

Improving particle receivers for CSP applications

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Introduction

Gas-solid fluidized beds are a well-known technology commonly employed in the field of chemical reactors. Nowadays, they are one of the main research trends for the improvement of the next-generation Concentrated Solar Power (CSP) plants, increasing the operational temperature of these plants over the current limit of 565°C, due to the limitations of the molten salts used as Heat Transfer Fluids (HTF).

Because of its low Technology Readiness Level (TRL), a lot of research work in different areas is required before they can be deployed in commercial plants. Among these areas, granular material development and characterization, fluidized-bed design, and fluid-dynamic studies can be highlighted.

This poster presents some research results in all these different fields.

Experimental facility

The tests were carried out in a high-temperature gas-solid fluidized bed integrated with a beam-down solar reflector (Fig. 1). This configuration features a receiver where concentrated solar radiation (emulated using a 4kW Xe-lamp) focus directly onto the bed from above, promoting intense particle mixing and uniform heat transfer under controlled conditions. Different thermocouples and pressure transducer can be attached.

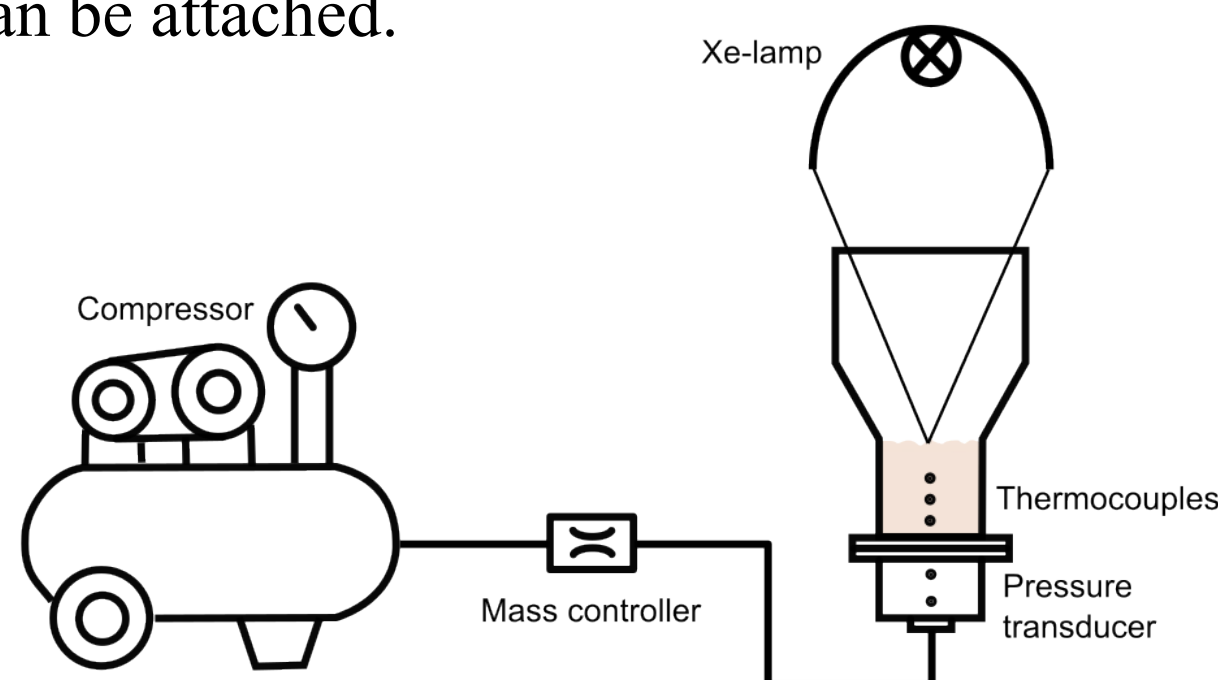


Figure 1. Experimental facility schema.

Improving particle absorptivity

Raw silica sand is cheap but has low solar absorptivity (0.42) compared to SiC (~0.90). Instead of a surface coating, prone to detaching under abrasion, manganese ions were diffused directly into the sand's crystal lattice by heat-treating it with manganese carbonate (600–900 °C) (Fig. 2). This raised absorptivity to 0.84 and improved charging efficiency by 20-24%, remaining stable through 10 fluidization cycles and a 24 h high-temperature erosion test. Modelling predicts this could cut the solar flux needed for high-temperature operation by 40-60% at industrial scale.

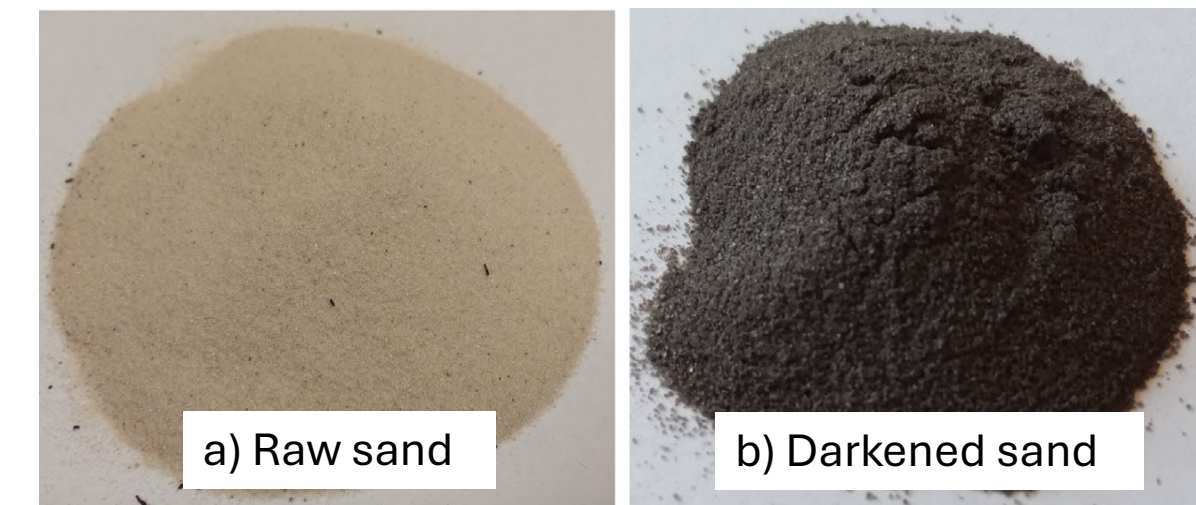
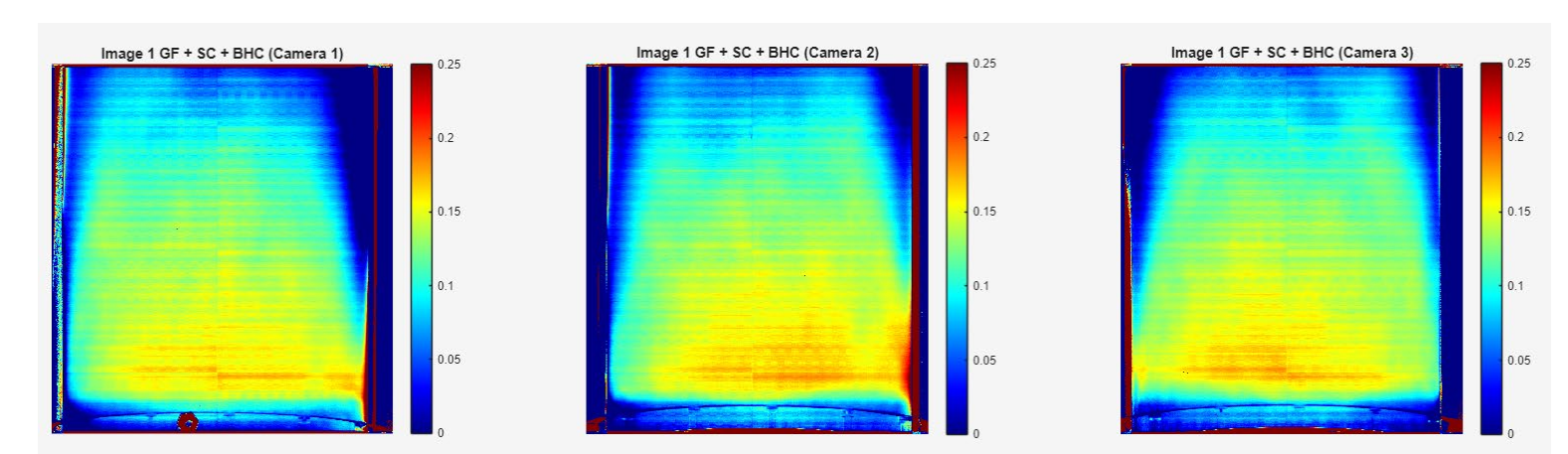


Figure 2. Characterized materials.

Reducing punping cost

Conventional gas distributor plates (perforated or multi-orifice) are prone to buckling and clogging, while alternatives like tuyeres are costly and generate erosive gas jets. This work explores additive manufacturing (3D printing) as a way to produce customized distributor plates with new internal geometries, fabricating 16 configurations by varying grill width, layer stacking angle and internal channel arrangement, printed in carbon-fiber-reinforced PETG. Testing in cold-flow fluidized beds (8 cm and 31 cm diameter) showed that some internal geometries performed comparably to a conventional metallic distributor, while others failed to reach proper fluidization, as straight through-holes allowed sand to weep through, progressively reducing the pressure drop over repeated cycles. In the large-scale bed, signal analysis (standard deviation, PSD, wavelet transform) revealed a clear dominant peak at the frequencies typical of bubbling fluidized beds, with 3D-printed distributors showing clearer fluidization signatures than the metallic reference, especially at low flow rates. X-ray imaging (Fig. 3) of the hydrodynamics further revealed a marked difference between homogeneous and heterogeneous (graded-porosity) distributors, with airflow preferentially channelling over time through the higher-porosity central section of the non-homogeneous plates.



a) Homogeneous plate

b) Non-homogeneous plate

Figure 3. X-Ray images of homogeneous and non-homogeneous distributor plate.

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