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Improving Heat Transfer Performance of Flat Plate Water Solar Collectors Using Nanofluids

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Abstract: This study delves into both experimental and analytical examinations of heat exchange in a straight channel, where Al_2O_3-water nanofluids are utilized, spanning the Reynolds number spectrum from 100 to 1800. Diverse volume fractions (1%, 2%, and 3%) of Al_2O_3-water nanofluids are meticulously prepared and analyzed. The essential physical properties of these nanofluids, critical for evaluating their thermal and flow characteristics, have been comprehensively assessed. From a quantitative perspective, numerical simulations are employed to predict the Nusselt number (Nu) and friction factor (f). The empirical findings reveal intriguing trends: the friction factor experiences an upward trend with diminishing velocity, attributed to heightened molecular cohesion. Conversely, the friction factor demonstrates a decline with diminishing volume fractions, a consequence of reduced particle size. Both the nanofluid's viscosity and heat transfer coefficient exhibit a rise in tandem with augmented volume flow rate and concentration gradient. Notably, the simulation results harmonize remarkably well with experimental data. Rigorous validation against prior studies underscores the robust consistency of these outcomes. In the pursuit of augmenting heat transfer, a volume fraction of 3% emerges as particularly influential, yielding an impressive 53.8% enhancement. Minor increments in the friction factor, while present, prove negligible and can be safely overlooked.

Keywords: Nusselt number; friction factor; nanofluids; flat plate solar collectors; solar energy

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0 Introduction

Renewable energy emerges as a superior solution to the challenges of energy depletion, owing to its abundant availability and eco-friendly nature. Notably, solar water heater collectors stand out as a pivotal application of solar energy. These collectors serve the purpose of directly harnessing solar radiation and converting it into usable heat or electricity, finding applications across various industrial sectors. Engineered to harness sunlight's heat-absorbing potential, these collector systems play a crucial role in transforming solar energy into practical forms.

Defined as the component responsible for converting solar energy into diverse usable forms, the solar collector captures electromagnetic radiation across a spectrum, ranging from infrared to long-range ultraviolet (UV), with a visible solar energy component constituting 49%[1-3]. Enter nanofluids-dispersions of nanomaterials possessing enhanced properties. These nanofluids find extensive utility in diverse manufacturing contexts, including vehicle cooling, solar energy systems, and heat exchangers, thanks to their distinctive thermal attributes.

However, integrating nanoparticles into nanofluids introduces concerns, primarily surrounding nanoparticle stability within the base fluid. The interactions between nanoparticles and the overall stability of the nanofluid warrant thorough examination.

Previous research has explored the use of alumina nanoparticles at concentrations of 1%-3% mixed with water in laminar flow scenarios. Surface temperatures and pressure differentials across the test section were measured, revealing a notable increase in numerical values: 12%, 14%, and 16% enhancement in numbers correlating with nanofluid concentration and Reynolds number, respectively. This suggests that nanofluids have the potential to bolster the efficiency

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The impact of nanofluids' additives on overall solar system efficiency has been systematically evaluated. During experimental trials, the concentration of nanofluids proved to significantly influence the efficiency of solar collectors. This influence extended to parameters such as friction coefficient and Nusselt number, which were meticulously correlated through adept correlation equations. Moreover, input coefficients, including Reynolds number and nanoparticle size concentrations, were explored under flux conditions. Intriguing findings emerged from these computations. The authors substantiated that as the Reynolds number decreases, the coefficient of friction factor increases. Simultaneously, the coefficient of heat transmission exhibits an increment as both Reynolds number and particle size increase. This interplay underscores the intricate relationship between fluid dynamics, nanoparticle characteristics, and heat transfer efficiencies.

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