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ANSYS FLUENT Simulation of Natural Convection and Radiation in a Solar Enclosure

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Abstract : In this study, multi-mode heat transfer characteristics of spacecraft solar collectors are investigated computationally. Two-dimensional steady-state incompressible laminar Newtonian viscous convection-radiative heat transfer in a rectangular solar collector geometry. The ANSYS FLUENT finite volume code (version 17.2) is employed to simulate the thermo-fluid characteristics. Several radiative transfer models are employed which are available in the ANSYS workbench, including the classical Rosseland flux model and the more elegant P1 flux model. Mesh-independence tests are conducted. Validation of the simulations is conducted with a computational Harlow-Welch MAC (Marker and Cell) finite difference method and excellent correlation. The influence of aspect ratio, Prandtl number (Pr), Rayleigh number (Ra) and radiative flux model on temperature, isotherms, velocity, the pressure is evaluated and visualized in color plots. Additionally, the local convective heat flux is computed and solutions are compared with the MAC solver for various buoyancy effects (e.g. Ra = 10,000,000) achieving excellent agreement. The P1 model is shown to better predict the actual influence of solar radiative flux on thermal fluid behavior compared with the limited Rosseland model. With increasing Rayleigh numbers the hot zone emanating from the base of the collector is found to penetrate deeper into the collector and rises symmetrically dividing into two vortex regions with very high buoyancy effect (Ra >100,000). With increasing Prandtl number (three gas cases are examined respectively hydrogen gas mixture, air and ammonia gas) there is also a progressive incursion of the hot zone at the solar collector base higher into the solar collector space and simultaneously a greater asymmetric behavior of the dual isothermal zones. With increasing aspect ratio (wider base relative to the height of the solar collector geometry) there is a greater thermal convection pattern around the whole geometry, higher temperatures and the elimination of the cold upper zone associated with lower aspect ratio.

Keywords : thermal convection, radiative heat transfer, solar collector, Rayleigh number
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