Journal of Cleaner Production 112 (2016) 3915–3926

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Energy and exergy efficiency of a flat plate solar collector using pH treated Al_2O_3 nanofluid

Z. Said [a, b, *], R. Saidur [c], M.A. Sabiha [b], A. Hepbasli [d], N.A. Rahim [e]

[a] Department of Engineering Systems and Management (ESM), Masdar Institute of Science and Technology, Abu Dhabi, United Arab Emirates
[b] Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[c] Centre of Research Excellence in Renewable Energy (CoRE-RE), King Fahd University of Petroleum and Minerals (KFUPM), Dhahran 31261, Saudi Arabia
[d] Department of Energy Systems Engineering, Faculty of Engineering, Yasar University, 35100 Bornova, Izmir, Turkey
[e] UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 29 April 2015
Received in revised form
21 July 2015
Accepted 22 July 2015
Available online 29 July 2015

Keywords:
Nanofluid
Flat plate solar collector
Energy
Exergy
Efficiency improvement
Al_2O_3

ABSTRACT

Application of nanofluid to increase the thermal efficiency of a traditional solar collector is getting tremendous attention among the scientific community. Al_2O_3–water nanofluid, as a working fluid and its effect on the energy and exergy efficiencies of a flat plate solar collector was examined experimentally. Volume fraction used for this study was 0.1% and 0.3%, while the size of the nanoparticles was ~13 nm. Experiments were carried out using a stable nanofluid which was obtained by controlling the pH of the solution over a period of 30 days. The mass flow rates of the nanofluid varied from 0.5 to 1.5 kg/min. Energy and exergy efficiencies of a flat plate solar collector using water and nanofluids as working fluids were matched. The results revealed that nanofluids increased the energy efficiency by 83.5% for 0.3% v/v and 1.5 kg/min, whereas the exergy efficiency was enhanced by up to 20.3% for 0.1% v/v and 1 kg/min. Thermal efficiency of the system was found to be more than 50% compared to the existing system available in the literature. New findings on the stability and exergy analysis of the solar collector system operated with a pH controlled nanofluid are reported.

1. Introduction

Solar energy research field is gaining increasing responsiveness in thermal applications, due to their extraordinary performance in energy storage density and energy conversion efficiency. Solar thermal processing is being used as the cleaner pathways for the production of hydrogen, carbon nano particles, industrial carbon black, and metals with substantially reduced CO_2 (Ozalp et al., 2010). For many years solar collectors have been existed. In the current years their practices are undergoing resurgence due to the focus in renewable energy sources (Joshi et al., 2005; Lee and Sharma, 2007; Sutthivirode et al., 2009; Fong et al., 2012; Tian and Zhao, 2013). Flat plate solar collectors have been broadly used to enhance the working fluid temperature within the range of 30 °C–100 °C. The performance of a flat plate solar collector depends on the absorption of solar radiation, which then in the form of absorbed energy is transferred to the working fluid inside the pipes of the solar collector (Kalogirou, 2004). Water, Ethylene glycol, acetone or a combination of water and ethylene glycol can be used as the working fluid (Choi and Eastman, 1995; Prasher et al., 2005), but the thermal conductivity of these fluids is low. Flat plate solar collectors are mainly used in domestic hot water system (Zambrana-Vasquez et al., 2015). Therefore, improving the performance of this type of solar collector is extremely crucial.

The first law of thermodynamics cannot identify the inner losses for calculating the flat plate solar collector's efficiency. However, second law of thermodynamics (i.e. exergy analysis) can determine and evaluate the causes of thermodynamic imperfection and able to indicate the possibilities of thermodynamic improvement of a system (Amini et al., 2007; Rosen, 2008). Though the first law of thermodynamics has been used by engineers and scientists but in recent years exergy concept has gained considerable interests in the thermodynamic analysis of thermal processes (Koroneos and Tsarouhis, 2012). Thus, the aim of this study will be on the comprehensive energy and exergy investigation of a flat plate solar collector operated with nanofluids.

* Corresponding author. Department of Engineering Systems and Management (ESM), Masdar Institute of Science and Technology, Abu Dhabi, United Arab Emirates.
E-mail addresses: zaffar.ks@gmail.com, zsaid@masdar.ac.ae (Z. Said).

http://dx.doi.org/10.1016/j.jclepro.2015.07.115
0959-6526/