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ScienceDirect

Energy Procedia 69 (2015) 487 – 496

Energy Procedia

International Conference on Concentrating Solar Power and Chemical Energy Systems, SolarPACES 2014

Numerical modeling of a two-tower type fluidized receiver for high temperature solar concentration by a beam-down reflector system

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Abstract

This study describes the flow and thermal field of a two-tower fluidized receiver, aimed to be incorporated into a beam-down reflector system. An experimental visualization and numerical simulation were made to accumulate phenomenological knowledge, in order to complete the design of a demonstration model. Visualization of the cold particle bed with no irradiation revealed that global circulation occurs between the two towers by the aeration with different line velocities. The numerical simulation revealed that this global circulation enhances the transport of sensible heat from the irradiated layer in the high pressure tower to the low pressure tower. The global circulation in the two-tower fluidized receiver has the potential to be extended for use in a thermal receiver and direct storage system. Unexpectedly, local circulations occur on the high and low pressure sides, and are stronger than the global circulation. These local circulations contribute to the thermal mixing in each tower. The bottom distributor on the low pressure side can cause an uprising flow which leads to the local circulation. The design of the distributor is suggested to be elaborated based on these findings.

Keywords: Solar receiver; Beam-down reflector system; Fluidized bed; Numerical simulation

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doi:10.1016/j.egypro.2015.03.057

1. Introduction

Concentrated solar power (CSP) has been introduced in Southern Europe and the United States. It is expected to prevail in the sun belt of Middle East and North Africa and in Asian countries, including China and India. Commercial CSP plants use synthetic oil or molten salt as heat transfer fluid (HTF) [1]. Some plants employ heat storage systems for buffering cloud cover and improving dispatchability [2]. Newer point concentration power plants receive solar heat at temperatures around 560℃. This limitation results from thermal cracking of molten nitrate. High temperature receivers are being developed to have a higher energy retention rate. The Deutsches Zentrum für Luft- und Raumfahrt (DLR; German Aerospace Center) tested an open-type volumetric receiver at the Jülich tower plant to produce hot air exceeding 700℃. Sandia National Laboratory developed a falling-sand receiver for high temperature absorption and storage [3]. The DLR also experimented with an air–particle heat exchanger for high temperature CSP [4].

The authors of the present study proposed the fluidized receiver—a windowed fluidized bed directly irradiated by concentrated light [5]. This was meant to be incorporated into a beam-down reflector system. Previously, numerical simulation and experiments were conducted on a cylindrical type fluidized receiver to show the flow and thermal field of particles. Air streams with varying velocities were shown to cause circulation of particles within the cylindrical receiver. This inner circulation enhanced the thermal mixing of particles, which can contribute to attenuation of the re-radiation loss. The concept of a fluidized receiver originates from the fluidized bed reactor for thermo-chemical water splitting [6, 7]. The previous paper revealed the potential of a fluidized system to be extended to high-temperature thermal concentration [5].

This study describes the visualization and numerical simulation of a two-tower type fluidized receiver. This receiver can transport irradiated particles from a high pressure tower to a low pressure one, which is intended to act as a thermal storage system. This fluidized receiver is meant to be installed in a 100 kWth Miyazaki beam-down reflector system. In preparation for a demonstration of this system, the visualization and numerical simulation were conducted in order to gain insight into the thermal and fluidal characteristics of the receiver. A flow visualization was made of the cold particles in the transparent channel. The numerical model of the two-tower type receiver was developed for designing the demonstration solar system. The input data for the concentrated light was taken from flux measurements of the Miyazaki beam-down system. Two-dimensional contours of temperature and vector diagrams were examined to reveal the physics of solar light absorption into the solid particles and air.

2. Experimental visualization of cold bed

The authors propose to utilize a fluidized bed as a high temperature receiver for a beam-down reflector system.

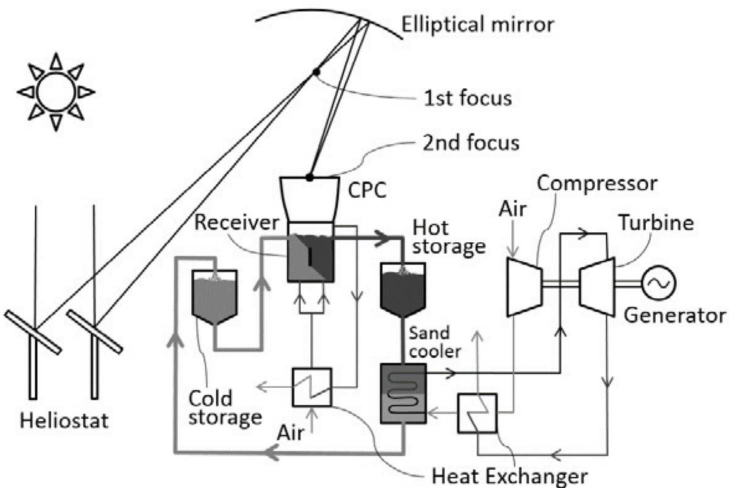

Fig. 1. Solar hot air turbine with fluidized receiver.