Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 101 (2016) 782 – 789

Energy Procedia

71st Conference of the Italian Thermal Machines Engineering Association, ATI 2016,

14-16 September 2016, Turin, Italy

Parabolic trough system operating with nanofluids: comparison with the conventional working fluids and influence on the system performance

V. Ferraro[a]*, J. Settino[a], M. A. Cucumo[a], D. Kaliakatsos[a]

[a] *University of Calabria, Department of Mechanical, Energetics and Management Engineering (DIMEG)*
Via P. Bucci – 87036 Rende (CS), Italy

Abstract

To analyse the behaviour of a parabolic trough operating with nanofluids, and compare its performance to the more traditional ones using oil, a model for the thermal analysis of the system has been developed and implemented in Matlab. The simulations have been performed for a suspension of Al_2O_3 in synthetic oil and its characteristics compared to the corresponding basic liquid used by itself. The string has been assumed to have a length of 100 m and a concentrating surface area of 550 m^2. The simulations have been carried out for different DNI (Direct normal irradiance) and variable mass flow, ensuring a temperature at the collector outlet below 400 °C. For a proper comparison, the following variables and efficiency indicators have been checked: power output, pumping power, thermal efficiency and overall efficiency of the parabolic trough system.

Peer-review under responsibility of the Scientific Committee of ATI 2016.

Keywords: Parabolic trough system; Nanofluids; Matlab.

* Corresponding author. Tel.: +39 0984 494822; fax: +39 0984 494673.
E-mail address: Vittorio.ferraro@unical.it

Peer-review under responsibility of the Scientific Committee of ATI 2016.
doi:10.1016/j.egypro.2016.11.099

1. Introduction

Water, synthetic oil and ethylene glycol represent the most conventional heat transfer fluids. They play an important role in many industrial processes, such as power generation, chemical processes, automotive and microelectronics applications. However, the continuous technological development has led to new challenges in the heat transfer field. The conventional method for increasing the heat exchange is to increase the available area. In the last decades, instead, the research has been focused on the development and analysis of a new generation of fluids, known as nanofluids, which could offer new possibilities to increase the heat transfer performance. The term nanofluids has been introduced, for the first time, by Choi in 1995 [1], to indicate promising fluids, consisting of a suspension of nanoparticles in a basic fluid. The nanoparticles could be either metallic (Cu, Al, Fe, Ag, Au) or non-metallic (CuO, Al_2O_3, Fe_3O_4, TiO_2, SiC), while the basic fluid is usually one of the conventional heat transfer fluids, currently used [2]. The extremely small particle dimension ensures a high specific surface area, i.e. a larger surface area is available for heat transfer between particle and fluid. Moreover, the risk of sedimentation and clogging, typical of the early generation of solid suspensions based on the use of micro and millimetric particles, can be avoided. Depending on the particle type and their concentration, a variation of the fluid properties, like thermal conductivity, density and viscosity, can be obtained. This determines a higher flexibility of nanofluids, which makes them suitable for various applications [3].

In this work, the use of nanofluids in a parabolic trough system has been analyzed. A mathematical model of the parabolic trough has been developed in Matlab, in order to investigate the effects of using nanofluids and compare it with the conventional heat transfer fluids. In particular, the behavior of a suspension of Al_2O_3 in synthetic oil has been analysed and compared to synthetic oil used by itself.

Nomenclature

A	area, m^2
C_p	heat capacity, $J/(kg\ K)$
D	diameter, m
h	convective heat transfer coefficient, $W/(m^2\ K)$
k	conductive heat transfer coefficient, $W/(m\ K)$
Q	solar thermal power, W/m^2
R	thermal resistance, $(m^2\ K)/\ W$
T	temperature, K
x	axial coordinate, m
ε	emissivity
θ	angle, rad
ϕ	particle volumetric concentration
μ	viscosity, (Pa s)
Subscript	
a	air
abs	absorber tube
bf	basic fluid
ext	external
int	internal
nf	nanofluid
par	parabolic mirror

2. Mathematical Model of a parabolic trough system

A two-dimensional model of a parabolic trough has been developed in Matlab. It has been assumed that the temperature of both the absorber and the fluid change only along the axial direction (x), while the temperature profile in the radial direction has been evaluated under steady state conditions. The radiation has been considered