Mechanical and Industrial Engineering-College of Engineering-Sultan Qaboos University

Experimental Testing and Analysis of Parabolic Concentrating Solar Collector with Al2O3-Water Nanofluid

Muntashir Mohammed Razzak

Abstract

Oman is an equatorial country that receives abundant solar energy. Perhaps the best method of harnessing this high availability of solar energy, both for private and commercial use, would be to employ solar collectors. These collectors can be of several types, such as non-concentrating flat plate or concentrating type. Parabolic trough collectors are concentrating collector's ideal for water heating, space heating and generation of electricity. It has been observed that nature and properties of the working fluid in the solar collectors and the type of receiver tube in concentrating type collectors can greatly affect its performance. In this project, a concentrating parabolic trough solar collector was constructed, and experiments were carried out to measure its performance. 2 types of receiver tube were utilized and compared – a bare stainless-steel receiver tube and an evacuated receiver tube. The Heat Transfer Fluid (HTF) used was water and Aluminum Oxide (Al2O3) Nanofluid of 30 nm diameter nanoparticle size, and the thermal performance of the nanofluids over the water as working fluid is contrasted. Nanofluids are fluids which contain immersed nanoparticles within the base fluid. The advantage that they possess over conventional heat transfer fluids, is their better thermal conductivity and convective heat transfer coefficients. The Al2O3 nanofluids were tested at 0.1%, 0.2%, 0.3% and 0.4% mass concentrations. Five different flow rates were used, ranging from 46 l/h to 138 l/h. Tests with the stainless-steel tube with water as the heat transfer fluid produced efficiency of 27% at a flow rate of 138 l/h. For tests with the evacuated receiver tube, the peak efficiency was 30.1% at the same flow rate, similar heat flux and operating conditions. Using evacuated receiver tube compared to the bare vi stainless-steel tube always produced thermal efficiency of approximately 3% higher. With regards to the variation of efficiency with the solar flux and time, it was determined that the highest efficiency is usually obtained at 12:30 PM in the afternoon, when the flux is highest. Subsequently experiments are repeated with Aluminum Oxide nanofluids of the 4 mass concentrations. Al2O3 of 0.4% mass concentrations produced better thermal efficiency results than lower mass concentrations. All the mass concentrations produced better efficiency than water. The peak thermal efficiency of 39.1% was obtained using the evacuated receiver tube and 0.4% mass fraction of nanofluids, flowing at 138 l/h. Under the same conditions for water as the HTF, the peak efficiency was 30.1%. Nanofluids also consistently gave better temperature difference compared to water when testing conditions were similar. On average the use of nanofluids over water provided an efficiency improvement of up to 9%. Therefore, from the results it can be concluded that the performance of the concentrating parabolic trough solar collector is enhanced by the usage of an evacuated receiver tube and aluminum oxide nanofluids as working fluids.

Keywords: Parabolic trough solar collector, Stainless steel receiver tube, Al2O3-water nanofluid, Thermal efficiency, Temperature difference, Flow rate, Mass concentration.

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