Heat and mass transfer modeling for an irradiated suspension of reacting particles: application to petcoke gasification

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The steam-gasification of petroleum coke using concentrated solar radiation as the source of high-temperature process heat is proposed as a viable transition path to solar hydrogen production. The advantages are three-fold: 1) the calorific value of the feedstock is upgraded; 2) the gaseous products are not contaminated by the byproducts of combustion; and 3) the discharge of pollutants to the environment is avoided.

In order to support the engineering design and predict the performance of high-temperature steam-gasification reactors that operate with a particle cloud, theoretical models are developed and implemented. Monte-Carlo and radiosity methods for treating radiation heat transfer in participating media; CFD for convection/conduction heat transfer and fluid mechanics are applied.

Thermal radiative transport coupled to the reaction kinetics is analyzed for heterogeneous chemical systems in which their optical properties, species composition, and phases vary as the chemical reaction progresses. Of special interest is the transient radiative exchange within particle/gas suspensions, featuring absorbing-emitting- scattering medium. The simulation includes a model with the following characteristics:

- polydisperse media
- non-isothermal
- non-grey (wavelength dependent radiation)
- non-diffuse (direction dependent radiation)
- shrinking particle (kinetics from experimental studies)

Results are presented for the 5kW prototype reactor for the gasification of carbonaceous product. Experiments are run with three different types of feedstock. Dry powder as well as a powder-water mixture (slurry) of petroleum delayed coke are gasified. In addition a coke vacuum residue liquid at temperatures above 120 °C is employed.

Scaleup studies are performed for a reactor at a power level of 350 kW. Ideal reactor geometry, feedstock type and feeding rates are determined for both configurations. General considerations aimed to support future engineering design are drawn from the in-detail analysis of these optimal operational conditions.