SOLSTICE	Name of the PhD: **Ronny GUEGUEN** Title of the PhD thesis: **Flow and Heat Transfer in Fluidized Beds Tubular Solar Receivers** Dates (start/end): 01-2020 – 31.2022
Supervisors	(Name and institution): Françoise BATAILLE, Gilles Flamant, Samuel MER – PROMES (CNRS)

Context and objectives

The thesis is part of a research program developed in the PROMES (CNRS) laboratory since 2011. The main idea of the program is to use fluidized particles as heat transfer fluid in a tubular solar receiver of a solar power plant, in order to reach higher exit temperature than the temperatures reached with molten salt (limited at 565°C). Thus, it allows using high efficiency conversion cycles and then increasing the global efficiency of the plant. The objective of the thesis is to characterize the flow and the heat transfer in such a solar receiver.

Approach

The work is organized in three main parts:
i) An experimental study of the gas-particle upward flow at ambient temperature. A one-tube mock-up has been built at the laboratory. Composed of a glass tubes, it is instrumented with pressure sensors along the tube height. Several methods of analyses of the pressure signal are used to characterize the structure of the flow.
ii) A similar mock-up has been built with a metallic (Inconel) tube in order to be heated by concentrated solar power. Instrumented with pressure sensors and with thermocouples, the objective is to study the influence of temperature on the gas-particle flows structure, in particular on the fluidization regimes, their transitions, and the associated heat transfers.
iii) Preliminary estimations show that a solar receiver with a power of 50 MW_{th} is feasible. On this basis, the objective is to develop a model of a solar receiver at commercial scale, with a varying geometry in order to reach thermal efficiencies of around 85% and more.

Main results

i) Experiments have been conducted. The superficial air velocity in the tube varies between 0.1 and 0.65 m/s and the particle mass flux varies up to 122 kg/m²s (i.e. around 700 kg/h). Several fluidization regimes have been observed and characterized. The particle volume fraction is decreasing with the increase of the air velocity independently of the fluidization regime (from 0.34 to 0.19 without particle circulation in the range of the air velocities tested). Furthermore, for a given air velocity, the particle volume fraction increase with the increase of the particle flow rate because of supplementary pressure drops. Then, for a given air velocity, the circulation ignition might induce a change of the fluidization regime. The fluidization regimes have been identified and characterized by analyses of the relative temporal pressure signals using several methods. These methods are the cross-correlation (in the temporal domain), the incoherence analysis (in the frequency domain), the direct analysis of the relative pressure fluctuations, and the evolution of the particle volume fraction. Due to the tank capacity, the acquisition time is limited. It limits the accuracy of the methods of analysis and the use of one single method may be insufficient. However, the combination of all the methods results in the improvement of the sensitivity of the identification process. Several configurations of the fluidization regimes have been identified, with transitions between regimes due to the coalescence along the tube height and depending on the air velocity. These transitions are regrouped in Figure 1.

ii) The mock-up is now built but not yet placed in the focus of the solar furnace.

iii) A simplified thermal model of a solar receiver at commercial scale has been set-up in order to determine the influence of the geometry (of the absorber and the cavity) on the thermal efficiency. A total number of 360 tubes has been estimated to correspond to the desired power of 50 MW_{th}. The effect of the active (tubes) and passive (cavity) surfaces has been studied and discussed, with considering a homogeneous incident solar flux of 400 kW/m². Only from a thermal point a view, i.e. without the integration of the heliostat field, it results that the geometrical parameters that mainly govern the thermal efficiency of the receiver are the area of the aperture of the cavity and the distance between the aperture and the absorber's tubes. Realistic ranges of the geometrical parameters have been concluded. Future works will integrate an incident non-homogeneous solar flux distribution to the absorber, and a coupling with a heliostats field to define the geometry of the cavity and its aperture that minimizes the spillage losses while maintaining a high value of the receiver thermal efficiency.

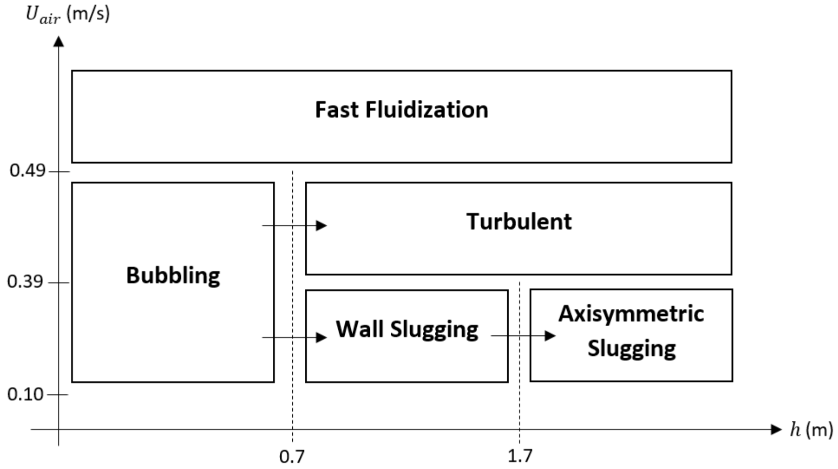

Figure 1: *Diagram of the fluidization regimes encountered in the tube and their transitions depending on the tube height and the air velocity.*

Publications in scientific journals and international conferences

Yimin Deng, Florian Sabatier, Raf Dewil, Gilles Flamant, Alex Le Gal, et al. Dense upflow fluidized bed (DUFB) solar receivers of high aspect ratio: Different fluidization modes through inserting bubble rupture promoters. Chemical Engineering Journal, Elsevier, 2021, 418, pp.129376. ⟨10.1016/j.cej.2021.129376⟩. ⟨hal-03187264⟩

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Alex Le Gal, Benjamin Grange, Ronny Gueguen, Michael Donovan, Jean-Yves Peroy, et al. Particle flow and heat transfer in fluidized bed-in-tube solar receivers. *SOLARPACES 2019: International Conference on Concentrating Solar Power and Chemical Energy Systems*, 2019, Daegu, France. pp.070002, ⟨10.1063/5.0028761⟩. ⟨hal-03187301⟩

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