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Granular Flow Field In Moving Bed Heat Exchangers: A Continuous Model Approach

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Abstract

Moving Bed Heat Exchangers (MBHX) are a promising option to discharge thermal energy from hot bulk materials, which can be used in solar thermal power plants as heat transfer and storage medium. A precise determination of the flow field in a MBHX is required to predict its thermal performance. This paper presents a continuous model approach, based on the theory of soil mechanics to describe the granular flow inside the heat exchanger. The simulation results are compared to a preceding model and experimental data. For this purpose two different tube bundle geometries are analyzed. The results are evaluated by means of contour plots of the flow field and the velocity magnitude of the granular material at the tube surfaces. The new model captures the flow at the top of the tubes quite well but shows need for further improvement in the lower part of the tubes.

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1. Introduction

In concentrating solar power (CSP) plants, the electric power generation can be decoupled from the instantaneous solar irradiation by using a thermal energy storage (TES) system. This increases the flexibility of the power plant.

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The suitability of a TES system mainly depends on the heat storage material being used. One possible option are molten salts and their mixtures. However, typical limitations of these materials are the limited temperature range, the technical effort to avoid solidification, the corrosion behavior and the relatively high costs [1].

As opposed to this, fine grained materials are thermally stable at temperatures above 1000 °C. Furthermore, they are environmentally friendly and can be very cost efficient, especially when using natural stones like quartz sand. Therefore, these materials are considered for CSP plants (e.g. [2, 3]). The idea is to heat up the material (> 800 °C) by concentrated solar radiation and store the hot material inside a thermally isolated tank. According to the requirements, hot material can be discharged from the tank to generate steam in a Rankin Cycle and to produce electricity.

One of the key questions regarding this concept is how to discharge thermal energy from the hot granular material. For this purpose a moving bed heat exchanger (MBHX) is suitable due to low parasitic loads and a good performance when operated at part load [2]. Inside this component, the granular material moves slowly downwards, driven by gravity, flowing around heat exchanging surfaces, e.g. tubes which are traversing the bulk material (Fig 1).

The efficient construction of such a MBHX requires a detailed prediction of the heat transferring properties. Unfortunately, granular materials show a different flowing behavior than Newtonian fluids. One of the main differences is that they can form stagnant areas, where the flow completely comes to rest (see Fig. 1, left). This is of particular interest in the vicinity of the tubes, where the resting particles may lead to a strong reduction of heat transfer at the tube surface. Therefore it is of great importance to correctly predict the flow field around the tubes in order to correctly predict the thermal performance of the device.

In preceding works [4, 5] bulk flow in a MBHX has already been modeled by describing the granular material as a continuous medium. However, the approaches were either very simple or could not properly capture the formation of the stagnating zones mentioned above.

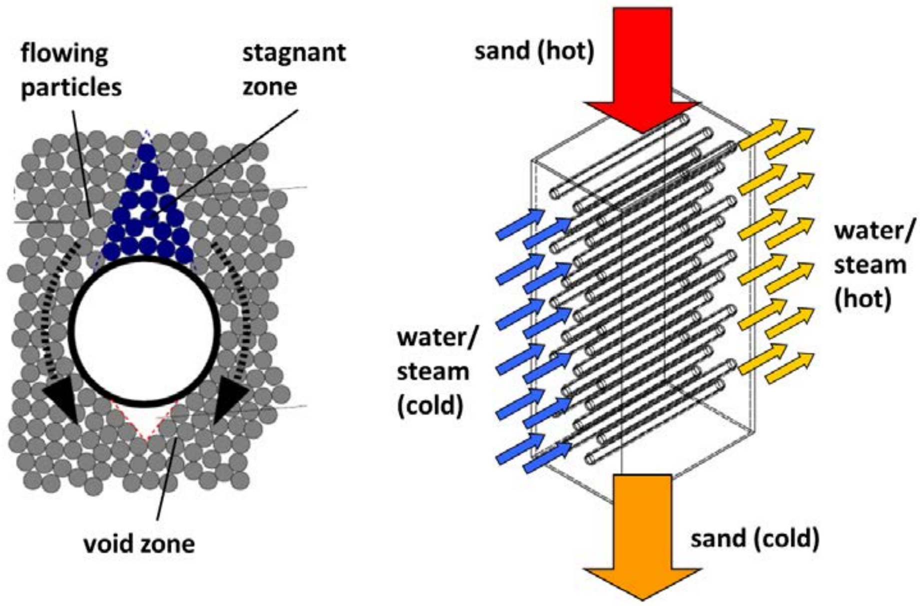

Fig. 1. Flow field around tube (left) and schematic sketch of a moving bed heat exchanger (right).

The model used in this work follows the approach of Baumann et al. [4, 2], by making use of the Eulerian multiphase flow model. This approach treats the bulk as two continuous phases interpenetrating each other. One