SOLPART

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

European funded project - Grant Agreement number 654663

Deliverable D3.1

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

Deliverable D3.1: Report on high temperature thermal storage design and related construction materials

Date of Delivery: 03rd February 2017

Deliverable Author(s): Matthias Lange, Stefania Tescari, Alfonso Rodríguez Sánchez

1 Introduction and Objectives

One of the key requirements of solar thermal treatment of powders, especially in the case of powders where the treatment kinetics are slow, and the treatment time high (see D1.1), such as in the lime or cement production, is the possibility to store the calcined product in its hot state overnight. This way, a further calcination or downstream clinkering step can be run for 24 hours without reheating the material again. Continuous operation results in a smaller plant size and increased operation time, both being important factors for the economic performance.

In order to ensure that after several hours of night time storage, the product powder is still at a required temperature, the storage design and the insulation thickness need to be laid out carefully. In this work package 3.1, we created a custom model which estimates the storage temperature during operation in order to size the insulation and select an appropriate insulation material for the pilot system storage. The model can as well be used to predict the performance of a future full scale plant. It should however be understood that heat losses in a pilot system will be largely exceeding heat losses in an industrial scale storage due to the decreasing ratio of external hopper surface area to hopper storage volume (larger diameter, lower height).

2 Conclusion and Outlook

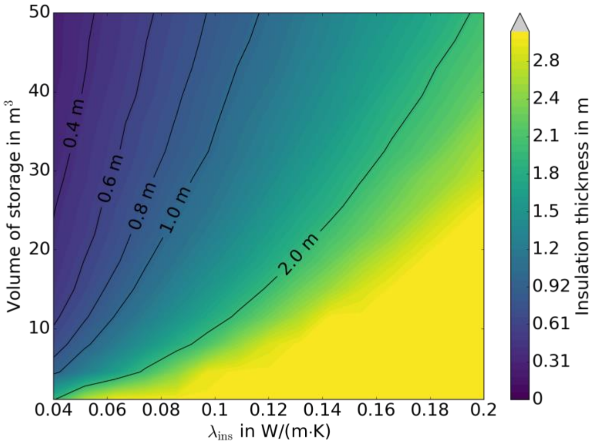
A simple model describing the temporal heat evolution of a particle bed in a thermal storage was developed. Hot particles enter the storage during the day and a continuous particle outlet stream is implemented.

The model gives an idea what influence the storage geometry and the material properties have. The most critical point in time is the end of the night, when the storage is at its emptiest state and the particles have cooled during the whole night. Then, in a short period of time, the temperature drops quickly. Therefore, keeping the temperature always above a certain level is a quite challenging constraint for the pilot plant scale.

The dimensioning of the pilot storage should take into account these model results, but a reasonable and practical design should be aimed at. Hence, when designing the storage, it should be kept in mind that the model overestimates the heat loss due to some simplifications. Furthermore, it has not been validated with real measurements, but only with other theoretical solutions. The future improvement of the model will include the temperature stratification within the particle bed. Also the idealized internal heat transfer could be a major overestimation, especially when the storage is rather empty. It is likely, that limited convection and radiation through the dust may create a thermal resistance that does not allow for assuming that the inner walls are at the particle bed temperature. Also, the top layer of the particles may cool down and form a kind of "protective layer" to prevent the bottom of the particle bed from fast cooling. All these points need to be assessed during the experimental validation.

Whereas all these considerations deal with the pilot scale storage, the model can also be applied to a full scale storage study. Large storage sizes are in strong favor of the thermal performance, since reducing heat losses, considered as a positive outlook for the large-scale future. The figure below shows the insulation thickness which would be necessary to reach the very ambitious goal of never dropping below 900 °C when entering at 950 °C, again with the insulation characteristics and outer wall convection coefficient at the set values of the above assumptions.

Figure: Required insulation thickness to stay above 900 °C with particles entering at 950 °C. Large scale study for future plant layout



When the storage volume is increased, the mass flow of the particles is also increased so that the minimum filling of the storage stays at 55% in all cases. This value corresponds to the size of 360 liters in the pilot scale, which was found to be one possible optimum. When increasing the size to 50 m^3, the insulation can be reduced to commonly applied thicknesses (0.3 to 0.4 m), depending on the insulation material and design (multilayer insulation). These results will be further developed in WP 7 for the full scale design and its associated economic assessment.

3 Literature

[1] HL. Zhang, J. Degrève, J. Baeyens, R. Dewil, "Wall-to-suspension heat transfer in a CFB downcomer". Jnl. of Powder Technology, 2015.

[2] *VDI Heat Atlas*, 2 ed. Berlin; Heidelberg: Springer-Verlag, 2010.

[3] E. U. Schlünder, "Particle heat transfer," presented at the Heat transfer 1982.Proceedings of the Seventh International Heat Transfer Conference, München, Fed. Rep. of Germany, Washington, 1982.

For more information, please contact SOLPART Coordinator (CNRS-PROMES): gilles.flamant@promes.cnrs.fr