SOLPART

High Temperature Solar-Heated Reactors for Industrial Production of Reactive Particulates

European funded project - Grant Agreement number 654663

Deliverable 5.1

WPX – Testing and performance evaluation of the pilot solar unit

Deliverable Report on first on-sun experiments of the pilot solar reactor

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1 Introduction and objectives

The SOLPART Consortium chose the horizontal fluidized bed design for developing the pilot scale solar calciner technology because of its main characteristics:

- Homogeneity of particle temperature due to efficient mixing by the fluidization gas,
- Easy control of particle residence time,
- Close design that enables exhaust gas recovery,
- Capacity to be scaled-up.

COMESSA performed the complete design with the assistance of CNRS and the company organized the manufacturing. The specifications fit with the SOLPART project target: CaO equivalent production capacity of 30 kg/h corresponding to about 60 kg/h calcium carbonate at the reactor inlet.

The particles to be calcined being heated indirectly through a wall that absorbs the concentrated solar radiation the main operation constraint is the maximum acceptable wall temperature. In general, during on-sun operation and at equilibrium, this temperature depends on the incident solar flux on the wall and on the fluidized particle-to-wall heat transfer coefficient. As the reaction temperature to decompose calcium carbonate is ranging from 850°C to 900°C and the maximum working temperature of the refractory alloy wall is 1100°C, only a 200°C maximum temperature difference is acceptable. This latter value allows defining the level of the net solar flux absorbed at the wall: 150 kW/m^2 for a 750 $W/m^2.K$ heat transfer coefficient (optimistic value).

Previous estimation assumes a homogeneous solar flux distribution on the wall that is not realistic but that may be expressed as a first objective: (1) to reduce as low as possible the heterogeneity of solar flux distribution on the reactor wall in order to avoid hot spot. The work done to achieve this target is explained in paragraph 4.

Operation of the solar calciner needs controlling the fluidization quality, the particle flow and the temperature distribution at the wall and inside the fluidized bed. The control of these characteristics defines the second objective of this first experimental campaign: (2) to identify the technical obstacles that affect the fluidization quality, the particle flow rate and the temperature distribution, and to propose solutions to overcome them. The results are presented in paragraph 5.

Finally, paragraph 6 summarizes the results of the first successful solar calcination test with the pilot scale solar reactor and the measures proposed to improve the conversion of the feedstock.

2 Conclusion

The main functional part of the SOLPART pilot-scale reactor-receiver has been delivered and tested at the Odeillo's 1MW solar furnace.

The test period included,

1. The development of a heliostat aiming strategy including optical measurements using a mock-up and optimisation software programing.
2. The implementation of the sensors and the development of the data acquisition system.
3. The measurement of component characteristics and the identification of problems to be solved. The particle feeding device, the fluidization air distributor, the fluidization air preheating and the front wall temperature distribution (linked to the solar flux distribution) are mainly concerned.
4. The preliminary on-sun test that leads to the successful partial decomposition of calcite.
5. The proposition of solutions to address the main issues identified.

Dedicated measurements and data processing involving genetic algorithms resulted in selecting the heliostat configurations enabling to deliver a homogeneous solar flux on the reactor-receiver.

Several commissioning tests were carried out with calcite ($CaCO_3$) to qualify the behaviour of the setup. These tests enabled to improve the particle supply system, the heliostat aiming strategy and the fluidization distributor. Average fluidized bed temperatures up to 735°C and maximum particle temperatures up to 855°C were reached. A first calcination test was performed and a conversion rate of about 20% was reached.

Further improvements of the heliostat aiming strategy, of the air preheating and of the operating conditions will be implemented in order to increase the average temperature of the fluidized bed and hence the conversion rate of the particles.

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