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Packed-bed Thermal Energy Storage Analysis: Quartzite and Palm-Oil Performance

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Abstract

A packed bed for solar energy storage in the form of sensible heat has been investigated using two-phase continuous model. The system contains Quartzite as the filler material and Palm oil as the heat transfer fluid. The aim of this work is to propose an eco-friendly storage system which uses natural concrete and certified sustainable oil for medium temperature thermal storage. Using the developed model, the performance of the Palm oil has been compared with two different synthetic oils which has shown that the Palm oil could efficiently be used as a heat transfer fluid for a working temperature below 300°C.

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Keywords: sensible heat; energy storage; packed bed; continuous model; Quartzite; Palm oil.

1. Introduction

Solar energy is one of the sustainable solutions to limit the greenhouse gases emitted by conventional energy systems. Great efforts have been devoted in this field for small and large scale development. However, the alternative character of solar energy still represents a real challenge for scientific research. In this context, energy storage is one of the promising key to correct partially the variability of the solar radiations by enlarging the operating hours of the solar system and improving its autonomy.

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Research in the field has shown that concentrated solar power technologies are easily coupled with thermal energy storage systems [1]. Among the existing types, sensible heat storage has been the most suitable, in terms of thermal efficiency and cost effectiveness, for concentrated solar power systems (CSP). While molten salt and synthetic oil are widely used for utility scale [1], different researches are progressing in other thermal energy storage types.

Actually, the present work is part of the COLDSUN project which aims to study theoretically and experimentally the coupling of solar Fresnel field to double effect absorption machine to produce air conditioning. In order to improve the reliability of the installation, the system has sensible heat thermal energy storage (SHTES) unit to store excess energy during the day time and restore it when the solar radiations are insufficient to run the absorption cycle. In this paper, the focus is on the thermal storage system (TES), which is a one tank thermocline with a packed bed of rocks and has oil as the heat transfer fluid (HTF).

Nomenclature

a_{sf}	specific surface area [m^{-1}]
Bi	Biot number
C_p	thermal heat capacity [$JKg^{-1}K^{-1}$]
D	diameter of the bed [m]
d_p	equivalent rock diameter [m]
h_{sf}	interstitial convective heat transfer coefficient [$W/m^{-2}K^{-1}$]
H	height of the bed [m]
k	thermal conductivity [$W.m^{-1}K^{-1}$]
K	permeability [m^2]
m_f	mass flow rate [$Kg.s^{-1}$]
Re	Reynolds number
T	temperature [K]
ΔP	pressure drop [Pa]
t	time [s]
v	velocity [$m.s^{-1}$]
z	axial coordinate [m]
	Greek letters
ε	porosity of the bed [m]
μ	dynamic viscosity [Pa.s]
ρ	density [$Kg.m^{-3}$]
	Subscripts
f	fluid
in	inlet
re	recovering
s	solid
st	storage
0	initial

The reduced cost of the one tank thermocline comparing to the two tanks indirect TES has attracted several studies [2,3,4]. While many previous works have considered air as the heat transfer fluid [5,6], in this study, the Palm Oil with Quartzite have been investigated. The choice of the working fluid is actually motivated by the eco-friendly aspect of using natural and certified sustainable oil instead of conventional or synthetic oils that impact the