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NUMERICAL STUDY OF THE BUNDLE EFFECT IN THE CONVECTIVE HEAT TRANSFER

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ABSTRACT A number of heat transfer applications make use of the heater element arrays or the banks of the heater tubes, like evaporators, core of a nuclear reactor, cooling of electrical devices, etc. The presence of multiple heating elements can either enhance or deplete the net heat transfer of the system. Hence, it is important to understand the interactive behavior of the heating elements and the convective flow of the fluids around them. A number of experimental studies have been carried out in this regard, which show that compared to the single tube, the heat transfer for the bundle may increase or decrease depending on the geometry and the working conditions. The objective of this work is to investigate the bundle induced effects on the natural convection heat transfer of individual tubes with respect to their position in the bundle. The system used is a 2D cross section of a water filled rectangular tank (400 mm x 200 mm x 180 mm) consisting of an inline arrangement of 16 tubes of diameter 20 mm each in three columns with an equilateral triangular pitch of 39 mm and s/D of 1.95. The transient, 2D simulations were carried out for the natural convection ($Ra = 2 \times 10^7$) heat transfer using volume of fluid method in OpenFoam 2.3. Simulations were run for the cases when a single, two and three tubes one above the other were heated; and an additional case where a total of seven tubes from three parallel columns were heated. Furthermore, an isolated single tube in the box was also numerically studied for various Ra values for comparison and validation purpose. The simulations were carried out for the boundary conditions of adiabatic walls and constant heat flux on the heated tubes. The system was considered to be at atmospheric pressure. The water in the container was assumed to be near saturated (370 K) and the Boussinesq approximation was assumed to be holding true. The results show that the heat transfer for the bundle is higher for even a single heated tube than that for an isolated single tube for the given geometry. The presence of the tubes in the bundle, even though unheated induce a chimney effect that tends to increase the flow velocity thereby increasing the heat transfer. But, the heat transfer keeps on decreasing for the each heated tube added on the upper side. Considering a particular tube, the heat transfer from it decreases when additional tubes above or below it are heated, compared to when it alone is heated in the bundle. The heating of the parallel columns of the tubes shows some asymmetry in the tubes of the side columns.