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next-CSP

High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage

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Deliverable D1.3

WP1 – Assessment of particle suspension as heat transfer fluid and storage material

Deliverable D1.3. Report on particle upward flow modelling using the NEPTUNE_CFD code

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1. Introduction: Background and specific objectives of Deliverable D1.3.

The novel Upflow Bubbling Fluidized Bed (UBFB) concept was developed in the framework of both a French National and a European project (FP7; CSP2 project) [1]. It involved a vertical receiver with an upflowing dense particle suspension (solid volume fraction between 29 and 37%). The vertical receiver tubes are exposed to concentrated solar irradiation. The bubble-induced particle displacement and the imposed upward movement are responsible for the high particle convection heat transfer in the UBFB. Heat transfer by radiation from the wall to the bed is limited to the particle layers adjacent to the wall. For its application as solar receiver, the study of the bubbling phenomenon and of the particle mixing is essential, and subject of the present deliverable. Initial experiments within the CSP2-project were carried out in short vertical tubes of small internal diameter (I.D.), and using group-A powders to limit sensible heat losses associated with the fluidizing air flow. A further scale-up to multi-megawatt capacity is however less obvious since it will involve the use of the parallel tube-concept, but needing tubes of a significantly taller height to efficiently make use of the concentrated heliostat beams and provide sufficient heat capture surface area [2]. In molten salt applications, receiver heights of 10 to 18 m are now common practice. This will hardly be possible using the UBFB since its gas-solid hydrodynamics depend strongly on the geometry of the tubes, with special emphasis on their I.D. and height [3].

Unfortunately, the flow behavior of group A-powders [4] inside long tubes has not been studied in detail in previous research. It was therefore required to build Next-CSP dedicated rigs and perform global and local measurements. Since such experiments are tedious and cannot cover a wide range of operating parameters, it was deemed essential to assess if the capacity and accuracy of the computational fluid modeling code NEPTUNE_CFD could be developed as an indispensable step for its future simulation use as a tool for the scaling up of the proposed technological solution (as performed in WP7).

To validate NEPTUNE_CFD simulations, two sets of mostly overall measurements were obtained in a single UBFB tube, with I.D. and length similar to the geometry of the proposed Next-CSP receiver. The comparison between experimental measurements and 3D numerical simulation of the particle suspension, respectively conducted by EPPT and INPT enables to evaluate and improve the NEPTUNE_CFD models' capability to predict the suspension behavior in the solar receiver and to enhance the understanding of mechanisms involved.

EPPT experimental measurements from Task 1.2, in conjunction with additional results presented below in this report, highlighted the paramount importance of the bubble growth and coalescence leading to the formation of slugs, strongly impacting the particle mixing and its associated receiver wall-to-UBFB heat transfer.

This specific behavior of Geldart group A particles, turned out to be challenging for numerical simulation. Indeed, the numerical simulation was expected to be more difficult than from already well-known and coarse Geldart group B particles (100 to ~500 µm) due to the increase in computational resources needed to simulate the behavior of smaller particles (30 to ~ 100 µm). These difficulties were initially underestimated and brought to light new scientific challenges toward the simulation of the hydrodynamics of such powders within small internal diameter tubes: previous work methods could not be transposed and new ones had to be foreseen and developed.

The report below will be addressing these issues toward the hydrodynamic simulation of the gas/particle flow within the receiver tubes.