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Numerical Investigation of Natural Convection Heat Transfer on Aligned Arrangement Tube Banks

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Abstract

The aim of the present study is to numerical investigate the 2-D natural convection heat transfer on an aligned arrangement of tube banks. The fluid was considered to be Newtonian, laminar and steady state with Boussinesq approximation. Number of tube was varied from 6 to 8 and Rayleigh number changed from 10^6 to 10^8. The ratio of longitude distance to cylinder's diameter (d_L /D) and the ratio of transverse distance to cylinder's diameter (d_T /D) were varied in rang of 1.5, 2 and 3. Tubes diameter and the passing air temperature were assumed to be 30cm and 300K respectively. The computational fluid dynamics was used to investigate the changes of the mean Nusselt number of the fluid passing through aligned arrangement of tube banks. The results showed that the maximum heat transfer rate was for the case with d_T /D=2, d_L /D=2 and Ra=10^8 characteristics.

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Keywords: Natural Convection; Tube Banks; Aligned Arrangement

1. Introduction

Natural convection heat transfer has many important applications in various branches of science and industry including electronic cooling devices, heat exchangers, Metallurgy, chemical and food industry, electric machinery, solar energy collectors, and so on [1]. The natural convection heat transfer around various objects divides into

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internal and external flows categories. The internal flows are limited by walls or cavities and external flows around the object are analysing in free space. The Nusselt number is a dimensionless parameter which is used to describe the heat transfer. The natural convection heat transfer around a horizontal cylinder with Circular cross-sections has various applications. One way to solve this kind of problems is to use the boundary-layer theory, which can be used under certain conditions and by considering approximations to simplify the equations [2]. The Curvature of the surface in solving the natural convection flow on a horizontal cylindrical surface considers with a very small Gravity number. The dimensionless equation of the natural convection heat transfer around a cylinder with a constant surface temperature can be expressed as Eq. (1).

$$\mathrm{Nu} = \mathrm{cRa_D}^{\mathrm{m}}\mathrm{Pr}^{\mathrm{n}} \tag{1}$$

Where c, m and n are constant parameters. The heat transfer of tube banks for those which have been placed in an enclosure has a wide range of engineering applications. Providing a general relationship for heat transfer of tube banks in a pseudo-isometric flow is dependent on the parameters of Equation (2) [2].

$$Nu = \mathrm{f}\left(Gr_D, Pr, \frac{d_T}{D}, \frac{d_L}{D}, {}^{D}/_{d}, N_L\right) \tag{2}$$

According to a review of articles about tube banks, there has not been any numerical analysis for natural heat transfer of tube banks with aligned arrangement and simultaneous changes in longitudinal and transverse pitch and the number of cylinders located in laminar fluid flow. Hence the objective of this study was to investigate the changes in the mean Nusselt number of the fluid passing through the tube banks with aligned arrangements by using of Computational Fluid Dynamics (CFD). The following assumptions were considered in this study:

- A 2-D problem of natural convection heat transfer on tube banks with aligned arrangements.
- Air with laminar regime as fluid.
- Boussinesq approximation to solve the equations.

2. Governing equations and problem formulation

For analysing of natural convection heat transfer around the cylinders, a 2-D rectangular zone with symmetry boundary conditions has considered. Fig. 1 shows this rectangular zone with the length of 24D and the width of 5D. (D is the cylinder's diameter)

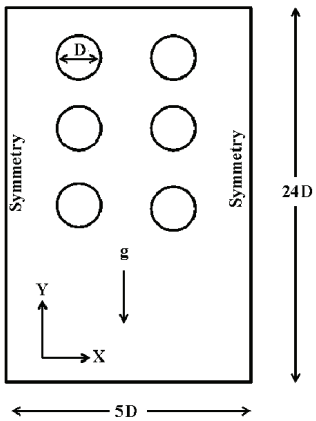

Fig. 1. Arrangement of 6 cylinders in tube banks with aligned arrangement.

The tube banks with aligned arrangement, which are exposed to the air flow with ratios of d_L, d_T and D are shown in Fig.2.