Experimental investigation of a carbon-based direct absorption parabolic trough solar collector

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1. Introduction

Recent studies have demonstrated the potential of nanoparticles to enhance the optical and thermal properties of heat transfer fluids (HTF) for direct absorption solar collectors (DASC) (Figure 1) [1-3]. Here, the HTF absorbs volumetrically the incident radiation, resulting in a more homogeneous fluid temperature distribution and reduced heat losses. By adding small volume fractions (0.001-1 vol%) of highly absorbing nanoparticles, the optical absorption of conventional HTF in the visible spectrum can be increased, allowing nanofluid-based DASC (NDASC) to compete with concentrating and non-concentrating solar thermal collectors [1, 4].

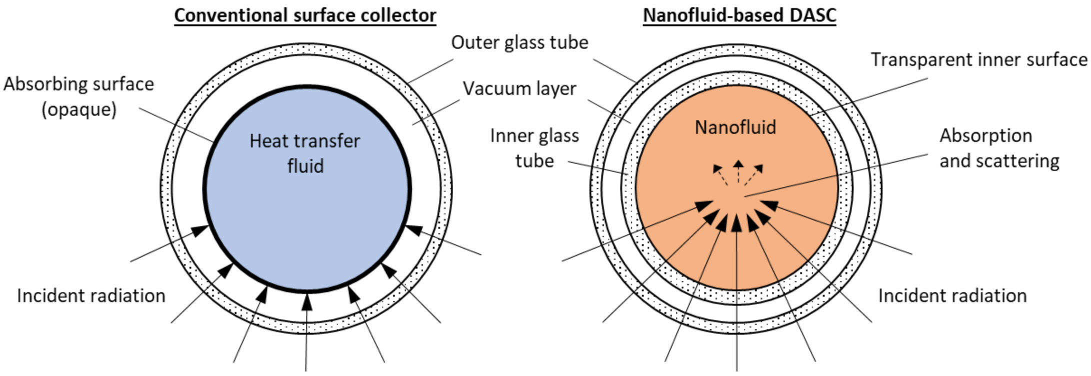

Figure 1: Schematic representation of the optical principle of a conventional tubular surface collector and a nanofluid-based tubular DASC.

Special attention is given to carbon nanoparticles owing to their outstanding optical and thermal properties. However, investigations related to graphene-based nanofluids for NDASC remain scarce. Consequently, our study aims to evaluate the performance of a graphene-based NDASC with a parabolic trough experimental pilot.

2. Nanofluid characterization

The 2D nature of graphene nanoparticles has been proven to strengthen the absorption properties of nanofluids owing to their high surface-to-volume ratio and inherent optical properties. In this work, the optical properties of a graphene dispersion in water in the UV, visible and near-infrared spectrum are investigated. Spectrophotometric measurements are conducted for nanoparticle concentrations ranging from 0.1 to 1 g/L. Results reveal a decrease of the optical transmission with the increment of graphene concentration. Furthermore, our investigations indicate that scattering of the nanofluid becomes negligible at concentrations equal to or higher than 0.2 g/L. Thereby, the extinction coefficient is considered equal to the absorption coefficient for these particle concentrations. By weight-averaging the spectral extinction coefficient with the AM1.5 spectrum, we observe a linear relationship between the mean extinction coefficient and particle concentration. The mean extinction coefficient increases from 32 m^{-1} to 272 m^{-1} for 0.1 to 1 g/L particles concentrations respectively. The optimum particle concentration for a NDASC application will depend on the receiver diameter, as it will determine the characteristic thickness of the fluid through which concentrated solar radiation passes. For our experimental collector dimensions, the optimal graphene concentration is 0.2 g/L to obtain a mean absorption of 88%.

3. Parabolic-trough NDASC experimental pilot

A NDASC parabolic trough experimental collector of 2m^2 aperture was designed and constructed. Unlike conventional parabolic trough collectors, this test facility features a 2-axis tracking concentrator with a double-glass evacuated tube of 33.6 mm inner diameter as linear receiver (Figure 2). A 0.2 g/L graphene nanofluid flows inside the inner tube to absorb the incoming radiation. The intercept factor of the collector has been evaluated qualitatively using the Camera-Target method (CTM). The primary objective of this experiment is to assess the efficiency of graphene-based concentrating collector and identify the areas of improvement. The experimental results reveal promising efficiencies as a function of the nanofluid mass flow rate.

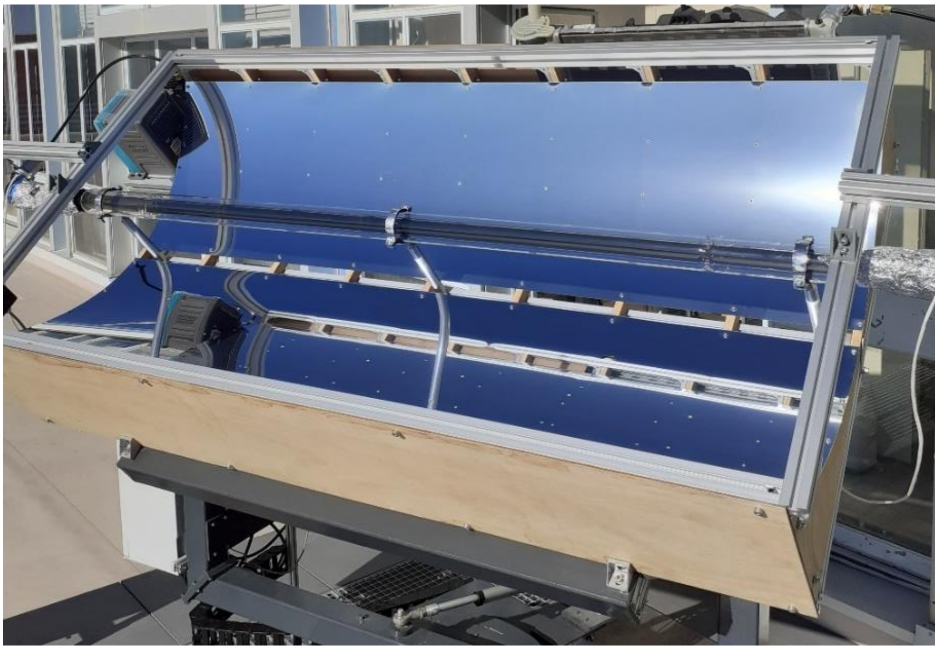

Figure 2: Parabolic trough NDASC experimental pilot with a 0.2 g/L graphene-based nanofluid.

References

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