SOLPART
High Temperature Solar-Heated Reactors for Industrial Production of Reactive Particulates
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Deliverable D3.3

WP3 – Development of high temperature storage and handling technologies for reactive particles

Deliverable Report on high temperature thermal storage experimental work and performance analysis.

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1 Introduction and Objectives

The objective of this work package is to design, construct and test at lab scale a high temperature storage system that will work at the targeted operating temperature of maximum 950 °C. The experiments on the storage were coupled to the solar reactor test, which took place at the DLR solar simulator. The solar simulator consists of 10 short arc xenon lamps, which can provide thermal energy of about 15kW at the aperture of the reactor, with a spectral distribution similar to that of the sun (details are given in D2.3). In the experiment, the particles are fed through a screw feeder and follow the path as shown in Figure 1 indicated by the green arrows. Their flow rate is controlled by the screw rotation in the feeder. The particles flow through the solar rotary kiln, where they are heated to 1000°C and calcined through incident solar radiation. Their movement is driven by the inclination and rotation of the crucible. The calcined particles fall through the hopper below the crucible and then through an insulated pipe to the storage box (see Figure 1). The length of the hopper and the insulated pipe is 0.12 and 0.28 m, respectively. The insulation around the reactor and the hopper were detailed in D2.3, while the pipe is insulated with 50 mm thick insulation. The insulation properties are shown in Table 1.

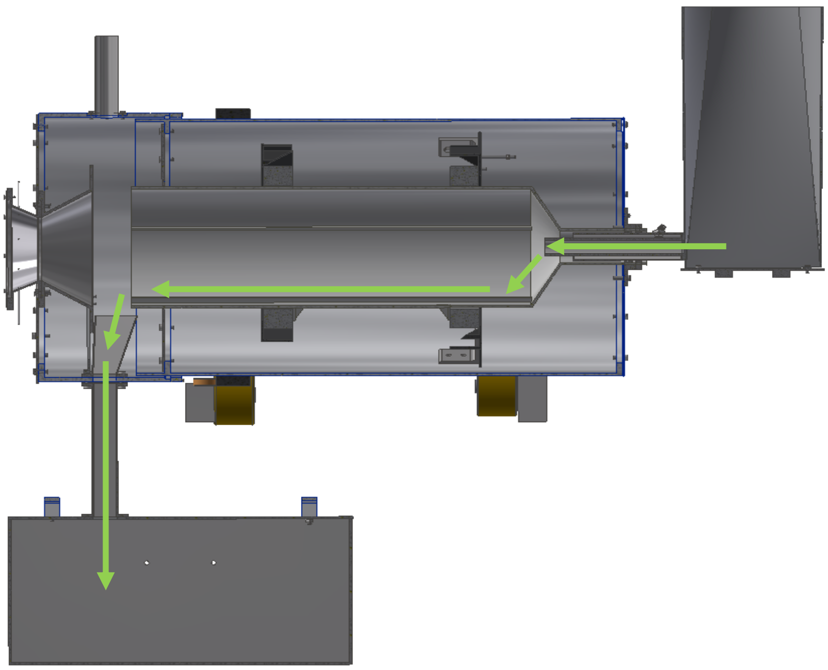

Figure 1: Schematics of the rotary kiln system and the storage.

Experiments are divided in two groups depending on the treated material: thermal with inert bauxite particles and thermochemical with cement raw meal (CRM) particles. In the thermal tests the incident solar radiation provides sensible heat, which increases the temperature of the inert particles flowing in the rotary kiln to about 1000 °C. The particles average diameter is 0.98 mm. In thermochemical tests, the incident solar radiation is utilized first to heat the particles to about 900°C, and second to chemically transform the calcium carbonate to calcium oxides (calcination reaction). In the both processes, the hot particles/calcined hot particles are then fed into the storage system. CRM is composed of 80 % calcium carbonate and has much smaller particle size (50% of mass below 75 μm) than the inert particles. Specific heat capacities of both inert and active calcined material are given in Table 2.

Table 1: Insulation characteristics

Details	Insulation-1	Insulation-2
Reference	[1]	[2]
Supplier	Unifrax	PROMAT
Type	Insulfrax	Promasil-1100
Form	Blanket	Solid Foam
T_{Max} (°C)	1200	1050
Thermal conductivity at 600°C (W/m.K)	-	0.101
Thermal conductivity at 800°C (W/m.K)	0.18	0.125
Density (kg/m³)	128	300

Table 2: Specific heat of bauxite and CaO particles

Material	Specific heat (J/kg.K)
Bauxite	$-1.12 \cdot 10^{-3}T^2 + 2.07\,T + 264$
CaO	$(49.9503 + 4.887916 \cdot 10^{-3}T - 0.35206 \cdot 10^{-6}T^2 + 0.046187 \cdot 10^{-9}T^3 - 0.8251 \cdot 10^{6}/T^2)/0.056077$

2 Conclusion and outlook

In the present deliverable, a high temperature particle storage system was designed, developed and tested under real experimental conditions. The experiments on the storage were coupled to the solar reactor test, which took place at the DLR solar simulator. Experiments are divided in two groups depending on the treated material: thermal with inert bauxite particles and thermochemical with cement raw meal (CRM) particles. Two storage systems were developed, in the preliminary storage only thermal test were carried out and a second (new) storage was developed to overcome the limitations of the old (preliminary) storage. Following are the improvements made in the new storage system

- The inlet opening of the new storage lid was made bigger to make room for pipe expansion to avoid bending of the lid
- The new storage was fixed on the holding structure to empty it from the bottom using a knife edge valve (it also used to control the rate of flow of the particle)
- Seven thermocouples were used for temperature measurement and fixed in its position using thermocouple guide pipe

The new storage system was tested and its performance was calculated. The main conclusion is that the heat losses through the outer wall can be easily reduced by a thicker or more performing insulation layer, but most of the heat is lost when the particles fall into the storage. Further studies are needed to decrease these losses to allow storing of particles at higher temperature. The cooling down of the storage during the experiments is also used to validate the numerical model which shows maximum relative error about of 11 % in comparison with the experimental data.

For more information, please contact SOLPART Coordinator (CNRS-PROMES):
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Literature

[1] Unifrax, Insulfrax S Matte, product datasheet.
[2] Promat, PROMASIL®-1100 SUPER 2018 26.01.2018]; Available from: http://www.promat-hpi.com/en/applications/home-appliances/cooking/promasil-1100-super-domestic-cookers.