CFD Simulations of Nanofluid Heat Transfer in Solar Thermal Applications

Dr. Ityona Amber
School of computing Engineering and Technology
Robert Gordon University
Aberdeen
UK

A computational fluid dynamics (CFD) study of the heat transfer performance of a tubular receiver carrying an oil-based nanofluid. Numerical simulations consider a sinusoidal tubular receiver, externally heated by a non-uniform solar heat flux, through which high temperature fluid(s); Syltherm 800 synthetic oil and oil-based Functionalised Multi-Wall Carbon nanofluid are transported. The flow is investigated for conditions over the range $4.25\times10^4 \leq Re \leq 4.25\times10^5$, corresponding to design flow values for a proposed solar receiver. Beyond this range, the flow is considered to be fully turbulent. The finite volume method commercially available ANSYS software is used to solve the coupled steady-state turbulent Navier-Stokes and energy equations using the κ - ω SST turbulence model. The thermophysical properties of the working fluids are assumed to be temperature dependent. The model has been rigorously validated against numerical and experimental data published in the literature. The results demonstrate that the use of FMCNT nanofluid led to a 27% increase in the Nusselt number, with a more significant 60.7% improvement at higher Reynolds numbers. The addition of rectangular fins contributed to a 33% increase in the Nusselt number, while maintaining a pressure drop of less than 40%. When both FMCNT nanofluid and fins were combined, the heat transfer coefficient improved by 74%, reaching 5516 W/m^2K, resulting in an overall performance increase of 96.2%. This study demonstrates that heat transfer in parabolic trough collectors (PTR) can be improved with nanofluids and fins.

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