High temperature ceramic heat exchanger for heat recovery in coal and biomass gasification processes

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Chair of Combustion, Heat- and Mass Transfer

Field of Research

Today, feedstock in organic chemistry is mainly made from petroleum. The production of base chemicals out of coal for mid-term and out of biomass for long-term regard can partly substitute the worldwide high consumption of petroleum resources. High temperature gasification processes as the Winkler-process[1] are appropriate for an efficient conversion of coal or biomass into a raw gas. Afterwards this is synthesized into base chemicals (e.g. olefins, methanol, dimethyl ether, ammoniac). Several syntheses processes (e.g. Fischer-Tropsch-, DME-, and Methanol-syntheses) run at a temperature level of 300 °C whereas the raw gas leaves the gasifier at over 900 °C. Therefore a new waste heat concept has been developed to use this energy and to optimize the overall process.

Results

The waste heat concept to increase the process efficiency within the XtL-process[1] consists of a ceramic high temperature heat exchanger, an indirectly heated gas turbine and a heat recovery boiler.

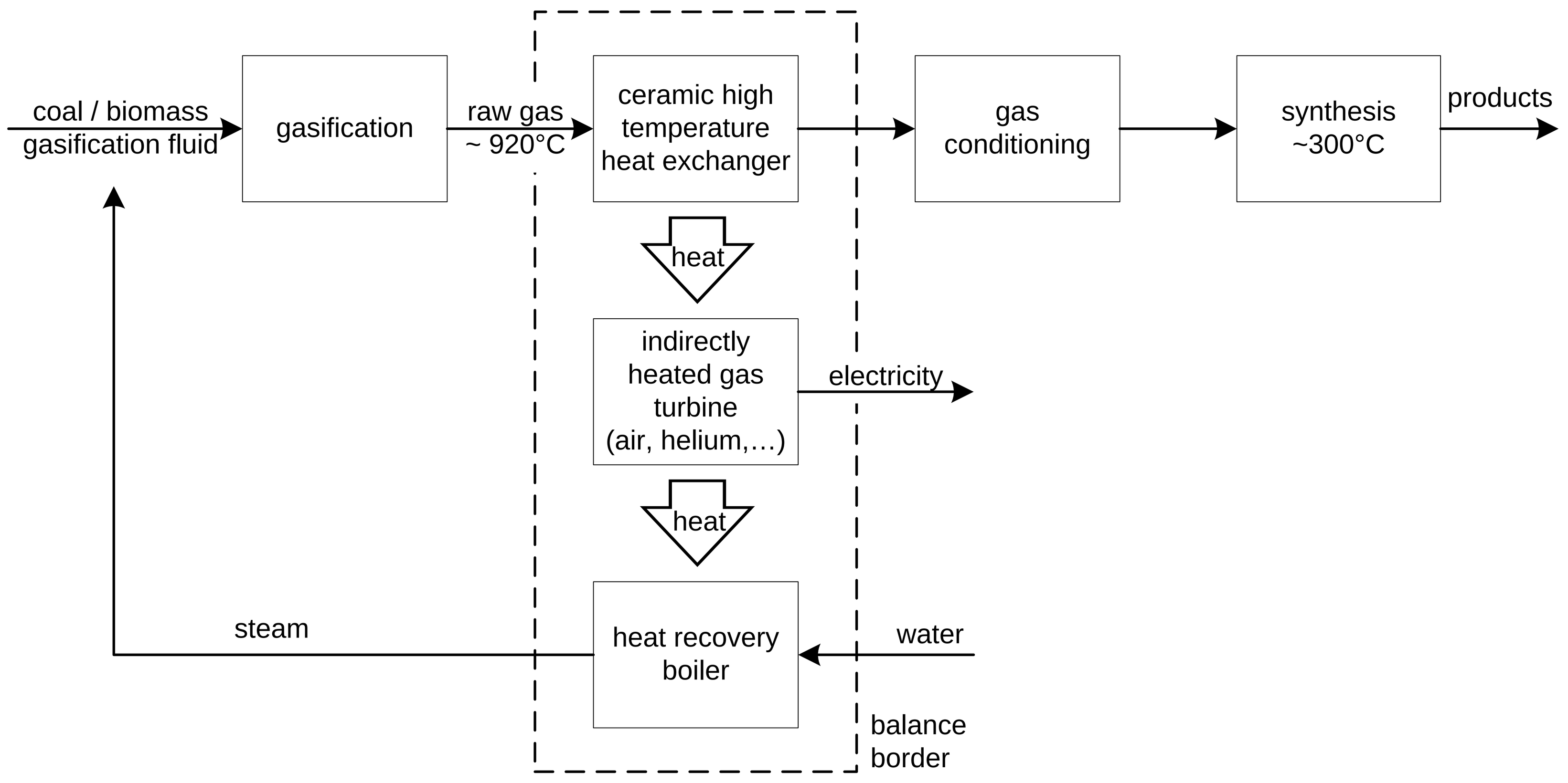

Fig. 1: Concept of waste heat recovery to improve the process for the material use of coal/biomass (applied for a patent).

The results of mass and energy balances show a potential of up to 9,6MW additional technical power with an integrated open gas turbine cycle which is indirectly heated. Besides, the defined models provide the total amount of steam needed to run the gasifier. Thereby the gasification fluid (steam) uses the waste heat of the gas turbine process within the gasification process.

		Model 1	Model 2a	Model 2b
		Open GT (air)	Closed GT (air)	Closed GT (helium)
π (pressure ratio)	–	6,7	4,7	2,7
P_{GT} (net gas turbine power)	MW	9,6	8,1	7,6
η_{GT} (gas turbine)	%	20,9	17,6	16,5
Mass flow working fluid	kg/s	65,3	64,2	13,8
Mass flow steam	kg/s	11,9	14,0	14,2
Ratio of steam generation	%	100	117,6	119,1
η_{GB} (point balance)	%	91,1	100[2]	100[2]
Power of steam generation (net)	MW	33,4	39,2	39,7
Total power	MW	43,0	47,3	47,3

Table 1: simulation results for different models of the waste heat concept.

Methods

The two following schemes of the investigated models show the best results for the waste heat concept:

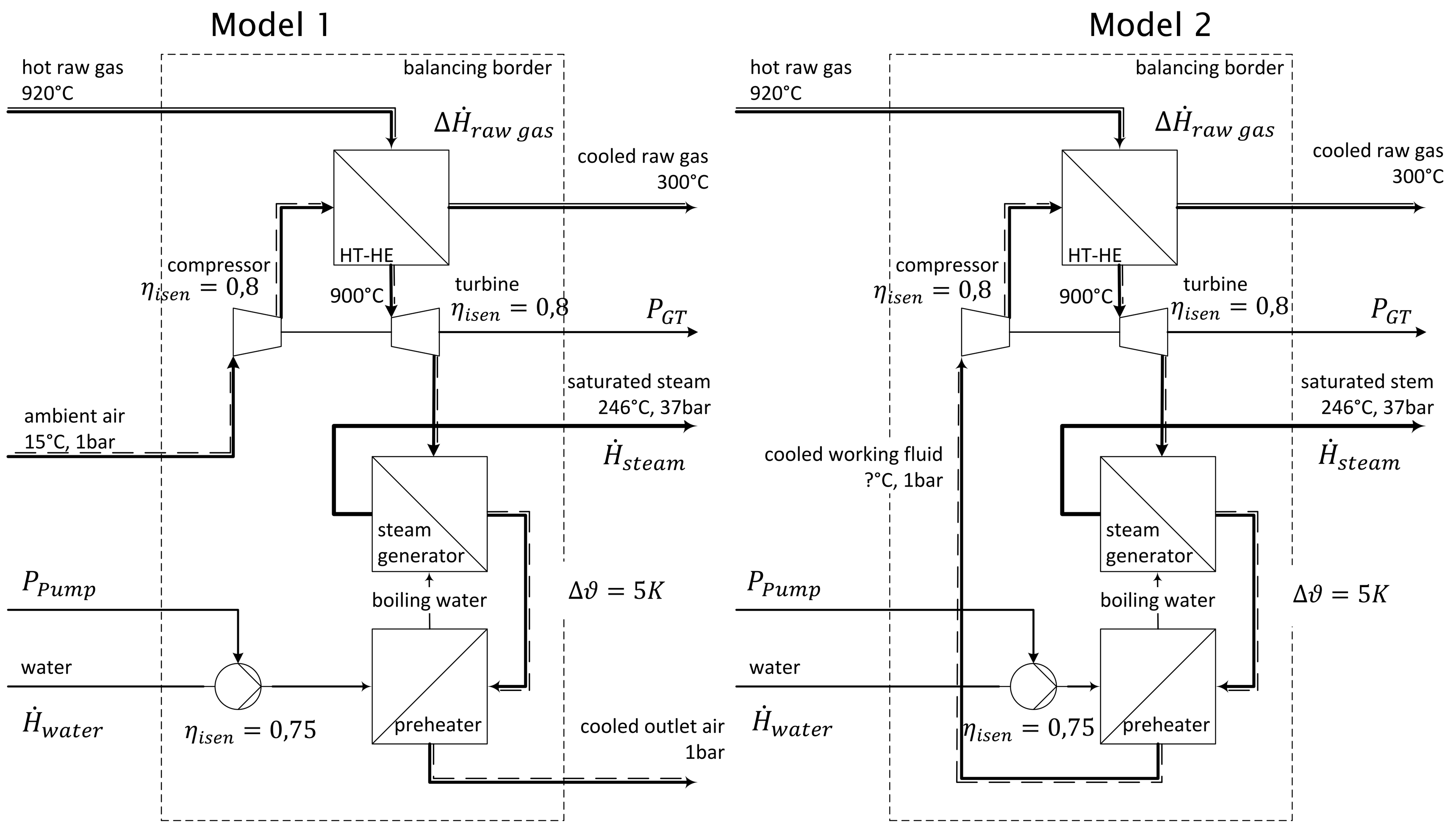

Fig. 2: Model 1 (open) and model 2 (closed gas turbine cycle) with steam generation as gasification fluid and the boundary conditions.

To realize such waste heat concepts, an innovative high temperature heat exchanger, resistant to corrosion, is needed. The approach of research therefore is based on ceramic heat pipes:

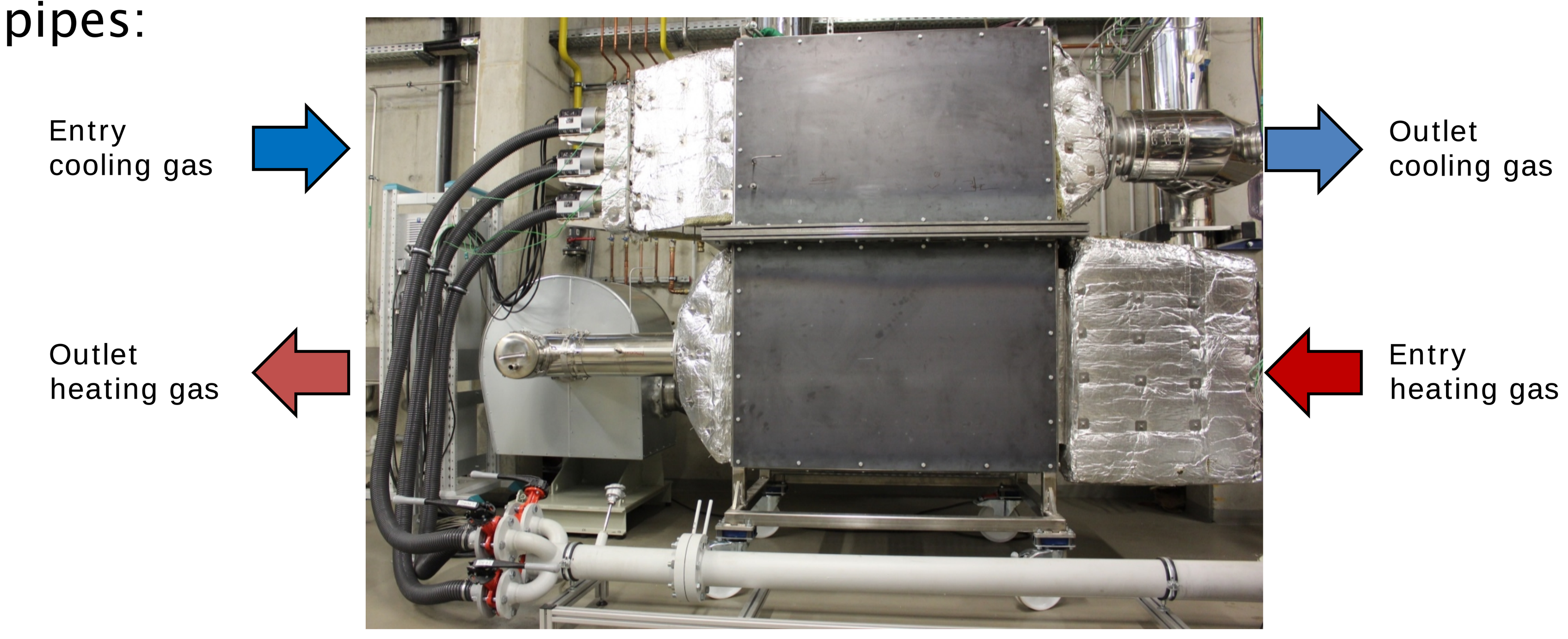

Fig. 3: Demonstration plant of a high temperature heat exchanger with ceramic heat pipes

Perspective

The simulation results show the high potential of the waste heat concept. For the implementation of this concept, a heat exchanger technology is needed, which is resistant to temperatures over 900 °C and to the highly corrosive atmosphere of the raw gas containing alkaline components especially by using biomass. High durability under these conditions can be performed by a heat pipe heat exchanger made of SiC, which has been recently built as a test rig at the TU Dresden. For this, geometrically simple ceramic heat pipes with regard to the manufacturing process have been developed. Sodium and zinc are adaptable as working fluids for the intended temperature range. After several tests of single heat pipes, they will be used to validate a mathematical model of the heat pipe heat exchanger performance.

[1] p. 411 ff. in: Schmalfeld, Jörg: Die Veredlung und Umwandlung von Kohle; Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle e.V., Hamburg 2008.

1 XtL: includes different processes to synthesize liquid fuels out of different feed stock: GtL (Gas to Liquid), CtL (Coal to Liquid) and BtL (Biomass to Liquid)

2 The point balance for Model 2a and 2b has to have100% efficiency due to the closed gas turbine and without considering energy losses to the environment. In that case no energy is lost to the environment. So that value is calculated to check the balancing.