Journal of Cleaner Production 92 (2015) 343–353

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Performance enhancement of a Flat Plate Solar collector using Titanium dioxide nanofluid and Polyethylene Glycol dispersant

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

[a] Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R & D, University of Malaya, 50603 Kuala Lumpur, Malaysia
[c] Department of Energy Systems Engineering, Faculty of Engineering, Yasar University, 35100 Izmir, Turkey
[d] Department of Electrical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[e] Department of Engineering Systems and Management, Masdar Institute of Science and Technology, PO Box 54224, Abu Dhabi, United Arab Emirates

ARTICLE INFO

Article history:
Received 26 November 2014
Accepted 3 January 2015
Available online 17 January 2015

Keywords:
Nanofluid
Pressure drop
Energy
Exergy
Thermal conductivity
TiO_2

ABSTRACT

The use of TiO_2–water nanofluid as a working fluid for enhancing the performance of a flat plate solar collector has been studied. The volume fraction of the nanoparticles was 0.1% and 0.3% respectively, while the mass flow rates of the nanofluid varied from 0.5 to 1.5 kg/min, respectively. Thermo-physical properties and reduced sedimentation for TiO_2-nanofluid was obtained using PEG 400 dispersant. The results reveal the impact and importance of each of these parameters. Energy efficiency increased by 76.6% for 0.1% volume fraction and 0.5 kg/min flow rate, whereas the highest exergy efficiency achieved was 16.9% for 0.1% volume fraction and 0.5 kg/min flow rate. Results showed that the pressure drop and pumping power of TiO_2 nanofluid was very close to the base fluid for the studied volume fractions.

1. Introduction

The fast development in population and economy accomplishments in tropical countries has resulted in an increase in energy intake, which accelerates the reduction of available energy resources. The reduction of conventional energy sources and increasing concerns on global warming are supporting the use of renewable and clean energy sources (Davis and Martín, 2014). Solar thermal energy is considered as one of the cleanest energy sources (Koroneos and Nanaki, 2012) and the production cost of solar energy is reducing with advances in technology (Fu et al., 2015). Solar collectors are the main components of solar energy system which transform solar radiation into heat which is transferred to a medium. Various types of solar collectors are available, but the most productive and commonly used is flat plate solar collector (FPSC). FPSC is cheaper and based on simpler technology, but it has comparatively low efficiency and outlet temperatures. There are several conventional approaches to improve the collector's efficiency. For example, the size can be optimized or the glazing materials altered, but these modifications are often inconvenient. One of the most convenient and effective methods to increase the efficiency is to substitute pure water (acting as the functioning fluid) with a higher thermal conductivity fluid. Solid nanoparticles can be suspended in a base fluid in order to obtain a high thermal conductivity. These fluids, known as 'nanofluids', can greatly enhance the heat transfer performance of conventional fluids (Yousefi et al., 2012a).

The highest possible useful work during a process, in which the system with a heat reservoir is brought into equilibrium, is defined as exergy of a system (Nguyen et al., 2014). Irreversibility in a process can reduce the exergy of a system. To optimize complex thermodynamic systems, an exergy analysis is used. The term exergy was proposed in 1956 by Rant, but the idea was not established until 1873 by Gibbs (1873). Exergy analysis has become a powerful method to evaluate the efficiency of thermodynamical systems by reducing energy related system losses, while maximizing energy savings and significantly help society to move towards sustainable development (Xydis, 2013).

Solar radiation which converted to heat is projected to deliver nearly 20% of overall heat demand by 2030 and 50% by 2050 in the European Union (EU). According to 'Vision 2030' by ESTTP

* Corresponding author. Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. Tel.: +60 3 7967 7611; fax: +60 3 7967 5317.
E-mail addresses: saidur@um.edu.my, saidur912@yahoo.com (R. Saidur).

http://dx.doi.org/10.1016/j.jclepro.2015.01.007
0959-6526/