Direct Absorption Solar Collectors with Magnetic Nanofluid

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Abstract

Direct absorption collectors (DASC) with nanofluids demonstrate superior thermal performance relative to conventional flat plate collectors. The volumetric absorption of heat by both the nanoparticles and the liquid in DASC becomes more efficient in case the extinction coefficient of the nanofluid is optimal. When the metal nanoparticles are used, the collector gains extra performance due to enhanced thermal conductivity and an excess heating originating from surface plasmon resonance. Even more, the magnetic nanoparticles may increase the collector efficiency, converting under the influence of an external magnetic field. In this contribution, we foremost demonstrate experimentally that a lab-scale DASC with an aqueous iron oxide nanofluid (184 nm) is up to 25% more efficient than the same collector with a carbon black nanofluid (51 nm) at equivalent particle concentration. We further develop a multiphase CFD-model for the solar heating of a magnetic nanofluid with 8nm MnZn ferrite particles. Enhancing the most standard approach to model nanofluids as single-phase liquids with altered thermal properties, we extended the two-fluid Eulerian-Eulerian method to account for such details of the process as: Brownian dispersion and sedimentation of nanoparticles, inter-phase slip, in-phase volumetric absorption of thermal radiation and magnetic forces, acting on nanoparticles. The model was validated against two independent experimental benchmarks, demonstrating discrepancies below 10%. As it followed from our simulations, the magnetic convection increases DASC efficiency up to 30% in a moderate magnetic field of 113 mT.