SOLPART

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

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Deliverable D7.1

WP7 – Plant integration, scaling up, economic and risk assessment of the solar process

Deliverable D7.1 Technical report on scaling up the solar process for cement, lime, dolomite and phosphate production

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Deliverable Author(s): Vishnu Budama, Gilles Flamant, Jorge Pablo Garcia Garcia, Gkiokchan Moumin, Anton Lopez Roman, Ana Filipa Santos, Stefania Tescari

1 Introduction

The cement production process is one of the major contributors of carbon emissions and global warming. The cement industry burns fuels to run the endothermic decarbonation of the cement raw meal as a part of cement production. This works studies the feasibility of using concentrated solar energy to run the chemical reaction in the cement production and thus reducing carbon emissions. A detailed study of process flows, mass and energy flows and solar field design is developed in this work. Design study for the scale-up of the reactor, thermal storage, and particle transport process to the requirements of 3500 tons/day. The design study of 1000 tons/day and 500 tons/day is also performed to understand the solar energy, solar field design and other parameters of the plant. Three different plant layout configurations are developed as a part of transportation of material flow and technical and economic constraints of each are discussed in detail. The size of the solar field, types of heliostats and receivers is analysed together with the storages dimension. As an extension to this, feasibility study of concentrated solar energy for the production of lime, phosphate and dolomite is also studied.

2 Conclusions

The feasibility of using concentrated solar heat energy in the cement, lime, dolomite and phosphate production processes is studied in this report.

For cement, the thermal decomposition of calcium carbonate consumes approximately 60% of the total energy consumption, this energy is provided by fuels combustion in a conventional cement plant. The purpose of this work is to design a calciner, called solar calciner or solar reactor, in which the endothermic energy for the thermal decomposition of calcium carbonate is supplied from the concentrated solar energy. The process flow sheet, mass and energy balance calculations are developed. The quantity of heat supplied (combined sensible and heat of reaction) per kg of calcium carbonate is same in both conventional and solar cases. Although the cement production plant runs 24h/d, the solar calciner runs only for eight hours per day and thus mass flow rate of particles in the solar calciner is three times compared to conventional plant. The heat rate supplied to the solar calciner is also three times compared to conventional calciner. Two storage systems are proposed in this model as the availability of solar energy is not continuous. Three different configurations were proposed for preheating of cement raw meal before the calcination process. The advantages and limitations of each case were discussed in details and the best of the three is proposed. The hybridization of cement production plant which runs with both fossil fuels and solar energy is practically not feasible because of the limitations of the process chemistry. The initial material composition must be changed according to the energy source, and the process needs several hours to reach an acceptable product quality. Switch between solar and conventional fuels two times a day would lead to several hours of transient operation in which the product has not acceptable quality. It was therefore decided that the calciner will be only solar and in case of several days without solar radiation, the plant could be shut off. Moreover, three production capacities of 3500, 1000 and 500 ton per day were studied, proposing two scenarios with a lower capacity instead of hybridized plant.

In the configuration proposed, the cement raw meal is pre-heated in two stages such that the sensible heat energy available in the CO_2 produced is used in beat way, while the heat coming from the cooler is continuously available. The concentrated solar heat required to the solar reactor for the production capacity of 3500 ton per day is 270 MW. A detailed design of the solar field to supply the required amount of heat energy to the reactor is developed. A good aiming strategy of the mirrors allows achieving a homogenous flux on the reactor but, this is possible only at the cost of spillage losses; a compromise between the two will give the optimized solution. Three 12X12 meter size windows are considered for the reactor to receive the solar flux. The analysis of scaling up of the reactor from lab size reactor with experimental data was discussed in details. The storage capacity was also studied in details, showing that the best plant operation was obtained with 2 days of storage.

The feasibility of using concentrated solar heat to produce lime, phosphate and dolomite is also analysed. The process flow sheets, mass and energy balance and the solar field design is discussed in details. The concentrated solar energy required for 300 tons of lime production per day is 40 MW, for 300 tons per day of dolomite production is 25 MW and for 1400 tons per day of phosphate production is 45 MW. The size of the solar field and the variation of the production per month are présented.

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