Innov Ener Res 2018, Volume 7
DOI: 10.4172/2576-1463-C2-006

2nd International Conference on
Renewable Energy and Resources
&
Energy Materials and Fuel Cell Research
August 27-28, 2018 | Boston, USA

Dimensionless dual phase model for thermocline energy storage behavior analysis

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Thermocline packed-bed single tank concept belongs to the category of sensible heat storage systems (SHS). It is currently presented as a promising and cost-effective technology to reach efficient thermal energy storage (TES) and sustainable management of the thermal process. However, this configuration still in a growth stage and need to be developed. Hence the necessity to investigate new thermal energy storage material (TESM) unexplored until now and determines their characteristics and their storage performances. In other words, one of the key factors to make this concept more attractive is the wise choice of TESM. In fact, it is well known by the most researchers that TESM must satisfy several requirements based mainly on the thermophysical properties such as low density, high thermal capacity, high thermal conductivity, thermal stability, etc. But it is often found that the choice of storage materials based on these criteria, which are intrinsic to the TESM, sometimes gives, under certain operating conditions and depending on the heat transfer fluid, inverse results concerning the thermal performance thermocline storage system. Because on the one hand even if the physicochemical adequacy between the TESM and the HTF is well taken into account in these studies, the adequacy between the thermophysical properties of the TESM and the HTF is habitually ignored. On the other hand, the compensation between certain intrinsic properties of the TESM makes the problem more ambiguous. For example, the choice of a material with high heat capacity is intuitively beneficial for the storage as the choice of a material of high thermal conductivity, which makes it possible to homogenize the temperature inside the same solid particle. But by analyzing the macroscopic participation of these properties in a thermocline storage system, it is easy to see that these coefficients have an opposite effect because the heat transfer in the porous bed is driven by the effective thermal diffusivity of the TESM (among other parameters). In this context, the aim of this work is to propose a dimensionless model that allows a clear analysis of the general thermal behavior of thermocline system by reducing the number of parameters. For this purpose, we have introduced dimensionless groups of parameter specific for this kind of system. The model proposed is based on a dual phase model describing heat and mass transfer inside the porous packed-bed contained in the storage tank. After validation, the developed model is used to simulate the behavior of charging and discharging the system. Subsequently, a parametric study revealed the information concerning the influence of each 2 dimensionless group on the discharge efficiency of the system. The results obtained made it possible to determine in a clear-cut the TESM choice criteria according to the HTF and the operating conditions of the thermocline.

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