Applied Energy 111 (2013) 80–93

Contents lists available at SciVerse ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

A new solution for reduced sedimentation flat panel solar thermal collector using nanofluids

Gianpiero Colangelo *, Ernani Favale, Arturo de Risi, Domenico Laforgia

Dipartimento di Ingegneria dell'Innovazione, Università del Salento, Via per Arnesano, 73100 Lecce, Italy

HIGHLIGHTS

- This work reports experimental results for flat panel solar thermal collectors using nanofluids as heat transfer fluids.
- Nanofluids with Al_2O_3, ZnO and Fe_2O_3, with different shapes and concentrations have been tested.
- Thermal conductivity enhancement and convective heat transfer coefficient of the nanofluids have been measured.
- A new design for flat panel solar thermal collectors using nanofluids has been made.

ARTICLE INFO

Article history:
Received 3 April 2012
Received in revised form 4 April 2013
Accepted 24 April 2013
Available online 24 May 2013

Keywords:
Nanofluid
Sedimentation
Flat panel solar thermal collector
Convective heat transfer coefficient

ABSTRACT

The present paper reports the experimental results and the potential performance of the investigation on flat solar thermal collectors using nanofluids as innovative heat transfer fluids for solar energy applications. The straight use of heat-transfer nanofluids in traditional solar flat panel revealed some technical issues, due to the nanoparticles sedimentation. Therefore, sedimentation has been investigated both in standard solar flat panels and modified ones made from transparent tubes. The results of the first tests showed that the main sedimentation parameter is the flow velocity and to better control it a standard flat panel was modified changing the cross-section of the lower and top header of the panel, that have been tapered to keep constant the fluid axial velocity. The modification of the panel shape (patent pending) enabled a negligible particles deposit.

After different nanofluids were tested on the panel prototype, water–Al_2O_3 was chosen as heat transfer fluid. All tested nanofluids were prepared in batch and their thermal conductivity and convective heat transfer coefficient were measured prior of their use as heat transfer fluid in the solar panel. A thermal conductivity enhancement up to 6.7% at a concentration of 3 vol% was observed, while the convective heat transfer coefficient increased up to 25%.

1. Introduction

Nanofluids are innovative heat transfer fluids that can be used in energy systems because of their superior thermophysical properties with respect to conventional heat transfer fluids [1]. Nanofluids can be applied in energy storage systems [2].

Nanofluids are biphasic suspensions of nanoparticles in conventional base fluids (<100 nm) of metal or metal oxide, which improve the thermal conductivity, k (W/m K) and the convective heat transfer coefficient, h (W/m^2 K). Nanoparticles are more stable in liquid media compared with larger particles, which give severe problems of abrasion, sedimentation and clogging, as early studies have shown [3,4]. However, nanoparticles produce an increase in the suspensions viscosity if compared to the base fluids and a composition with a non-Newtonian behavior [5]. Viscosity is also influenced by the dispersant used to reduce the sedimentation of the solid phase [6].

Nanofluids thermophysical properties were investigated by several studies on thermal conductivity and convective heat transfer coefficient for different materials and particle size. Minsta et al. [7] measured the thermal conductivity of water-based nanofluids using CuO nanoparticles with an average diameter of 29 nm, and Al_2O_3 nanoparticles with average diameters of 47 and 37 nm respectively. They observed an enhancement between 2% and 24% at room temperature, for a volume fraction between 1% and 14% of CuO; an increase of the thermal conductivity up to 30% with Al_2O_3, in a range of volume fractions from 1% to 18%, but no clear differences of results for the particle sizes. Lastly, they noted a temperature dependence of the thermal conductivity. Kim et al. [8] obtained a thermal conductivity enhancement of 8.0% and 11.0% with the dispersion of 3.0 vol% of Al_2O_3 nanoparticles, with an average diameter of 38 nm in water and ethylene glycol, respectively. Similar results were obtained using ZnO and TiO_2 nanoparticles, with

* Corresponding author. Tel.: +39 0832297752; fax: +39 0832297777.
E-mail address: gianpiero.colangelo@unisalento.it (G. Colangelo).

0306-2619/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.apenergy.2013.04.069

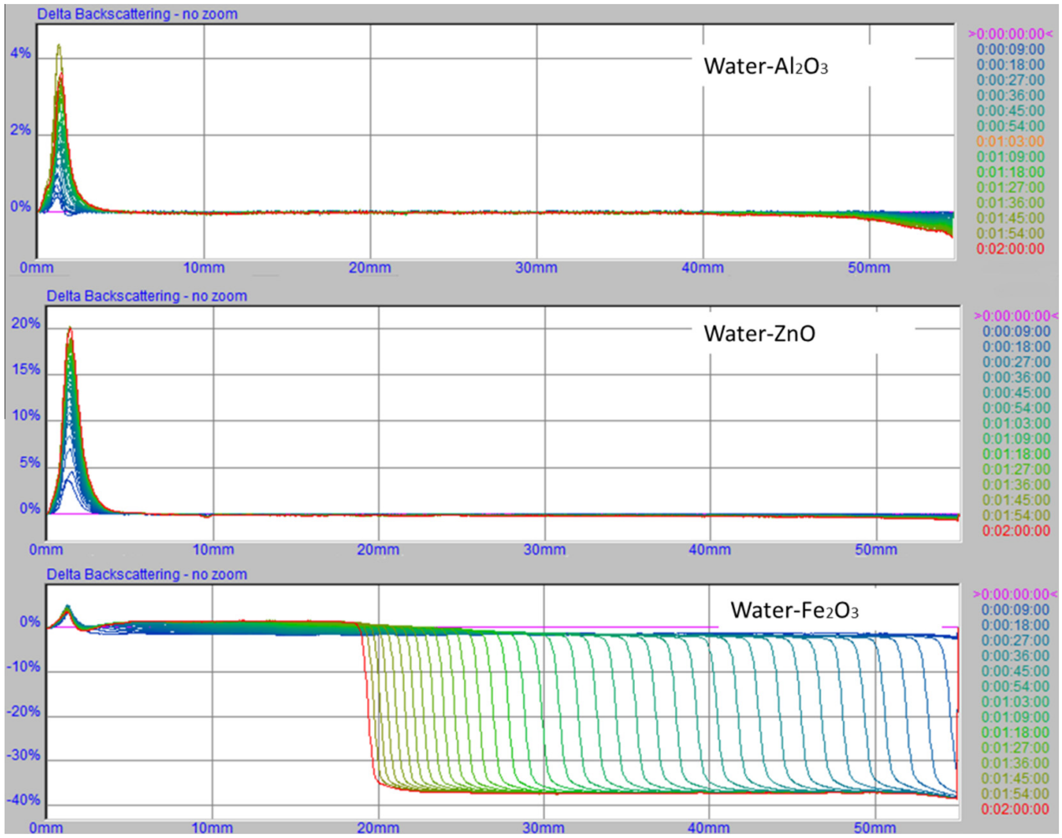

Fig. 1. Delta backscattering measurements of water based nanofluids at 1 vol%.

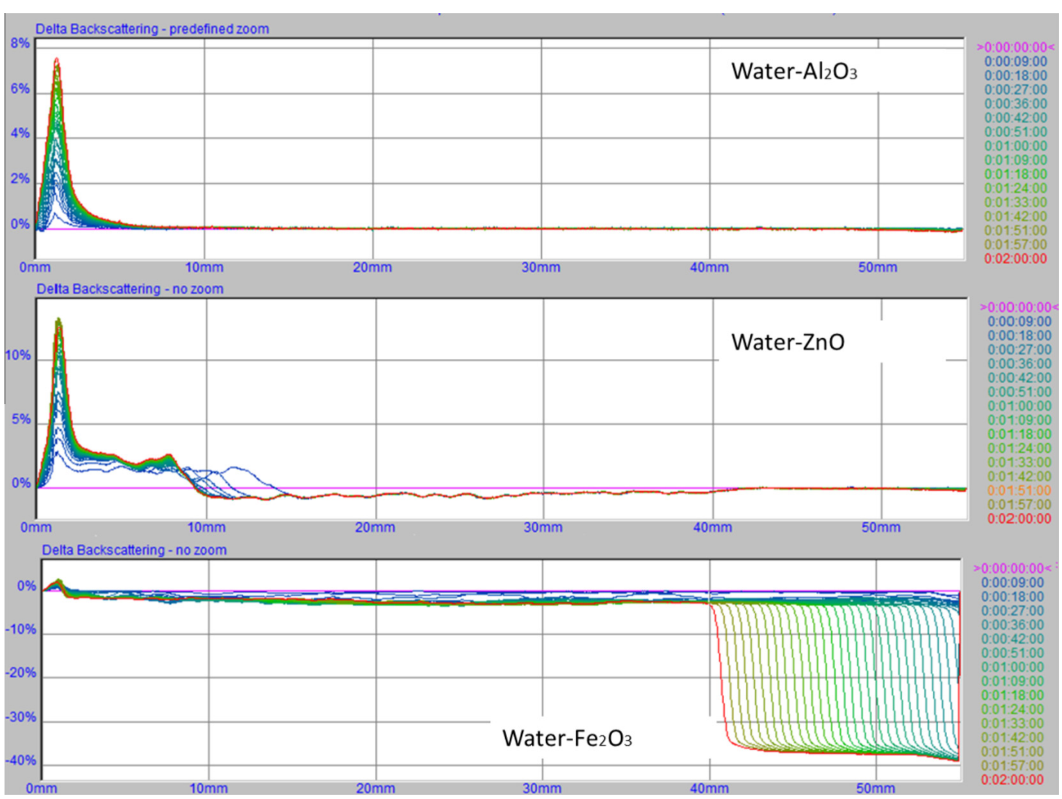

Fig. 2. Delta backscattering measurements of water based nanofluids at 2 vol%.

average sizes of 60 nm and 34 nm, while better enhancements were measured with a particle size of 10 nm. Hwang et al. [9] evaluated the thermal conductivity of oil-Multi-Walled-Carbon-Nanotube (MWCNT) and they obtained an enhancement up to 8.7%,