Hydrogen Production by Solar Reforming of Natural Gas – Reactor Modelling

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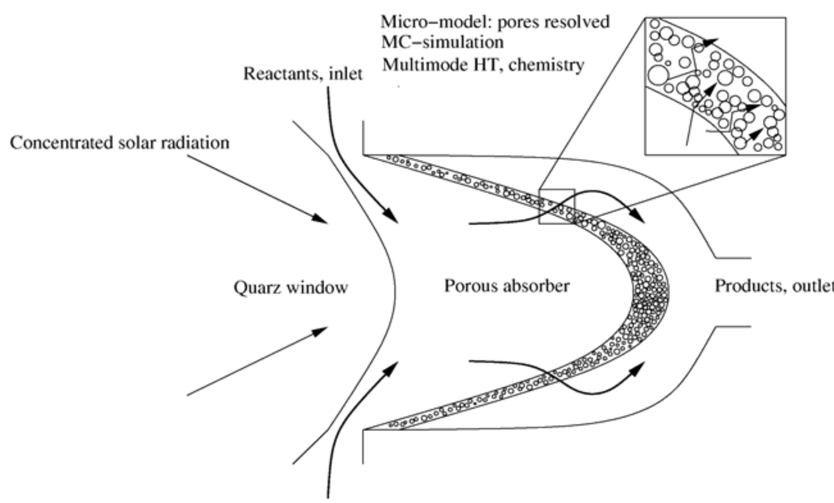
Solar-thermal steam and dry reforming of methane and consecutive energy transformation processes are investigated. The net reactions can be represented by:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

$$CH_4 + CO_2 \rightarrow 2CO + 2H_2$$

Both reactions can be used in closed-cycle processes (solar thermochemical heat-pipe) as well as in open-cycles. In the former approach, the exothermic reverse reactions are applied to generate high-temperature heat without greenhouse gas emissions to the atmosphere, whereas the latter approach produces solar-upgraded fossil fuels with 24% emission avoidance.
The above reactions are carried out in a solar reactor that features a directly-irradiated catalytic porous absorber (see adjacent Figure). The process involves heterogeneous - gas-phase on catalytic surface - chemical reacting flows with multi-mode heat transfer.



Scheme of solar reactor configuration

The process is studied on different scales: system, reactor, and pore-scale.
At the system level, a thermodynamic analysis is performed. The chemical equilibrium composition of the system is computed over a wide range of temperatures and pressures. The preferable operating conditions are 1373 K and 10 bars. A 2nd-Law analysis is carried out for calculating maximum exergy efficiencies and for identifying irreversibility sources.
At the reactor level, volume averaged pore-scale models is used to study the energy and mass transport processes inside the porous medium.
Finally, at the pore-scale level, the mass, momentum, and energy conservation equations with coupling to chemical kinetics are formulated and solved numerically. Emphasis will be given to the fundamental aspects of radiation heat transfer within a reacting flow through a porous medium.