HIGH SOLAR FLUX HEATING OF UPFLOW BUBBLING FLUIDIZED BED CIRCULATING IN OPAQUE VERTICAL TUBE - 3D NUMERICAL SIMULATION

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Current solar Heat Transfer Fluids (HTF) have a limited working temperature (< 600 °C) and present operational risks. We proposed to use air-fluidized Dense Particle Suspensions (DPS), also called Upflow Bubbling Fluidized Bed (UBFB), in tubes as a new HTF and storage medium in the frame of the so-called CSP2 FP7 European project (http://www.csp2-project.eu/). UBFB can operate up to the solid sintering temperature, thus improving the plant efficiency, it has no lower temperature limitation and is riskless. The DPS capacity to extract heat from a tube absorber exposed to concentrated solar radiation was demonstrated on a single-tube experimental receiver that was tested at the focus of the CNRS 1 MW solar furnace in Odeillo. The DPS flowed upward through the absorber tube (i.d. 3.6 cm) that passed through a 50 cm high cavity where it was exposed to concentrated solar flux that heated the DPS. The tube wall-to-DPS Heat Transfer Coefficient (HTC) first values were calculated by Flamant et al. (1). A stable outlet temperature of 750 °C was reached with a metallic tube and a particle reflux in the near tube wall region was evidenced by Benoit et al. (2).

In this paper, the UBFB behavior is studied using the multiphase flow code NEPTUNE_CFD (3). Hydrodynamics of SiC Geldart A-type particles (40 µm Sauter diameter) and heat transfer imposed by a thermal flux at the wall are coupled in 3D numerical simulations. The convective/diffusive heat transfer between the gas and dispersed phase, and the inter-particle radiative transfer (Rosseland approximation) are accounted for. The numerical and experimental results are compared in order to validate the model. The heat exchange between the particles close to the tube wall and those in the tube center is characterized.

Three cases were simulated that corresponded to experimental cases. Figures 1 and 2 show vertical cross-sectional views of the tube in the middle of the irradiated cavity colored by the particle volume fraction $\alpha_p$ and by the DPS temperature, respectively, both averaged over 150 s, for a high solid mass flux case (45 kg/m².s). $\alpha_p$ is higher close to the wall (0.36) than in the central zone (0.25) where bubbles with almost no particles pass. The temperature is higher close to the wall where the DPS receives a heat flux. In the lower part, the temperature radial gradient is greater due to the recirculation: particles that were heated in the higher part are going downward close to the wall while particles that just entered the heated zone are going up in the center.
Figure 1: Vertical cross-sectional view of the tube colored by the particle volume fraction $\alpha_p$, in the middle of the irradiated cavity.

Figure 2: Vertical cross-sectional view of the tube colored by the DPS temperature, in the middle of the irradiated cavity.

REFERENCES