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Mathematical model of heat mass exchange in a channel with a nanofluid under nonuniform heating by a concentrated heat flux

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This work is aimed at determining the expediency of using a nanofluid (a special suspension with nanoparticles) as a heat transfer agent for a parabolic trough solar plant. Adding nanoparticles to a base heat transfer agent intensifies convective heat exchange inside the channel, thus increasing the total heat efficiency of the receiver system. A refined nonlinear 3D mathematical model was developed to study heat-and-mass transfer in the receiver system of a parabolic trough solar plant that consist of a concentrator and a tube heat receiver with a nanofluid. In the mathematical model, the values of the nonuniform heat flux on the tube heat receiver surface are found by approximating numerical data obtained by the Monte Carlo method. This simplifies the classical coupled deterministic-statistical mathematical model and allows one to obtain a purely deterministic model solved by the finite volume method. The model also accounts for the thermal conductivity of the heat receiver wall, the actual ambient conditions, and the heat loss from the heat receiver surface. A numerical algorithm was developed to conduct numerical parametric studies on determining the temperature fields of Syltherm800/Al₂O₃ nanofluid heat transfer agent. This nanofluid is prepared from the traditional heat transfer agent of parabolic trough solar plants – Syltherm800 silicone oil – by adding aluminum oxide nanoparticles thereto. The numerical studies were conducted both for pure Syltherm800 oil and for Syltherm800/Al₂O₃ nanofluid with an Al₂O₃ nanoparticle concentration of 3, 5, and 8 per cent. This study is the first to find that the use of a nanofluid as a heat transfer agent for a parabolic trough solar plant produces a positive effect only in the case of the laminar flow of a nanofluid heat transfer agent with a high nanoparticle concentration. A verification of the obtained numerical data showed that they are in satisfactory agreement with experimental ones.

Keywords: *mathematical model, parabolic trough solar plant, heat transfer agent, nanofluid, numerical study.*

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