

# Effect of Thermal Buoyancy on the Wake Behaviour of a Triangular Cylinder: A Review

Babita Rai<sup>1</sup>, S.K. Singh<sup>2</sup>P.G. Scholar, Dept. of Mech. Engg., M.B.M. Engg. College/J.N.V University, Jodhpur, Rajasthan, India<sup>1</sup>Professor, Dept. of Mech. Engg., M.B.M. Engg. College/J.N.V. University, Jodhpur, Rajasthan, India<sup>2</sup>

**ABSTRACT:** Heat transfer characteristics of cylindrical bluff body finds importance in the design of thermal systems. For a heated cylinder, flow becomes complicated due to developed buoyancy forces. Contamination of the thermal buoyancy in low Reynolds number forced flow significantly influences the wake dynamics, flow field and heat transfer. Cross-section of the cylindrical body also decides heat transfer from the body. Heated circular and square cross-section bluff-bodies are mostly studied. Heated triangular cross-section cylinder has very limited available literature. Present paper first discusses the fundamental terms related to the effect of thermal buoyancy on the fluid flow around cylindrical bluff-bodies. Then the paper reviews recent literature for the flow past a triangular cross-section cylinder in mixed convection regime considering the effect of buoyancy. The review has been presented for cross-buoyancy, aiding-buoyancy and opposing-buoyancy flow configurations. Effect of buoyancy parameter i.e. Richardson number (Ri) on Strouhal number, drag coefficient, lift coefficient, critical Reynolds number, local and averaged Nusselt number have been discussed. Effect of Richardson number on the flow field has been illustrated by instantaneous streamlines.

**KEYWORDS:** Triangular cylinder, vortex shedding, thermal buoyancy, mixed convection.

## I. INTRODUCTION

Heat transfer behavior of cylindrical bluff-bodies has been the topic of great significance due to its engineering applications in heat exchangers, electronics cooling, nuclear reactors and design of thermal systems. Researchers have extensively studied the flow past circular and square cross section cylinders. Triangular cylinder being a sharp edged bluff body has potential to change the flow and temperature field significantly. Rai and Singh (2017) presented a comprehensive review of unsteady flow and heat transfer around a triangular bluff-body. The authors discussed basic terms and parameters related to fluid flow and heat transfer around cylindrical bluff-bodies and presented recent review of flow past a triangular cross section cylinder in great detail. Rai and Singh (2017), in their review covered investigations of flow across unheated triangular cylinder and heated triangular cylinder without considering the effect of thermal buoyancy. In the present paper, effect of thermal buoyancy on the wake behavior of a triangular cylinder is reviewed. Therefore, related basic terms and parameters are omitted here and can be viewed in Rai and Singh (2017). However, basic theory and definition related to effect of buoyancy are discussed below.

### 1.1 Heat transfer from a cylindrical bluff-body

When a cylindrical bluff-body is heated and its temperature is higher than the temperature of the surrounding fluid, heat transfer takes place between the body and the surrounding fluid primarily by convection mode. Natural convection takes place when fluid motion is caused by thermal buoyancy forces that result from the density variations, due to variations of temperature in the fluid. Heat induced thermal buoyancy force in natural convection heat transfer is characterized by a non-dimensional number known as Grashof number (Gr). It is defined as:

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 12, December 2017

$$\text{Grashof number (Gr)} = \frac{\rho^2 g \beta (T_w - T_\infty) d^3}{\mu^2}$$

Where,  $g$  = gravitational acceleration,  $T_w$  = Surface temperature of the body,  $T_\infty$  = free stream temperature,  $d$  = Projected width of the body. Forced convection between a heated body and surrounding fluid takes place when fluid is forced to flow over the heated body by some external source such as fans, blower, or pumps and creating an artificially induced convection current. Heat transfer characteristics of a heated bluff body is expressed by quantitative parameter known as Nusselt number ( $Nu = hd/k$ ).

## 1.2 Mixed convection heat transfer and Richardson number

When dealing with forced convection, the effects of natural convection are ignored. Similarly, forced convection is assumed to be negligible while dealing with natural convection. These are simplifying assumptions. However, in some situations free and forced convection effects are comparable. Mixed convection is a kind of heat transfer due to combined effect of natural convection and forced convection. This situation arises when the flow velocity is low and high temperature gradients are available in the flow field. The mixed convection heat transfer is characterized by a non-dimensional parameter called Richardson number (Ri). This shows relative importance of natural convection to that of forced convection heat transfer. It is defined as the Ratio of Grashof number to the square of the Reynolds number of the flow field.

$$\text{Richardson number (Ri)} = \text{Gr}/\text{Re}^2$$

In this equation, Gr characterizes the natural convection whereas Re characterizes the forced convection. If  $Ri = 0$  or  $Ri \rightarrow 0$ , then heat transfer is assumed to take place by forced convection. For mixed convection, both natural convection and forced convection effects must be considered in heat transfer calculations and Ri is of the order 1.

## 1.3 Effect of fluid flow direction on mixed convection heat transfer

In mixed convection heat transfer, the influence of heating depends upon the direction of free stream flow relative to the direction of buoyancy force (direction of gravity). There are three different types of mixed convection flow configurations that have been studied in literature. These are given as under:

**Aiding buoyancy:** This situation occurs when the buoyancy force (B) is in the same direction as of the forced motion ( $U_\infty, T_\infty$ ). The angle between forced flow and buoyancy force is zero. Vertically upward flow ( $T_\infty$ ) over a heated body ( $T_w > T_\infty$ ) is an example of aiding buoyancy. Figure 1.1 (a) shows the vertically upward flow over heated triangular cylinder with vertex of the cylinder facing the flow. Due to heating of the cylinder, buoyancy force is also in vertically upward direction. This is a case of aided buoyancy configuration.

**Opposing buoyancy:** It occurs when buoyancy force is in the opposite direction to that of forced motion. The angle between forced flow and buoyancy force is  $180^\circ$ . Vertically downward flow on a heated body or vertically upward flow on a cooled body ( $T_w < T_\infty$ ) is an example of opposing buoyancy. Figure 1.1 (b) shows the vertically upward flow over cooled triangular cylinder. This is the example of opposing buoyancy configuration.

**Cross-stream buoyancy:** It occurs when the buoyancy force is in the perpendicular direction to that of the forced motion. Figure 1.1 (c) shows horizontal flow over heated or cooled triangular cylinder. The buoyancy force is either in vertical upward or vertical downward direction. Hence, flow direction is always normal to the buoyancy force direction and it is the example of cross buoyancy configuration.

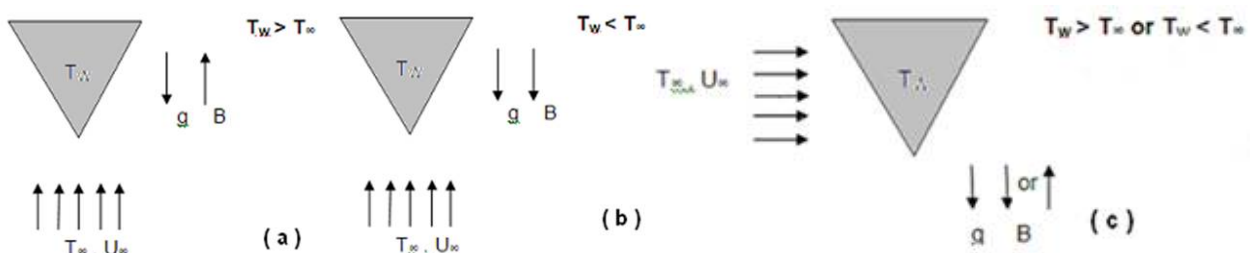


Figure 1.1: Schematic diagram of mixed convection configurations (a) aiding, (b) opposing and (c) cross buoyancy [g: gravity, B: buoyancy].

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 12, December 2017

## II. LITERATURE REVIEW

Present paper reviews recent literature related to the effect of thermal buoyancy on the wake behaviour of a triangular cylinder. The review has been presented for cross-buoyancy, aiding-buoyancy and opposing-buoyancy configurations. The behavior of flow and heat transfer parameters e.g. Strouhal number, drag coefficient ( $C_d$ ), lift coefficient ( $C_l$ ), critical Reynolds number, local and time-averaged Nusselt number have been discussed as a function Richardson number ( $Ri$ ).

### 2.1 Mixed convection flow past a triangular cylinder in cross-buoyancy configuration

Abbassiet. *al.* (2001) numerically investigated the mixed convection of air in a horizontal channel with built in triangular cylinder having an aspect ratio of 0.5. The channel was heated from bottom wall with Grashof number ( $Gr$ ) ranging from 0 to  $1.5 \times 10^4$  and Reynolds number based on the cylinder base was 100. Figure 2.1 shows that at Grashof number ( $Gr$ ) = 0, the Von Karman vortex street is centered at the axis channel. However, as Grashof number increases upto  $5 \times 10^3$ , convective cells appear alternatively from near the bottom and top walls along the curvatures of the Von Karman street. On further increasing the Grashof number to  $1.5 \times 10^4$ , thermal buoyancy force becomes important and fluid particles rise from the bottom to the top of channel. Von Karman street was seen to leave the channel axis and approach the bottom wall. The convective cells near the hot bottom wall were crushed by vortex street and the convective cells near top wall increased in the size due to sufficient space available.

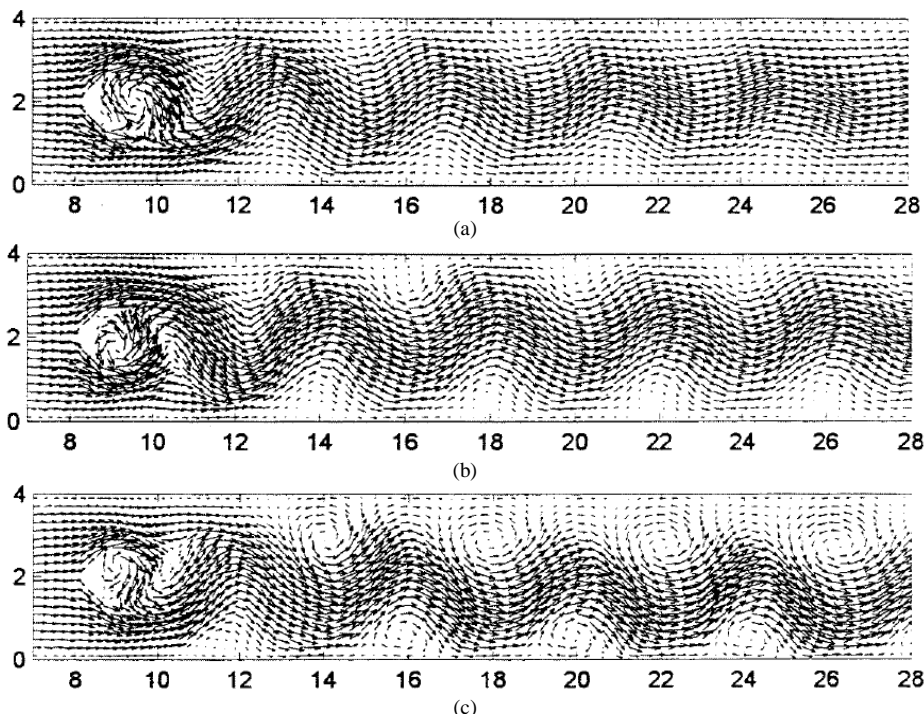


Figure 2.1: Flow structures at different Grashof numbers, (a)  $Gr = 0$ , (b)  $Gr = 5 \times 10^3$  and (c)  $Gr = 1.5 \times 10^4$ , Abbassiet. *al.* (2001).

Abbassiet. *al.* (2002) in a later study extended the study of laminar flow and heat transfer across a differentially heated horizontal channel with built in triangular prism. The Reynolds number and Grashof numbers was in the range 30 to 200 and 0 to  $1.5 \times 10^4$ , respectively. In figure 2.2, the authors showed that for Grashof number less than  $5 \times 10^3$ , averaged Nusselt number is almost constant and have the value nearly equal to that of forced convection. For Grashof number ranging from  $5 \times 10^3$  to  $10^4$ , averaged Nusselt number starts to increase slowly due to appearance of

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 12, December 2017

convective cells. When the Grashof number exceeds the value of  $10^4$ , the slanting of vortex Street to the hot wall increases the heat transfer considerably.

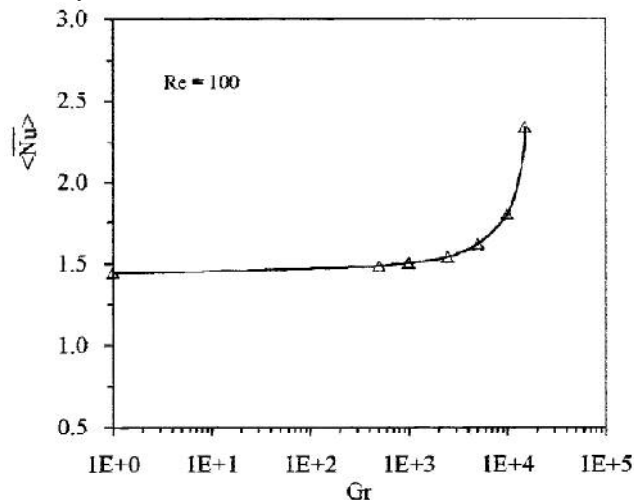


Figure 2.2: Variation of averaged Nusselt number with Grashof number (Gr) for Re 100, Abbassiet. *al.* (2002).

Hassabet *al.* (2013) experimentally studied the mixed convection heat transfer from three different sized equilateral triangular cylinders of side length 37, 50 and 70 mm. In the experiments, the Grashof number, Reynolds number and attack angles were ranging from  $26.32 \times 10^4$  to  $213.46 \times 10^4$ , 75.3 to 1251.6, and  $0^\circ$  to  $180^\circ$ , respectively. The authors reported that heat transfer is primarily by convection through side walls of the triangular cylinders. Average Nusselt number increases by increasing the triangular side length at the same Reynolds number and Richardson number.

Chatterjee and Mondal (2015) numerically simulated 2-D unconfined laminar flow behind a long heated equilateral triangular cylinder to study the effect of cross buoyancy on the vortex shedding behavior. The Reynolds number range was  $10 \leq Re \leq 100$  and Richardson number range was  $0 \leq Ri \leq 1$ . Figure 2.3 demonstrate the effect of thermal buoyancy on overall streamlines pattern. Figure shows that increased heating causes an upward drift of the streamlines in the wake zone, symmetry is lost and instability is intensified.

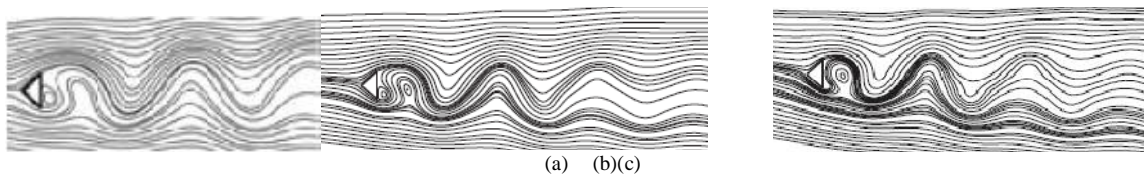


Figure 2.3: Instantaneous streamlines at Re = 100 for different Ri, (a) Ri = 0, (b) Ri = 0.5 and (c) Ri = 1.0, Chatterjee and Mondal (2015).

Figure 2.4(a) shows time variation of lift coefficient for Re = 100 at different Richardson numbers. Time signal of lift coefficient has sinusoidal variation and amplitude of fluctuation increases with increased heating. Figure 2.4 (b) shows the variation of time average lift coefficient with Reynolds number for different Richardson numbers. The average lift coefficient is zero at Ri=0 due to symmetric wake about the wake centerline. Heating induces asymmetry in the wake resulting in non-zero lift coefficient for Ri > 0. Increased heating produces stronger negative vortex and cylinder experiences a downward lift i.e. negative lift coefficient.

Figure 2.5(a) shows the variation of average drag coefficient with Reynolds number for different Richardson number. It was observed that at relatively lower Re, the drag coefficient was much higher for all Ri. However as Reynolds number increases, its value drops (for all Ri) due to flow separation. In vortex shedding regime ( $Re > 40$ ), the drag coefficient again increases with Re for all Richardson number. The drag coefficient decreases monotonically with increase in Richardson number. Figure 2.5 (b) shows the variation of Strouhal number with Reynolds number for different Richardson number. Strouhal number increases with Reynolds number and it is higher for high Richardson number.

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 12, December 2017

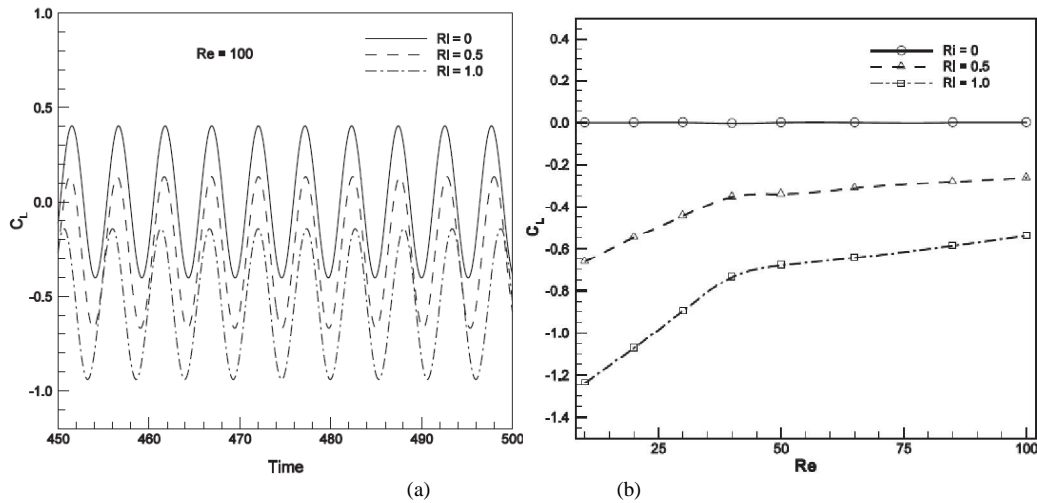


Figure 2.4: (a) Time variation of lift coefficients for  $Re = 100$  at different  $Ri$  and (b) Variation of time averaged lift coefficient with  $Re$  for different  $Ri$ , Chatterjee and Mondal (2015).

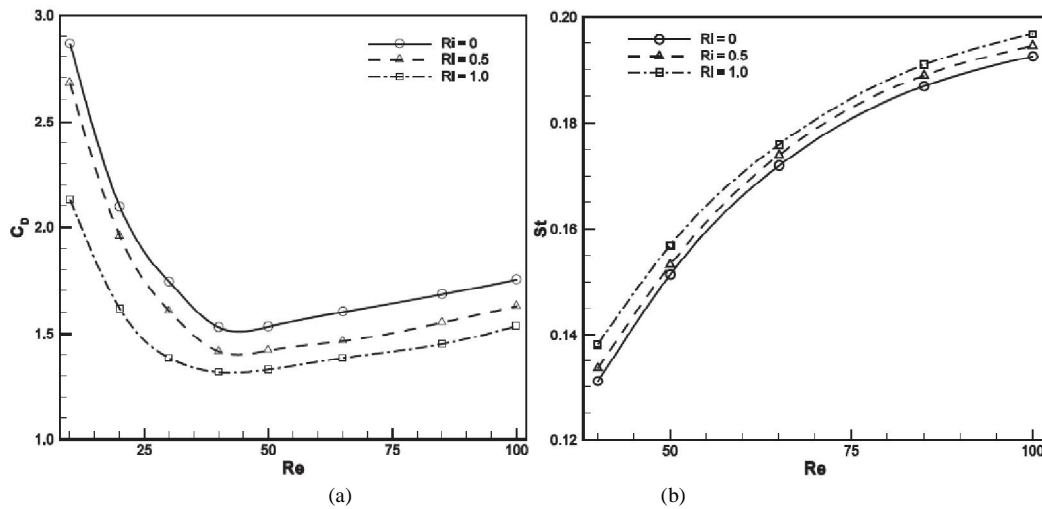


Figure 2.5: Variation of (a) Time averaged drag coefficient and (b) Strouhal number with  $Re$  for different  $Ri$ , Chatterjee and Mondal (2015).

Figure 2.6 (a) shows the variation of averaged Nusselt number with Richardson number for different Reynolds number. Averaged Nusselt number slightly increases with Richardson number and is higher for higher Reynolds number. Distribution of local Nusselt number along the surface of cylinder is shown in figure 2.6 (b) at  $Re = 100$  for different Richardson numbers. The figure shows that more heat transfer rate is experienced by the lower slanted surface (AC) of the cylinder as  $Ri$  increases. However, heat transfer rate decreases with  $Ri$  on upper slanted side (AB). The rear face (BC) experiences a change in symmetric to unsymmetrical distribution of Nusselt number as  $Ri$  increases from 0 to 1.

Rasool *et al.* (2015) investigated the effect of cross-buoyancy mixed convection for a confined equilateral triangular cylinder at a fixed blockage ratio of 25%. The Reynolds number was ranging from 1 to 150 and Richardson numbers in the range from  $Ri = 0$  to 2. The authors reported critical Reynolds number for the onset of periodic unsteady flow for  $Ri = 1$  and 2. Figure 2.7 shows the temporal history of lift coefficient for the Reynolds number 61 and 62 at  $Ri = 1$  (a and b) and for the Reynolds number 90 and 91 at  $Ri = 2$  (c and d). The figure shows that lift coefficient decays with time

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 12, December 2017

and becomes steady at  $Re = 61$  for  $Ri = 1$  and at  $Re = 90$  for  $Ri = 2$ . However, lift coefficient becomes periodic at  $Re = 62$  for  $Ri = 1$  and at  $Re = 91$  for  $Ri = 2$ . Therefore, critical Reynolds number exists between  $Re = 61$  and  $62$  for  $Ri = 1$  and between  $Re = 90$  and  $91$  for  $Ri = 2$ . The authors referred the value of critical Reynolds number for  $Ri = 0$  as 59 from the study of Srikantet. *al.* (2010).

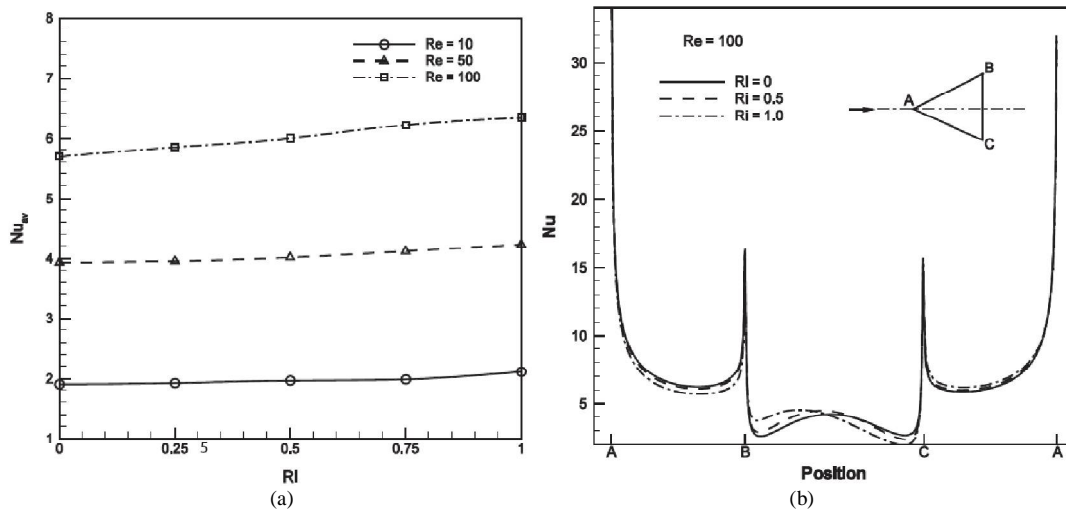


Figure 2.6: Variation of (a) Averaged Nusselt number with  $Ri$  for different  $Re$  and (b) Distribution of local Nusselt number along the surface of the cylinder at  $Re = 100$  for different  $Ri$ , Chatterjee and Mondal (2015).

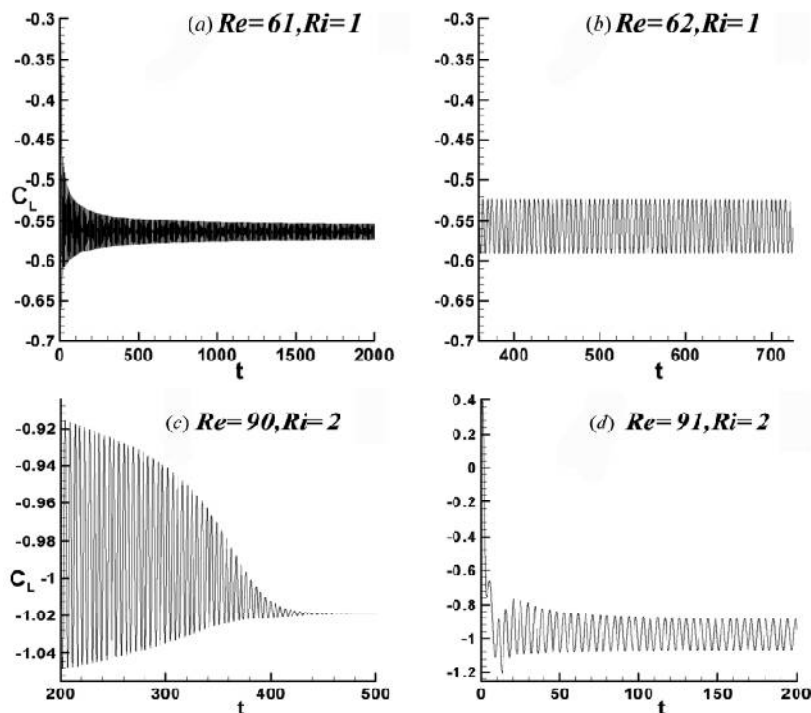


Figure 2.7: Temporal history of the lift coefficient (a and b)  $Re = 61$  and  $62$  at  $Ri = 1$  and (c and d)  $Re = 90$  and  $91$  at  $Ri = 2$ , Rasool et al. (2015).

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 12, December 2017

Dulhani and Dalal (2015) computationally studied the effect of thermal buoyancy on the wake dynamics and heat transfer characteristics of an isolated triangular cylinder at Reynolds number of  $Re = 80-160$  and Richardson number  $-1 \leq Ri \leq 1$ . The authors observed that upon application of buoyancy symmetry about mid plane is lost. The asymmetry increases with increase in heating/cooling. Figure 2.8(a) shows time averaged drag coefficient ( $C_D$ ) with respect to Richardson number at different Reynolds number. Figure shows that an increase in Reynolds number increases the  $C_D$ . However, increase in extent of heating or cooling, the drag coefficient decreases. Figure 2.8 (b) shows the variation of coefficient of lift ( $C_L$ ) with Richardson number at different Reynolds number. Due to buoyancy, asymmetry is induced in the flow field leading to non-zero lift force. Monotonic variation of  $C_L$  with Richardson number was seen. The authors also that averaged Nusselt number is nearly insensitive to Richardson number.

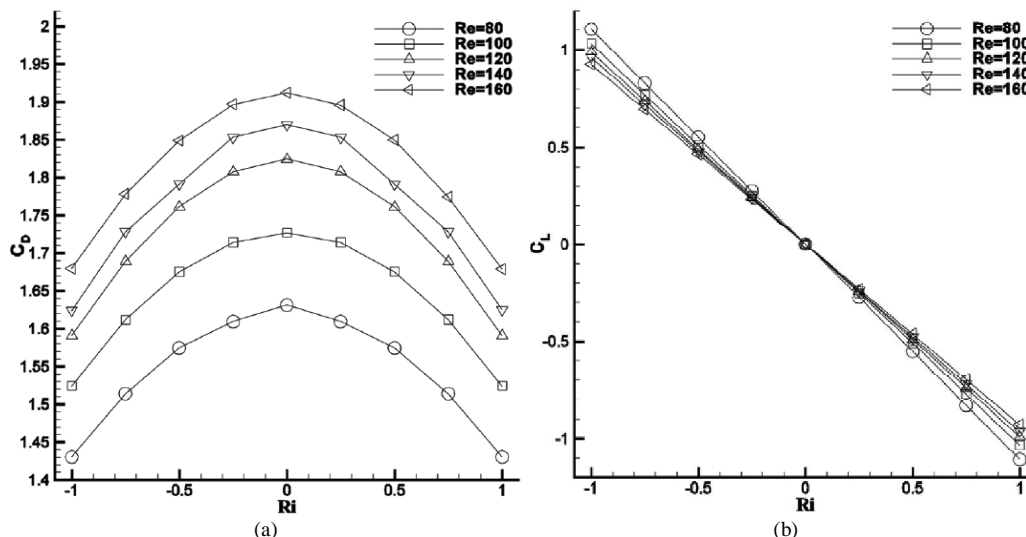


Figure 2.8: Variation of (a) averaged drag coefficient ( $C_D$ ) and (b) averaged lift coefficient ( $C_L$ ) with Richardson number at different Reynolds numbers, Dulhani and Dalal (2015).

## 2.2 Mixed convection flow past a triangular cylinder in aided-buoyancy and opposing-buoyancy configurations

Chatterjee and Ray (2014) numerically studied the effect of thermal buoyancy on the boundary layer separation over a triangular cylinder placed in a unconfined vertical channel. The Reynolds number and Richardson number was in the range  $5 \leq Re \leq 30$  and  $-0.5 \leq Ri \leq 3.5$ . The authors used a working fluid with  $Pr = 50$ . The effect of two different orientations i.e. vertex of the triangular cylinder facing the flow and base of the triangular cylinder facing the flow was studied under adding/opposing buoyancy configurations. Figure 2.9 and 2.10 shows the effect of Richardson number ( $Ri \geq 0$ ) for vertex facing the flow and base facing the flow geometry, respectively at  $Re=30$ . For  $Ri=0$ , steady twin vortices were seen for both the orientations. With increase in Richardson number, recirculation region progressively diminishes at downstream of the triangular cylinder for both the orientations. The authors have shown that at some critical Richardson number, recirculation length becomes zero. This phenomenon is known as onset of flow suppression (OFS). At  $Re=30$ , OFS for vertex facing the flow geometry was at  $Ri_{cr}=1.2$  and for base facing the flow geometry, OFS was at  $Ri_{cr}=0.25$ . However, at OFS, the flow was not completely attached on the surface of the body and small bubbles were seen close to the corners. The size of these bubbles progressively reduces with increased heating. At much higher heating of the object, complete flow suppression (CFS) occurs. At  $Re=30$ , CFS for vertex facing the flow geometry was at  $Ri_{cr}=3.5$  and for base facing the flow geometry, CFS was at  $Ri_{cr}=0.5$ . The results indicate that vertex facing the flow geometry requires more heating for the suppression compared to the base facing the flow geometry. The authors also reported that opposing buoyancy condition (i.e. negative Richardson number) destabilizes the flow and initiates vortex shedding. At  $Re=30$ , the critical Richardson number for which twin vortex pattern is changed to the vortex shedding is  $-0.10$  for vertex facing the flow geometry and  $-0.15$  for base facing the flow geometry.

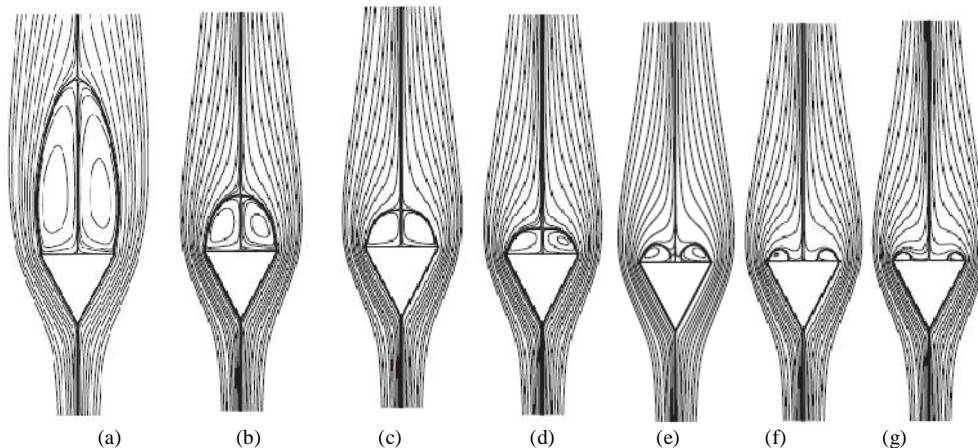


Figure 2.9: Streamlines at  $Re = 30$  for vertex facing the flow orientation at different Richardson numbers, (a)  $Ri = 0$ , (b)  $Ri = 0.5$ , (c)  $Ri = 0.75$ , (d)  $Ri = 1.0$ , (e)  $Ri = 1.2$ , (f)  $Ri = 1.5$  and (g)  $Ri = 2$ , Chatterjee and Ray (2014).

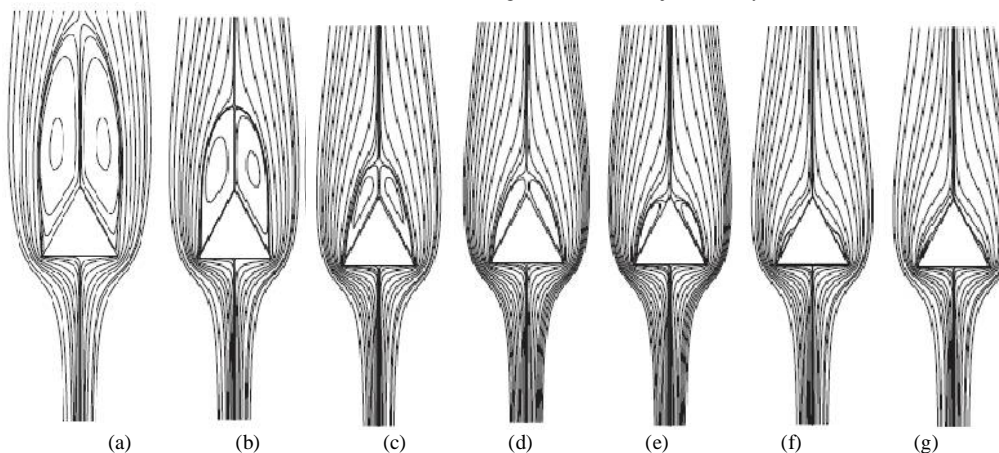


Figure 2.10: Streamlines at  $Re = 30$  for base facing the flow orientation at different Richardson numbers, (a)  $Ri = 0$ , (b)  $Ri = 0.1$ , (c)  $Ri = 0.2$ , (d)  $Ri = 0.225$ , (e)  $Ri = 0.25$ , (f)  $Ri = 0.4$  and (g)  $Ri = 0.5$ , Chatterjee and Ray (2014).

Varma et. al.(2015) numerically investigated mixed convective flow and heat transfer past a triangular cylinder placed symmetrically in a vertical channel at  $Re = 100$  and for three blockage ratio i.e.  $\beta = 1/3, 1/4$  and  $1/6$ . Effect of aiding and opposing buoyancy were studied by varying Richardson number in the range  $-1.0 \leq Ri \leq 1.0$ . The authors showed that at  $Ri = 1$ , the flow is steady for  $\beta = 1/3$ , whereas periodicity is seen in the flow for  $\beta = 1/4$  and  $1/6$ . The drag coefficient increases with increase in  $Ri$  for all blockage ratio. Similarly, Strouhal number increases with increase in  $Ri$  for all blockage ratio. Average Nusselt number increases almost linearly with  $Ri$  for different blockage ratio.

### III. CONCLUSION

This paper reported a detailed review of influence of thermal buoyancy on the wake characteristic of heated triangular cylinder. The studies presented pertain to cross-buoyancy, aiding-buoyancy and opposing-buoyancy configurations in mixed convection heat transfer regime. The effect of buoyancy has been explored by varying the buoyancy parameter i.e. Richardson number ( $Ri$ ). Flow and heat transfer behavior have been presented as a function of Richardson number. A few investigations relating the orientation of triangular cylinder with respect to incoming flow are included. Major conclusions derived from the detailed review can be summarized as under.



# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 12, December 2017

- 1) In cross-buoyancy configuration, increased heating causes an asymmetry in the wake, symmetry is lost and instability is intensified. The average lift coefficient changes from zero at  $Ri = 0$  to non-zero at  $Ri > 0$ . Increased heating produces stronger negative vortex and cylinder experiences a downward lift i.e. negative lift coefficient. The drag coefficient decreases monotonically with increase in Richardson number. Strouhal number increases with increase in Richardson number. Averaged Nusselt number slightly increases with Richardson number, Chatterjee and Mondal (2015).
- 2) In cross-buoyancy configuration, critical Reynolds number for onset of periodic unsteady flow exists between  $Re = 61$  and  $62$  for  $Ri = 1$  and between  $Re = 90$  and  $91$  for  $Ri = 2$ , Rasool et. al. (2015). The value of critical Reynolds number for  $Ri = 0$  was  $59$  as reported by Srikant et. al. (2010).
- 3) In cross-buoyancy configuration, on superimposing the positive or negative cross-flow buoyancy, symmetry of wake about mid plane is lost. The asymmetry increases with increase in heating/cooling. With increase in extent of heating or cooling, the drag coefficient decreases. Due to positive or negative buoyancy, asymmetry is induced in the flow field leading to non-zero downward or upward lift force. Averaged Nusselt number is nearly insensitive to Richardson number, Dulhani and Dalal (2015).
- 4) In aided-buoyancy configuration for steady flow regime ( $Re = 30$ ), with increase in Richardson number, recirculation region progressively diminishes at downstream of the triangular cylinder for vertex facing and base facing the flow orientations, both. At some critical Richardson number, recirculation length becomes zero and the phenomenon is referred as onset of flow suppression (OFS). At much higher heating of the object, complete flow suppression (CFS) occurs and flow is completely attached on the surface of the body. Base facing the flow and vertex facing the flow orientation of triangular cylinder respond in a different manner to flow instability as well as thermal buoyancy. In opposing buoyancy configuration, negative Richardson number destabilizes the steady flow and initiates vortex shedding, Chatterjee and Ray (2014).
- 5) In aided-buoyancy configuration for vortex shedding regime ( $Re = 100$ ), at  $Ri = 1$ , the flow becomes steady for blockage ratio ( $\beta$ ) =  $1/3$ , whereas periodicity is seen in the flow for  $\beta = 1/4$  and  $1/6$ , Varma et. al. (2015). Hence joint influence of buoyancy and blockage ratio controls the wake behaviour.

## REFERENCES

- [1] Abbassi, H., Turki, S., and Nasrallah, S. B., Mixed Convection In a Plane Channel with a Built-in Triangular Prism, Numerical Heat Transfer, Part A, 39:307-320, 2001.
- [2] Abbassi, H., Turki, S., and Nasrallah, S. B., Channel Flow Past Bluff-Body: Outlet Boundary Condition, Vortex Shedding and Effects of Buoyancy, Computational Mechanics, vol. 28, pp. 10-16, 2002.
- [3] Chatterjee D., Mondal B., Mixed Convection Heat Transfer From an Equilateral Triangular Cylinder in Cross Flow at Low Reynolds Numbers, Heat Transfer Engineering, 36(1):123-133, 2015.
- [4] Chatterjee, D. and Ray, S., Influence of thermal buoyancy on boundary layer separation over a triangular surface, International Journal of Heat and Mass Transfer, 79, 769-782, 2014.
- [5] Dulhani Jay P. and Dalal, A., Flow past an Equilateral Triangular Bluff Obstacle: Computational Study of the Effect of Thermal Buoyancy on Flow Physics and Heat Transfer, Numerical Heat Transfer, Part A, 67: 476-495, 2015.
- [6] Hassab, M. A., Teamah, M. A., El-Maghlany, W. M., Kandil, M. A., Experimental Study for a Mixed Convection Heat Transfer from an Isothermal Horizontal Triangular Cylinder, International Journal of Engineering Sciences, Pages: 210-225, 2(6) June 2013.
- [7] Oosthuizen P. H., and Naylor D., An introduction to convective heat transfer analysis, WCB McGraw Hill, International edition, 1999.
- [8] Rai B., and Singh, S. K., A review of unsteady flow and heat transfer around a triangular bluff-body, International Journal of Innovative Research in Science Engineering and Technology, vol 6, issue 12, 22669-22678, December 2017.
- [9] Rasool T., Dhiman A., and Parveez M, Cross-Buoyancy Mixed Convection Around a Confined Triangular Bluff Body, Numerical Heat Transfer, Part A, 67: 454-475, 2015.
- [10] Srikanth S, Dhiman A K, Bijjam S, Confined flow and heat transfer across a triangular cylinder in channel, International Journal of Thermal Sciences, 49, 2191-2200, 2010.
- [11] Varma N., Dulhani J. P., Dalal A., Sarkar S., and Ganguly S., Effect of channel confinement on mixed convective flow past an equilateral triangular, ASME Journal of heat transfer, vol. 137, 121013-1-7, December 2015.