Optimization of high temperature volumetric solar absorber made of silicon carbide ceramic foam

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Nowadays, development of electro-solar power plant is progressing rapidly. Increasing "solar-to-thermal" efficiency is the key step to become more competitive in front of current dominant power plant. In this context, the OPTISOL project (from the ANR-SEED* program), aims to design new kinds of solar receivers: high temperature volumetric solar absorbers with controlled radiative properties made of silicon carbide (SiC) reticulate porous ceramic (RPC). The thesis purpose is the numerical optimization of radiative properties for the volumetric solar absorber considered, aiming to reach high solar-to-thermal efficiency for high fluid temperature.

Focusing on radiative properties (absorption coefficient, scattering coefficient, scattering phase-function) of these materials (SiC RPC), several predictive models are compared to spectral transmittance and reflectance measurements (bi-directional and directional-hemispherical) in the aim of determining new correlations based on ceramic foam characteristics (struts/pores size and porosity).

A mono-dimensional modelling is developed to solve Navier-stokes equations (conservation of mass and momentum) and energy equations (coupled heat transfers) inside the absorber, involving the equivalent homogenous medium hypothesis. Several radiative models are tested to approximate the radiative transfer equation (Rosseland, P-1 model, and two-flux approximation), and computed radiative source terms are compared to reference results obtained with Monte-Carlo algorithm using net-exchange formulation. Then, coupled flow-energy-radiation models considering radiative approximations (including MC) are solved and compared.

* ANR-SEED: this is a program focused on Decarbonised and Efficient Energetic Systems (SEED) from the National Agency for Research (ANR) in France.

Keywords: volumetric solar absorber, concentrated solar power (CSP), porous medium, reticulate porous ceramic (RPC), ceramic foam, silicon carbide (SiC), Navier-Stokes equations, flow modelling, pressure drop, Darcy-Forchheimer law, coupled heat transfers, conduction, convection, radiation, Rosseland, P-1 model, two-flux approximation, Monte-Carlo.