has low global warming potential



Main Operation Assumptions

- Demolition wood used
- No sorbents (limestone or others)
- Perfectly insulated system
- No fly ash
- The biomass reacts fully in the bed
- Atmospheric pressure
- 20% excess air for combustion
- Heat Exchanger system efficiency is 85%
- ORC system efficiency 14% [1]

Optimized heat flows



Boiler Thermal Efficiency 80.7%

Using flue gas for air preheat: 84%

Complete system efficiency: 10.2%

Operation Parameters

Flow rates
Flow rate of fuel = 0.063 kg/s
Flow rate of air = 0.45 kg/s
Mass flue gas/mass fuel = 7.93
Flow rate of thermal oil = 0.91 kg/s

Heat exchanger area:
Area at bed = 3.3 m2
Area at freeboard = 53.4 m2

Heat Balance
Qin = 1,1 MW + 0,05MW (Fuel and Air)
Qh = 941 kW(to ORC heat exchangers)
580KW at bed
361KW at Freeboard
Qstack = 183 kW (possible use for preheating of air, needed 65.9KW)

Air Inlet Temperature:
Ti=133 °C for 85% heat exchanger system efficiency
Design consideration to optimize ORC cycle to 800 kW

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[1] Desai, N.B., Bandyopadhyay, S. *Process integration of organic Rankine cycle* (2009) Energy 34

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