NATURAL CONVECTION HEAT TRANSFER FROM A HORIZONTAL, VERTICAL, SOLID OR HOLLOW CYLINDER: A NUMERICAL APPROACH

ABSTRACT

Numerical simulations have been carried out to study natural convection heat transfer from an isothermal horizontal or vertical solid or hollow cylinder in air. Three dimensional continuity, momentum and energy equations have been solved to predict the flow field and thermal plume around the cylinder. The present work has been categorized into five chapters. The first chapter is an introduction to the subject along with literature review while the second chapter is on the study of natural convection heat transfer from a short or long, solid or hollow horizontal cylinder suspended in air or placed on ground in a laminar range of Ra spanning from 10^4 to 10^8 for L/D in the range of $0.05 \leq \frac{L}{D} \leq 20$. It has been found that the average Nu for solid or hollow horizontal cylinders in air is marginally higher than when they are on ground for the entire range of L/D and Ra limited up to 10^7. Up to a Ra of 10^7 Nu for a solid cylinder in air is higher than that of Nu for a hollow cylinder in air but when Ra exceeds 10^7 Nu for a hollow cylinder is marginally higher than that of the solid cylinder until an L/D of 0.2. When, L/D exceeds 0.2 the situation reveres causing Nu for a solid cylinder to be again higher than that of the hollow cylinder when suspended in air. A solid cylinder on ground has higher Nu compared to that of a hollow cylinder on ground up to a Ra of 10^6. However, for higher Ra of 10^8 a hollow cylinder on ground has higher Nu compared to that of a solid cylinder on ground until an L/D of 5 and after that the situation reverses again. The third chapter presents the study about natural convection heat transfer from a hollow cylinder with inline and staggered holes. Interesting flow and thermal plume around the hollow cylinder with holes could be seen which could help to explain why there is more heat loss from a cylinder with staggered holes compared to a cylinder with inline holes at lower Ra of 10^5, whereas for higher Ra of 10^6 or more there exists an optimum d/D where the heat loss from the perforated cylinder has a maximum value and thereafter it reduces. A detail analysis of natural convection heat transfer from a vertical hollow cylinder in air in laminar ($10^4 \leq Ra \leq 10^8$) regime has been performed in chapter 4.The simulations have been carried out by changing the ratio of length to pipe diameter (L/D) in the range of $0.05 \leq L/D \leq 20$.It has been found that the average Nusselt number (Nu) for vertical hollow cylinder

suspended in air increases with the increase in Rayleigh number (Ra) and the Nu for both the inner and the outer surface also increases with Ra . However, with the increase in L/D, average Nu for the outer surface increases almost linearly whereas the average Nu for the inner surface decreases and attains asymptotic value at higher L/D for low Ra. In chapter 5, turbulent natural convection heat transfer from a vertical hollow cylinder suspended in air has been discussed in the turbulent range of Ra spanning from 10^{10} to 10^{12} and L/D from 0.125 to 20. Average surface Nusselt number and non dimensional mass flow rate of air through the hollow cylinder have been calculated and plotted with respect to the non dimensional input parameters such as Ra and L/D. Nu for both the solid and hollow cylinder increases with increase in Ra for all L/D. Nusselt number for the inner surface of the hollow cylinder is marginally lesser than that of the outer surface of the hollow cylinder for all L/D and Ra. Nu for a solid cylinder lies in between the Nu of the outer and inner surface of the hollow cylinder for all Ra and L/D. Correlations for Nu as a function of all the input pertinent parameters have been proposed in all the studies which could be used in academics as well as in industrial practices.