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Convective heat transfer around a triangular cylinder in an air cross flow

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ABSTRACT

Two dimensional laminar forced convection heat transfer around horizontal triangular cylinder in air is investigated numerically. Equilateral triangular cylinder of different side dimensions and configurations are examined under laminar conditions ($Re \leq 200$). Two configurations of the triangular cylinders are considered; one when the vertex of the triangle facing the flow and the other when the base of the triangle facing the flow. The computational procedure is based on the finite volume technique. Results are presented in the form of streamline and temperature contour plots around the circumference of the cylinder. Comprehensive discussion is also reported about the development of wakes at the rear of the cylinder for both configurations. Critical Reynolds number for both vertex facing and base facing flow are obtained as 38.03 and 34.7 respectively. Furthermore, heat transfer data are generated and presented in terms of the average Nusselt numbers versus the Reynolds numbers. The drag coefficient is also presented versus Reynolds number and validated by comparison with the available data in the literature. General correlations of Nusselt numbers are obtained for $Re \leq 200$ to cover the two investigated triangular configurations. A general correlation for each configuration is obtained and compared with the previous available results.

1. Introduction

Triangular cylinders in cross flow have many engineering applications in cooling of electronic components and heat exchangers. Survey of the literature shows that, correlations for the overall averaged Nusselt numbers for forced convection heat transfer from circular and non-circular cylinders have been reported by different authors. Churchill and Bernstein [1] have reported single comprehensive equation that cover the entire range of Reynolds number for circular cylinder in cross flow for a wide range of Prandtl number as follows:

$$\overline{Nu}_D = 0.3 + \frac{0.62 Re_D^{0.5} Pr^{1/3}}{\left[1+(0.4/Pr)^{2/3}\right]^{1/4}}\left[1+\left(\frac{Re_D}{282,000}\right)^{5/8}\right]^{4/5} \qquad (1)$$

The fundamentals of flow around circular cylinders have been reported in the standard reference by Zdravkovich [2] where Reynolds numbers range were given for different regimes of flow around smooth circular cylinder in steady flow. The applications and interpretations of data on flow around circular cylinders either experimental data, theoretical models, or computer simulations were comprehensively surveyed by Zdravkovich [3]. A review of the development and discoveries of several phenomena in the circular cylinder has been reported by Williamson [4]. The wake structure behind a circular cylinder has been computed for both two and three dimensional flow past a circular cylinder by Rajani et al. [5]. Aref et al. [6] have studied the bifurcations of the streamline pattern behind a bluff body as a vortex wake is produced. They have also reported two empirical correlations for the Strouhal number for the wake-producing flow behind a circular cylinder in cross flow; one for flow up to $Re = 200$ and the other for $Re \geq 400$. Their formula up to Reynolds number of 200 (laminar regime) is reported here for comparison.

$$St = 0.2175 - \frac{5.1064}{Re} \qquad (2)$$

Numerical simulation of two dimensional flow over a circular cylinder using the immersed boundary method has reported by Silva et al. [7]. In their results; the lift and drag coefficients and the Strouhal number were obtained for different Reynolds number up to $Re = 300$. Heat and fluid flow across a square cylinder in the two dimensional laminar flow regime have been studied for two different thermal boundary conditions by Sharma and Eswaran [8] in unconfined flow with artificial confining boundaries at blockage ratio = 1/20. The following correlation has been reported by [8] for an isothermal square cylinder in cross flow of air and it is shown here for comparison:

$$Nu = 0.359\sqrt{Re} + 0.442, \quad 1 \leq Re \leq 160 \qquad (3)$$

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