Experimental and Numerical Analysis of Heat Transfer in Grooved Tubes for Solar Collector Applications

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Abstract
Solar thermal energy research and utilization is progressing rapidly since it is clean energy and can achieve carbon credits in developed and developing countries. The energy conversion efficiency of most of the solar collectors is low, as much of the energy absorbed by collectors is lost due to transient atmospheric conditions. Reduction of losses and improving the performance of collectors by providing economical solutions has been the greatest challenge that scientists are facing even today. Material technology has achieved highest boundaries in all the applied fields ranging from medical to space. According to literature, the use of nanofluids in thermal devices improves the performance thereby further increasing the thermal conversion efficiency of solar collectors. The work here aims at numerically and experimentally studying the heat transfer enhancement obtained as a result of introducing grooved tube collector and using ZnO nanofluid as the working media in a solar flat plate collector. Helical grooves of different pitch are made in collector tubes that generate a spin flow which would increases the heat transfer rate at the expense of increased pressure drop. The convection heat transfer is enhanced as a result of flow through these grooved tubes which is the reason for the absorption efficiency increase. Heat transfer augmentation increase in grooved and plain tubes is compared here. Heat transfer augmentation is expected to increase when compared to a plain tube and a comparative analysis is carried out on the basis of the heat transfer coefficient, wall shear stress at constant Reynolds number and constant mass flow rate condition. The improvement in absorption efficiency at two different groove depth (e/d = .023, .0175) and varying flow velocity is also studied. The use of nanofluid has been a recent technological advancement as the metal/metal oxides dispersed in a base medium improved the absorptive solar energy by up to 95% which further increasing the thermal conversion efficiency. ZnO nanofluids are prepared by economical methods at different volume concentrations. The particle concentration is one determining
parameter and on increasing the concentration the heat transfer properties show a rise up to a maximum value and beyond which it decreases. The numerical analysis here is done for ZnO nanofluid with particle concentration varying from .5%–2%. The synergic effect of the two improvements in the heat transfer and fluid flow characteristic is studied experimentally and numerically in the transition and turbulent flow regimes.

Keywords
Flat plate collector, grooved tube, Heat transfer coefficient, Reynolds number, ZnO nanofluid