Design of a compact heat exchange system for a SOFC

GM Bachelor 6

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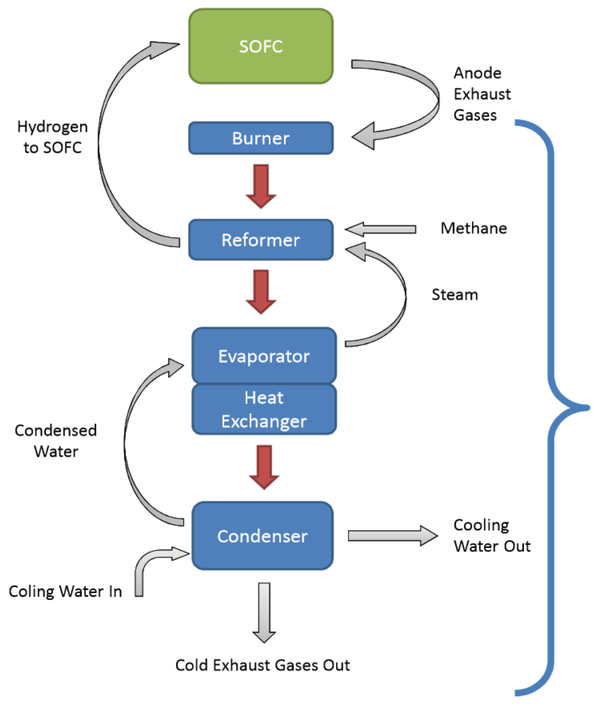
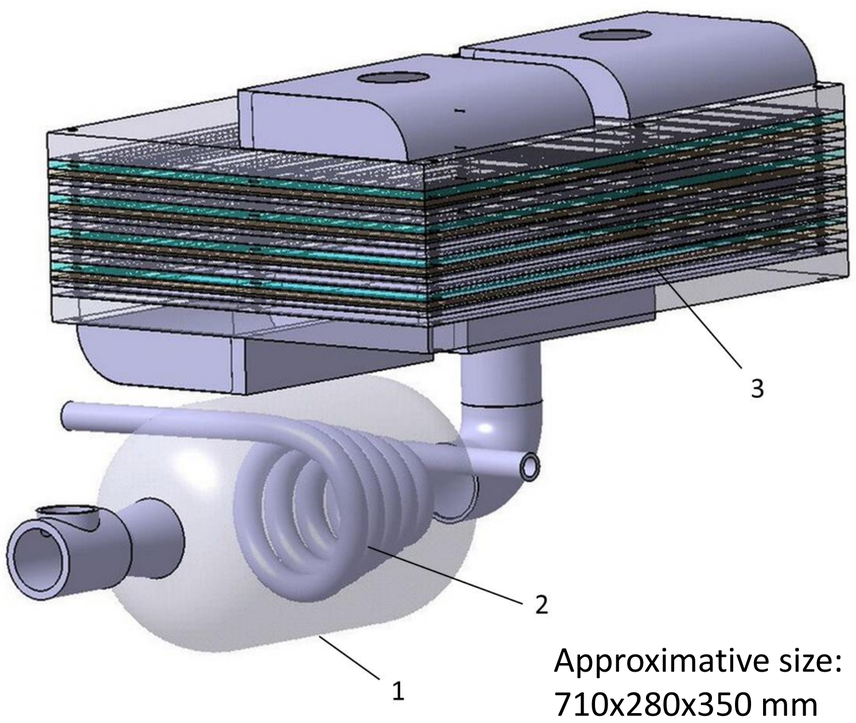
Project goal

design the most compact workable heat recirculation for solid oxyde fuel cell (SOFC)

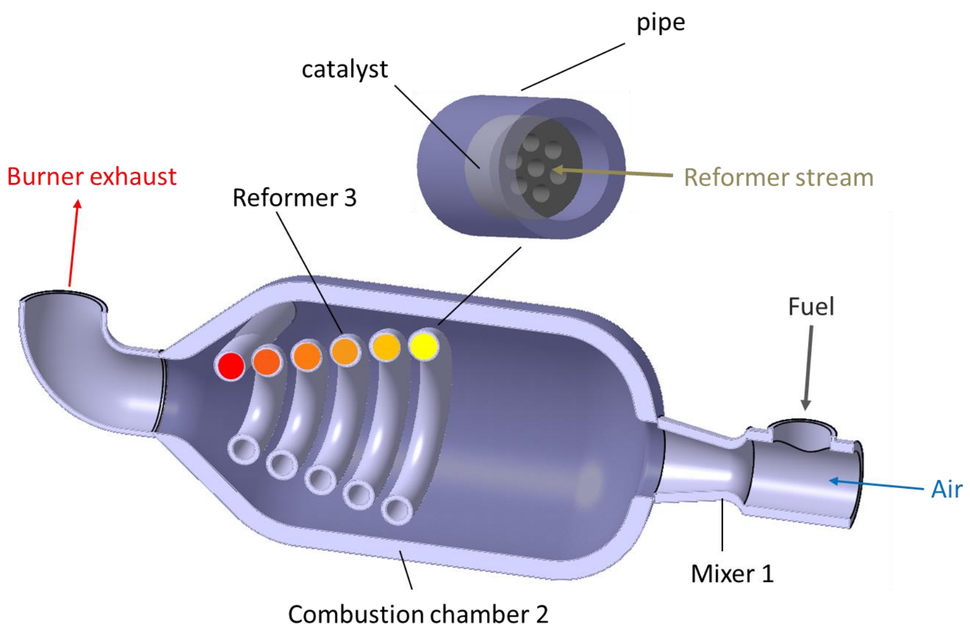


Design



Approximative size:
710x280x350 mm
Material: Stainless Steel

1. Burner



Complete combustion of the exhaust from the fuel cell
Inlet temperature : 487°C
Inlet molar composition : 1,3% CO 6,3% H_2
Outlet molar composition : 0% CO 0% H_2
Outlet temperature : 991°C
Debit : 0,00435 kg/s

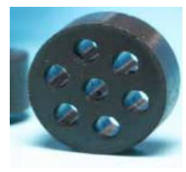
$$CO + \frac{1}{2}O_2 \rightarrow CO_2$$
$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

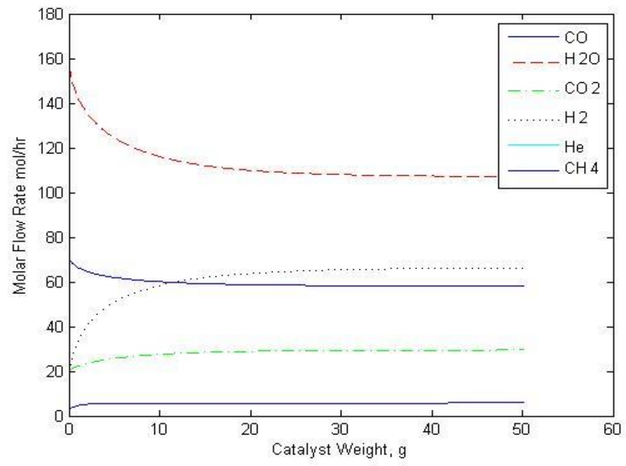
2. Reformer

$$CH_4 + H_2O \rightleftharpoons CO + 3\,H_2$$
$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

Methane reforming for the fuell cell anode
Transfromation : Natural gas and carbon monoxyd → Hydrogen
Catalyst : RKNGR (Nickel alloy)
Inlet temperature : 370°C
Inlet molar composition : 26,8% CH_4 (72,7mol/h) 4,14% H_2 (11,2 mol/h)
Outlet molar composition : 19,4% CH_4 (56,7mol/h) 23% H_2 (66,9 mol/h)
Outlet temperature : 460°C
Debit : 0,0014 kg/s
Power requierd : 1,03 kW
Catalyst weight requiered : 25g

Simulation
T= 460°C
P=100'000 Pa





3. Heat Exchanger

Evaporation

Evaporate a water stream
Inlet temperature : 50°C
Inlet vapor fraction : 0
Outlet vapor fraction : 1
Outlet temperature : 496°C
Debit : 0,00135 kg/s
Power requiered : 4,41 kW

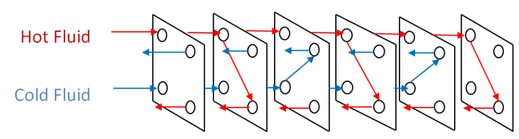
Heating

Heat up a water stream
Inlet temperature : 20°C
Outlet temperature : 50°C
Debit : 0,0004 kg/s
Power requierd : 1 kW

Cooling down

Cool down the burner exhaust and condensate the steam in it
Inlet temperature : 991°C
Outlet temperature : 50°C
Debit : 0,00435 kg/s
Power freed : 8,3 kW

Plate Heat Exchanger Theory

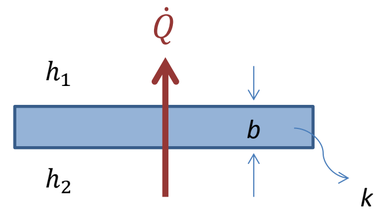


Logarithmic Mean Temperature Difference method (*LMTD)* :

$$\dot{Q} = U * A * LMTD$$

Overall Heat Transfer Coefficient U :

$$U = \frac{1}{\frac{1}{h_1} + \frac{b}{k} + \frac{1}{h_2}}$$

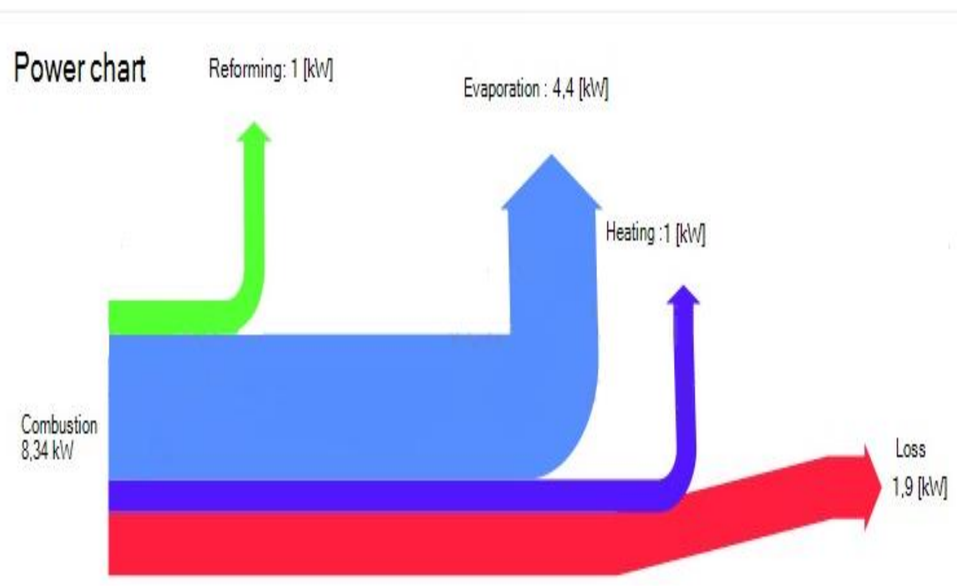


b : thickness of the plate
k: heat diffusion coefficient of the solid
$h_{1,2}$: plate-fluid convection coefficients
Convection coefficients were estimated using the empirical relation: $Nu = \frac{h*de}{k_{fluid}} = a * Re^b * Pr^c$

$$h = \frac{k_{fluid} * a * Re^b * Pr^c}{de}$$

de: equivalent channel diameter
a,b,c: empirical constants
Re, Pr and *Nu* are dimensionless numbers.
Design goal: maximise *U* by reducing the plate thickness *b* and maximise $h_{1,2}$.
Chosen optimal design: Plated Heat Exchangers

Power requirments



- Power chart shows operating power distribution
- Operating efficiency 77%

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