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Effect of wall proximity of two staggered triangular cylinders on the transport process in a channel

Mousa Farhadi *, Kurosh Sedighi, Afshin Mohsenzadeh Korayem

Faculty of Mechanical Engineering, Babol University of Technology, Babol, Islamic Republic of Iran

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A B S T R A C T

A numerical investigation has been carried out to analyze the heat transfer and the flow field around two isothermal triangular cylinders of equal size placed staggered in a horizontal plane channel with adiabatic walls. Computations have been carried out for Reynolds numbers (based on triangle width) 100, 250, and 350, lateral gap ratios (d/B) 0, 0.5, and 1, and longitudinal gap ratios (S/B) 1, 2, 3 and 4. The effect of longitudinal and lateral gap between obstacles and proximity of channel walls is investigated. Results show that when obstacles are placed in close vicinity of the channel's wall (d/B = 1), vortex shedding disappears at the downstream of triangles at Re = 100 and 250 at all S/B, but for Re = 350 creating and disappearing of the vortex shedding depend on the longitudinal gap ratio (S/B). Proximity of obstacles has more effect on the second triangle than the first triangle especially from longitudinal gap ratio equals 2, so that with approaching the channel wall, the Nusselt number for the first triangle decreases, while for the second triangle a different behavior is seen. Staggered arrangement causes the Nusselt number of the second triangle to become greater than the first triangle.

1. Introduction

Staggered arrangement of obstacles has been always one of the points of interest in heat transfer and fluid mechanic field. It is perhaps because of decreasing drag coefficient and increasing heat transfer. Wang et al. [1] studied drag reduction of a circular cylinder experimentally while a rod was placed upstream of the cylinder. They showed that the upstream rod can reduce the resultant force of the cylinder at various spacing between the rod and the cylinder for $\alpha < 5^\circ$ (α defined as the staggered angle of the rod and the cylinder), but for $\alpha > 10^\circ$ upstream rod cannot reduce the force on the cylinder any more. Zhang et al. [2] studied square cylinder with an upstream rod in a staggered arrangement. They found six different flow modes with various staggered angles and spacing ratios. Molki and Fotouhi [3] investigated the laminar forced convection heat transfer from a circular cylinder numerically. The results showed that the periodic nature of eddies causes an oscillatory behavior in the heat transfer coefficients. Sumner et al. [4] studied vortex shedding for different gap spaces and staggered angle, and they found that the behavior of the Strouhal number depends on the space of the circular cylinders. Dey and Das [5] investigated the drag and lift reduction on square cylinder with triangular solid numerically. The effect of triangular length and inclination angle on drag and lift coefficients was studied. Akbari and Price [6] studied flow patterns around two staggered circular cylinders in cross-flow at Re = 800. They found five distinct flow regimes, depending on pitch ratio and staggered angle. Matos et al. [7] studied staggered finned circular and elliptic tubes. They showed that the elliptical tube arrangements have better overall performance and lower cost than the traditional circular tube geometry. Ghosh et al. [8] investigated forced convective heat transfer over a bank of staggered cylinders. They showed that the rates of heat transfer between the fluid and the staggered cylinders are affected by both the Reynolds number and cylinder spacing.

The flow of fluids past bluff bodies such as square and circular cylinders occurs in many industrially important applications [9]. One of the basic configurations that can be also used as a bluff body is a triangular obstacle [10–16]. By reviewing the literature, it reveals that it has not been studied enough especially in the heat transfer field. Buresti et al. [10] carried out an experimental investigation for triangular prisms with two different cross sections (i.e. equilateral and isosceles with 90° apex angle). They tried to find the critical aspect ratio that below it vortex shedding shifts from alternate type (i.e. the usual Karman alternate shedding of vortices from the two sides of the body) to the second type of shedding (i.e. a symmetrical shedding of "arch-type" vortices). But just alternate vortex shedding was found for all aspect ratios. Csiba and Martinuzzi [11]

* Corresponding author. Tel.: +98 111 3234205, fax: +98 111 3212268.
E-mail address: mfarhadi@nit.ac.ir (M. Farhadi).
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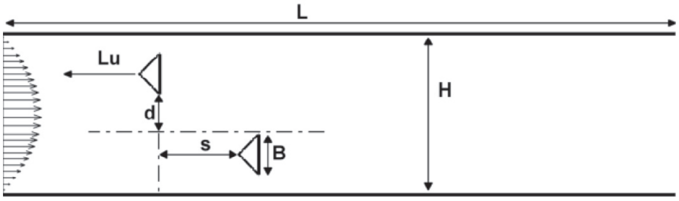

Fig. 1. Geometry of problem.

investigated experimentally the influence of the incidence angle of the Strouhal number of an isosceles triangle. They showed that when the Strouhal number is defined based on the triangle width (B), the Strouhal number increases with incidence angle, α, but when the Strouhal number is defined based on B′ = Bcosα as a length scale, Strouhal number is independent of α. The laser Doppler velocimetry

Table 1
Results of grid dependence.

Grid	Δx_{min}, Δy_{min}	$\langle \overline{Nu} \rangle_{\text{first obstacle}}$	$\langle \overline{Nu} \rangle_{\text{second obstacle}}$
187 × 68	0.023B	5.31	6.56
215 × 89	0.014B	5.52	6.81
215 × 100	0.012B	5.65	6.90
230 × 110	0.008B	5.7	6.93

(LDV) study of Ulrichs and Herwig [12] over a right-angled triangle about the separation behavior of bluff bodies in the vicinity of a wall showed that when the triangle is placed in the vicinity of the wall there will be two separate regions: (i) bluff body separation region and (ii) wall bounded separation region. As the triangle moves away from the wall, the wall bounded separation region eventually disappears. Abbassi et al. [14] carried out a numerical investigation to study forced convection of air for a two-dimensional

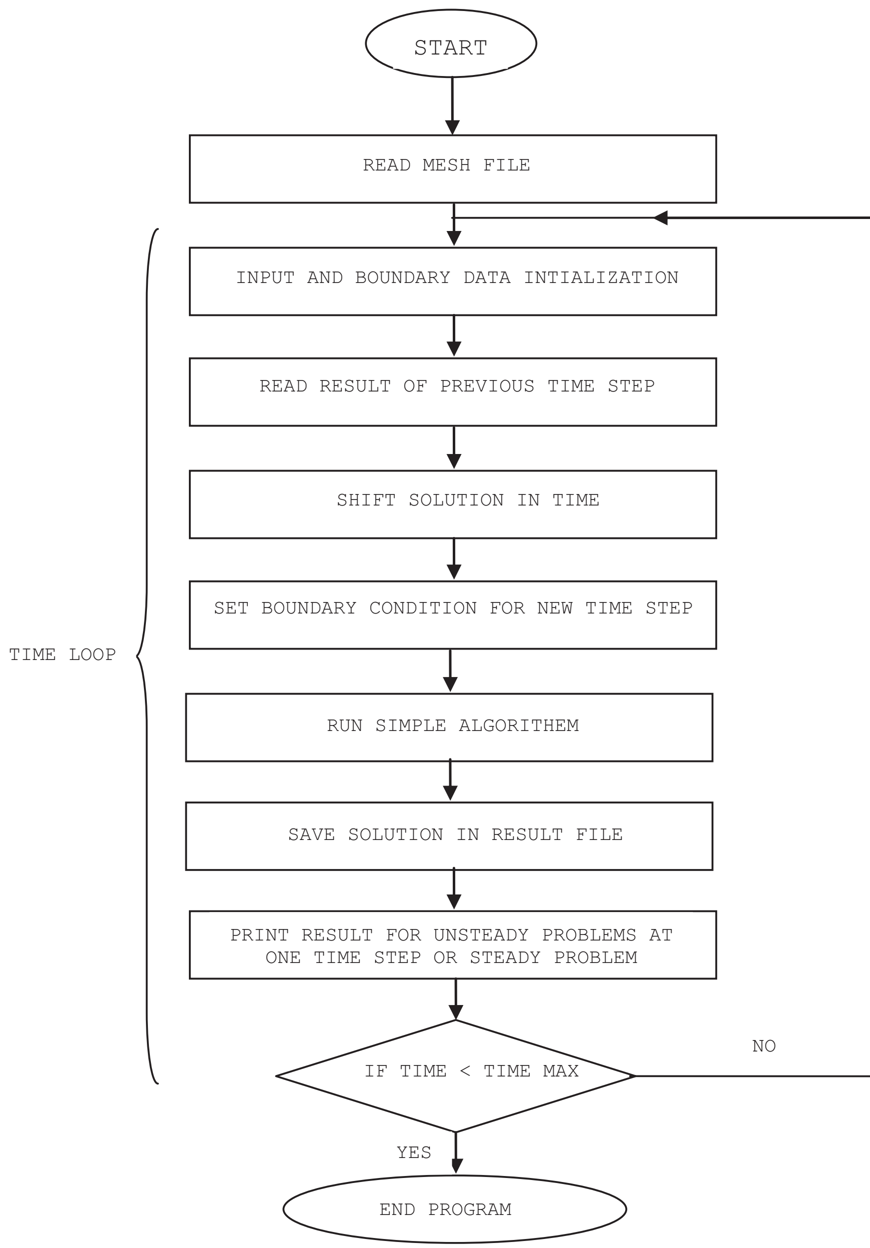

Fig. 2. Simple algorithm of the UTFN code.

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