International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 7, July-2014, pp: (61-67), Impact Factor: 1.252, Available online at: www.erpublications.com

Experimental Investigation of Heat Dissipation from a Heated Equilateral Triangular Cylinder in an Oscillating Channel Flow

Nirmal Singh[1]*, Sunil Nain[2]
[1,2]Mechanical Engineering Department, University Institute of Engineering & Technology, Kurukshetra, Haryana, India

---

Abstract: Experiments have been performed to investigate heat dissipation from a heated equilateral triangular cylinder in a channel by oscillating flow. During the experiments, the input power and oscillating amplitude (A) are fixed. The effects of the Reynolds number based on the mean flow velocity and the oscillating frequency (0 Hz $<f_p<$ 60 Hz) on the heat transfer enhancement are examined. The Reynolds number was determined for each oscillating condition. The heat enhancement factor is measured according to Reynolds number. The occurrence of the "lock-on" phenomenon is demonstrated for a triangular cylinder. "Lock-on" phenomenon is the phenomenon when the pulsating frequency is within the lock-on regime, heat transfer from the triangular cylinder is significantly enhanced. Experiments have been performed for two workpieces of triangular shape made of Aluminum and Silicon. In the present work two different horizontal and one vertical position of Aluminum work piece were taken and experiment was performed. In the experimental work one horizontal position of Silicon work piece was taken in order to compare the performance of two different materials. Various graphs have been plotted between the temperature & frequency and frequency and heat enhancement factor for different horizontal and vertical positions of work pieces with the variation in Reynolds numbers. These graphs show the effect of various pulsating frequency on the heat transfer enhancement. It has been found that pulsating frequency increases the heat transfer rate at different Reynolds numbers. Heat transfer increases with increase in the Reynolds number. During the experiment it has been found that at a particular frequency, the heat transfer rate is maximum.

Keywords: Lock on, Pulsating flow, Heat transfer enhancement, Triangular cylinder.

I. INTRODUCTION

Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long term performance and the aspect of the equipment. The existence of high performance thermal systems has simulated interest in methods to improve heat transfer. The study of improved heat transfer is referred to as heat transfer enhancement, augmentation or intensification. The performance of conventional heat exchanger can be substantially improved by a number of enhancement techniques. A great deal of research effort has been devoted to developing apparatus and experiments to define the conditions under which an enhancement technique will improve heat transfer. Most of the electronic equipments are destroyed due to shortcoming in temperature control that is why there should be maintenance of sustaining low circuit temperature as possible. Furthermore as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in chemical industries and marine applications. In this case the heat transfer rate can be improved by introducing a disturbance in the fluid flow by different enhancement technologies like breaking the viscous and thermal boundary layer.

2. Experimental Apparatus and System Operation

The experimental setup consists of flow around a triangular cylinder, as illustrated in Figure 1. The cylinder is undergoing a transient vertical oscillation motion that changes harmonically with time. The equilateral triangular cylinder with side length (l) is placed in a channel of height (H) and length (L). The leading edge of the triangle is placed at a distance (x_u) from the channel's inlet, and its trailing edge is at distance (x_d) from the outlet. Figure 1 shows the triangular cylinder with the important geometrical parameters. Y and X are the dimensional coordinates normal and along to the cylinder surface. The blockage ratio, which is defined as the ratio of the side of the triangular cylinder to the channels height, is 1/10. The air flow undergoing a vertical displacement oscillation motion and the following harmonic expression describes the motion: $U_I = U_O (1 + A \sin 2\pi f_p t)$ [33]

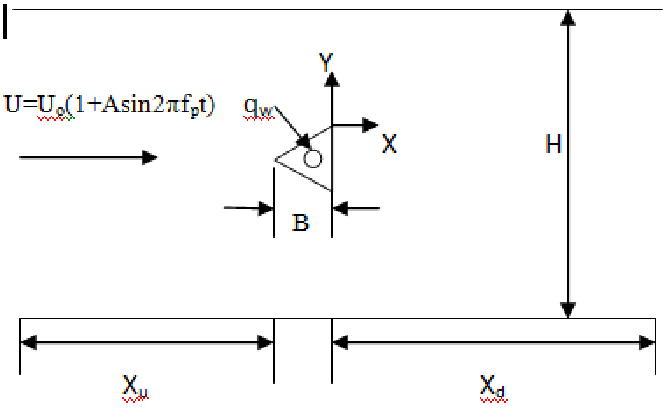


Figure 1: Heated equilateral triangular cylinder in a channel

To eliminate the effect of walls of wind channel we have to follow the equation L/D ≥ 50 and in present study L/D is 65. Where D is side length of work piece. Laptop has software which name is NCH TONE GENERATOR which work as oscilloscope and Function generator and give values in digital form.

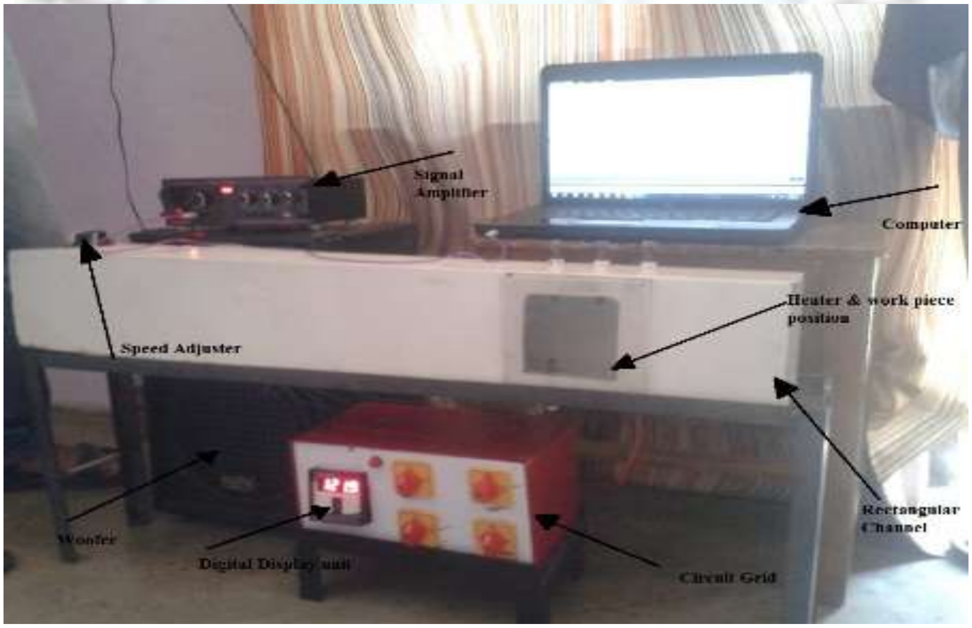


Figure 2: Experimental Setup

The software can produce the sound frequency 0-10000 Hz. But we perform our experiment within limit of sound frequency 0-60 Hz. We have to work with these sound frequencies because at higher sound frequency the woofer will damage. Function generator is a device which creates sound at different frequency and oscilloscope shows the value of frequency of sound.

3. System Operation

The experiments were performed in a channel fabricated with 10 mm thick cast iron with the same basic set-up as reported in. The channel is an open circuit, suction type with height H = 120 mm, width W = 150 mm, and length L = 960 mm. A steady main airflow was supplied by a AC fan. The inlet flow is straightened through a honeycomb and a fine grid mesh. All side of triangular cylinder, made of aluminium, was 15 mm. A triangular cylinder was installed at Xu= 60 mm and Xd= 275 mm in the channel. A 10 inch diameter woofer speaker was used to produce an oscillatory flow. Temperatures were measured by thermocouples. The inlet flow is straightened through a honeycomb and a find grid mesh. The uniformity of inlet airflow was confirmed by measuring the velocity distribution with a hot wire anemometer.

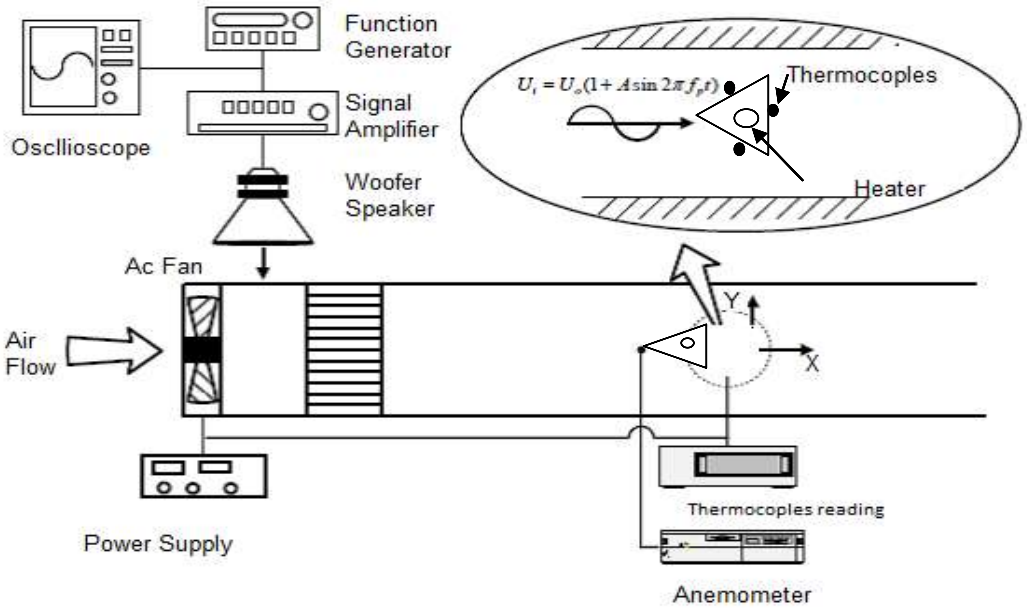


Figure 3: Experimental Apparatus

4. Results and Discussion

There are some advantages of forced convection over free convection which are given as, heat transfer rate increase and one more important thing is that whenever we increase the velocity of air in forced convection heat transfer increase significantly. The results were obtained after placing the work piece at two different horizontal positions and one vertical position. These are as:

Horizontal positions are as:

1. X_u = 355 mm, X_d = 200 mm.
2. X_u = 300 mm, X_d = 255 mm.
3. And vertical position is as:-

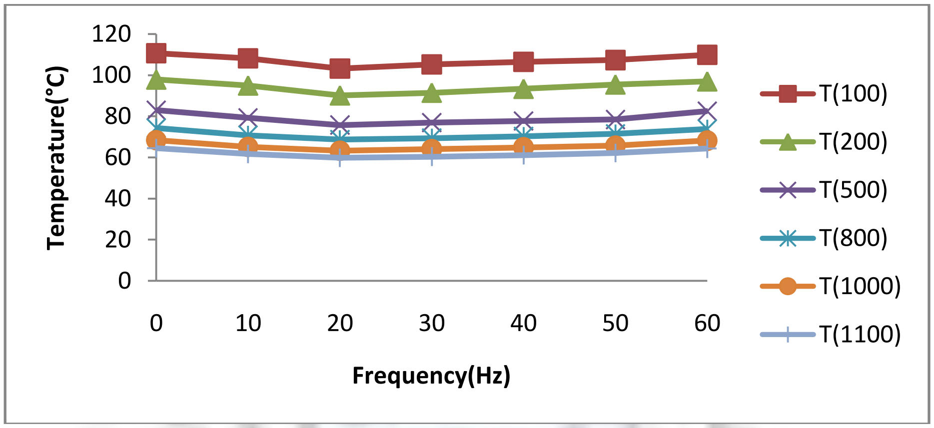
   Y_u=40mm, Y_d=80mm

Here X_u is the distance from the outlet to upstream face of the cylinder,

X_d is the distance from the outlet to downstream face of the cylinder
Y_u is the distance from the bottom of the channel to face of the cylinder
Y_d is the distance from the top of the channel to the face of the cylinder

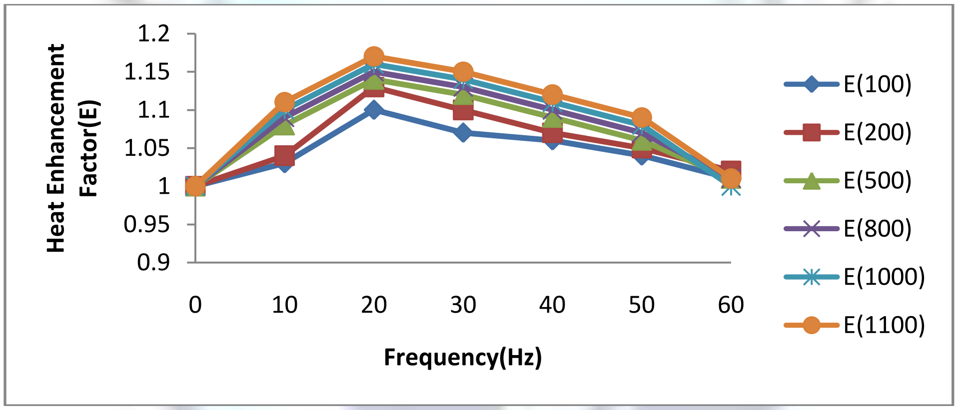
4.1 Forced convection with oscillating flow:

4.1.1 Variation of wall temperature at different frequency with different Reynolds No. (Re) at position1



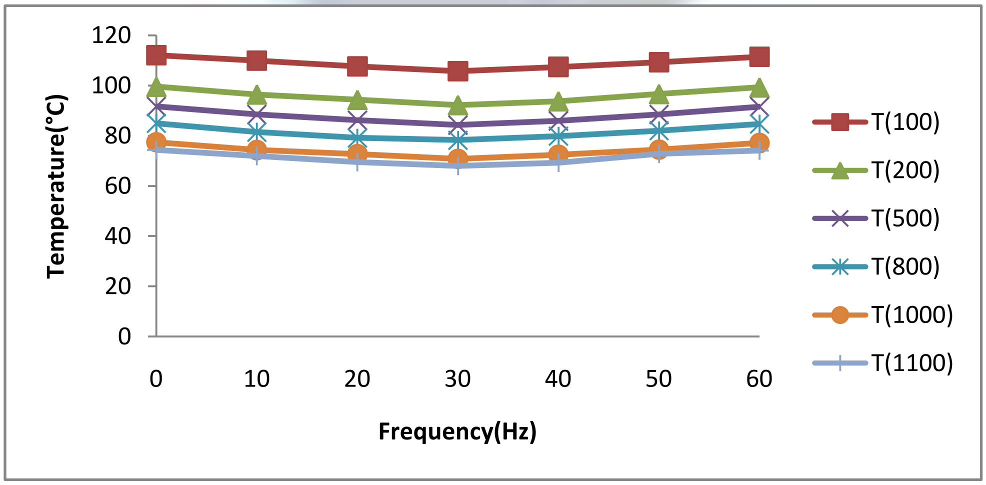
Graph. 1: Variation of wall temperature at different frequency with different Reynolds number (Re).

4.1.2 Variation of Enhancement factor (E) at different frequency with different Reynolds No. at position1



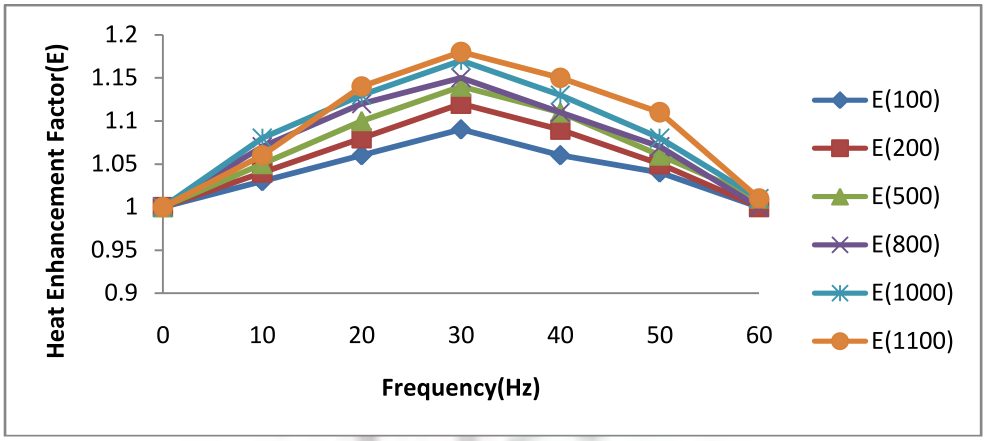
Graph 2: Variation of Enhancement factor at different frequency with different Reynolds number (Re).

4.1.3 Variation of wall temperature at different frequency with different Reynolds No. (Re) at position2



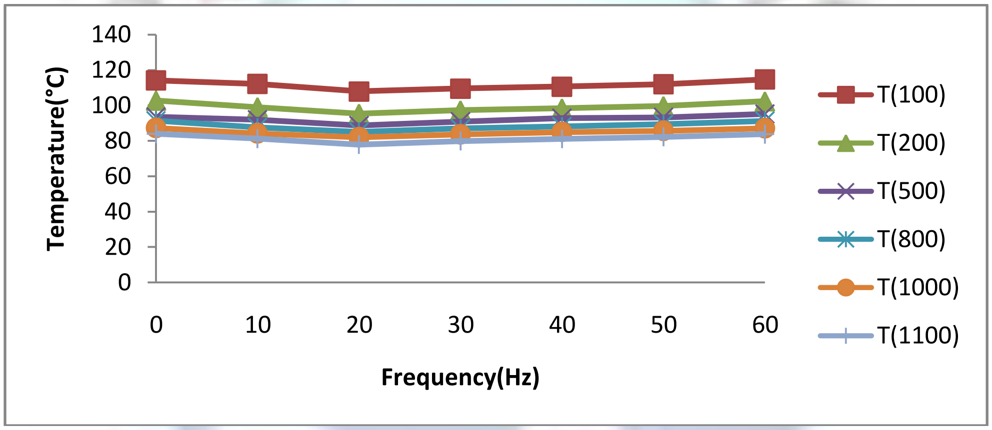
Graph 3: Variation of wall temperature at different frequency with different Reynolds number (Re).

4.1.4 Variation of Enhancement factor (E) at different frequency with different Reynolds No. at position 2



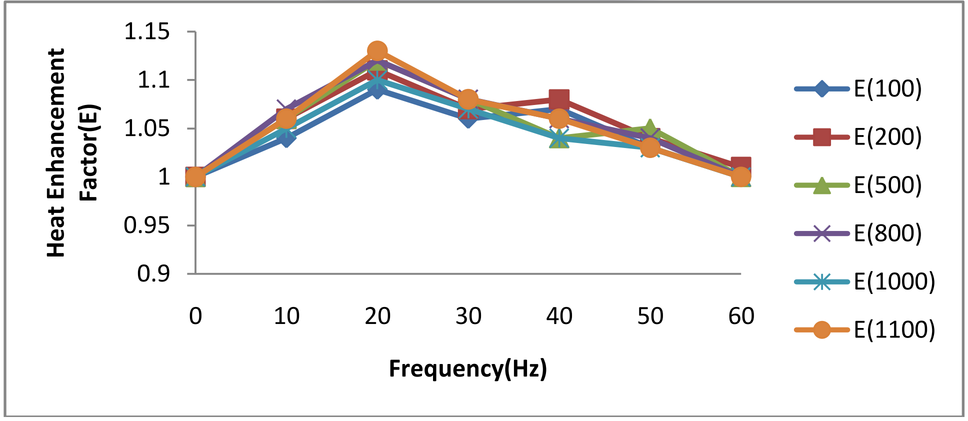
Graph. 4: Variation of Enhancement factor at different frequency with different Reynolds number (Re).

4.1.5 Variation of wall temperature at different frequency with different Reynolds No. (Re) at vertical position with respect to position2



Graph 5: Variation of wall temperature at different frequency with different Reynolds number (Re).

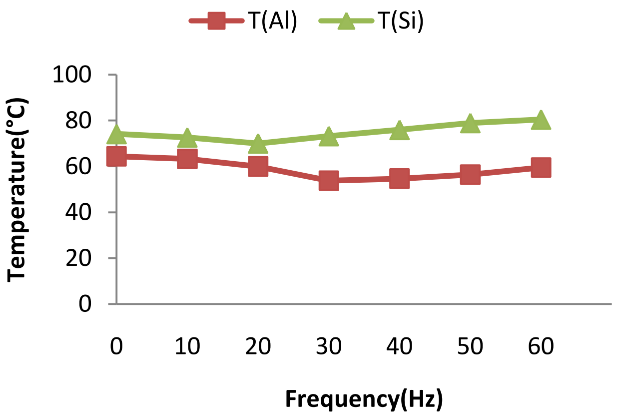
4.1.6 Variation of Enhancement factor (E) at different frequency with different Reynolds No. at vertical position with respect to position2



Graph 6. Variation of Enhancement factor at different frequency with different Reynolds number (Re

4.2 Comparison between overall performance of aluminum and silicon work piece at Reynolds no 1100

The wall temperature of aluminium work piece decreases up to frequency 30 Hz and again increases from 30 Hz to 60 Hz whereas the wall temperature of silicon work piece decreases up to 20Hz and increases from 20 Hz to 60 Hz .The temperature decrease and temperature increase is more in aluminium work piece as compared to the silicon work piece.



Graph 7: Comparison of overall performance between Al and Si at Reynolds no. 1100

Conclusions

The experimental study has been carried out to investigate heat dissipation from a heated triangular cylinder in an oscillating channel flow. Impact of the pulsating frequency (0 Hz <fp<60 Hz) and the Reynolds number based on the mean velocity (Re = 100, 200, 500, 800, 1000 and 1100) on heat transfer enhancement was investigated. Input power and the velocity amplitude were fixed in the present experiment.The obtained results lead to the following conclusions:

- It is found that heat enhancement increased with the rise of Reynolds number of steady flow and maximum at frequency 30 Hz along with Reynolds number 1100 in case of aluminium work piece.
- It is found that temperature drop is maximum at frequency 30 Hz along with Reynolds number 1100 in case of aluminium work piece
- It is found that temperature drop is maximum at frequency 20 Hz along with Reynolds number 1100 in case of silicon work piece
- Lock on phenomenon shows during frequency 0 to 20 Hz in silicon and aluminium on the first horizontal position due to the presence of more dense air on the first horizontal position.
- Lock on phenomenon shows during frequency 0 to 30 Hz in aluminium on the second horizontal position.
- Oscillation flow of air does not show regular trend in variation of wall temperature of the work piece on the vertical position of work piece.
- At frequency 40 Hz the system start vibration it shows the phenomenon “vortex induced vibration”.

In the conclusion, Experimental investigations have shown that flow pulsation resulted in an increased heat transfer rate when the lock on phenomenon occurred.

.

Nomenclature

A - Pulsating amplitude
B -Side length of a square cylinder, mm
E -Heat transfer enhancement factor, Nu_p/Nus
f -Dimensional frequency, Hz
fp -Pulsating frequency, Hz
h -Heat transfer coefficient, W/m^2k
H -Height of flow channel, mm
k -Thermal conductivity of air, W/mK
L -Length of flow channel, mm

Nu -Nusselt number
qw -Input heat flux, W/m2
Re -Reynolds number, UoB/ν
St -Strouhal number, fB/Uo
T -Local surface temperature, K
Ti -Inlet air temperature, K
Ui -Inlet air velocity, m/s
W -Channel width, mm
X –Stream wise coordinate
Xd -Distance from the outlet to downstream face of the cylinder, mm
Xu -Distance from the outlet to upstream face of the cylinder, mm
Y -Transverse coordinate

Greek symbols
β -Blockage ratio
ν -Kinematic viscosity, m^2/s

Subscripts
p -Pulsating component
s -Steady-state component

References

[1]. B. J. Vickery, [1965] “Fluctuating lift and drag on a long cylinder of square cross-section in a smooth and in a turbulent stream” School of Civil Engineering, University of Sydney, Australia.
[2]. Hakozaki, Higashi ku, & Fukuoka, [1982] “Strouhal numbers of rectangular cylinders”. Research institute for applied mechanics, Kyushu University, Hakozaki, Higashi ku, Fukuoka, 812, Japan. [3] A. Okajima, [1982] “Strouhal numbers of rectangular cylinders,” J. Fluid Mech., vol. 123, pp. 379-398.
[3]. R. W. Davis & E. F. Moore, [1982] “A numerical study of vortex shedding from rectangles,” J. Fluid Mech., vol. 116, 1982.
[4]. R. W. Davis, E. F. Moore, & L. P. Purtell, [1984] “A numerical experimental study of confined flow around rectangular cylinders,” Phys. Fluids, vol. 27.
[5]. C. Barbi, D. P. Favier, & C. A. Maresca, [1986] “Vortex shedding and lock-on of a circular cylinder in oscillatory flow,” J. Fluid Mech., vol. 170.
[6]. A. Mukhopadhyay, G. Biswas, & T. Sundararajan, [1992] “Numerical investigation of confined wakes behind a square cylinder in a channel,” Int. J. Numer, Meth.Fluids, vol. 14.
[7]. K. M. Kelkar & S. V. Patankar, [1992] “Numerical prediction of vortex shedding behind a square cylinder,” Int. J. Numer.Mehtods Fluids vol. 14.
[8]. H. Suzuki, Y. Inoue, T. Nishimura, K. Fukutani, & K. Suzuki, [1993] “Unsteady flow in a channel obstructed by a square rod (crisscross motion of vortex),” Int. J. Heat Fluid Flow, vol. 14.
[9]. K. Suzuki & H. Suzuki, [1994] “Unsteady heat transfer in a channel obstructed by an immersed body,” Annu. Rev. Heat Transfer vol. 5, pp. 174-206. [11] H. J. Sung, K. S. Hwang, & J. M. Hyun, [1994] “Experimental study on mass transfer from a circular in pulsating flow,” Int. J. Heat Mass Transfer, vol. 37.
[10]. D. Karanth, G. W. Rankin & K. Spidhar, [1994] “A finite difference calculation of forced convective heat transfer from an oscillating cylinder,” Heat Mass Transfer, vol. 12
[11]. T. G. Beckwith, R. D. Marangoni, & V. Lienhard, [1995] “Mechanical Measurements,” Addison Wesley Co Inc, New York.
[12]. C. H. K. Williamson, [1996] “Vortex Dynamics in the Cylinder Wake,” Fluid Mech., vol. 28.
[13]. C. H. Cheng, J. L. Hong, & W. Aung, [1997] “Numerical prediction of lock-on effect on convective heat transfer from a transversely oscillating circular cylinder,” Int. J. Heat Mass Transfer, vol. 40.
[14]. M. M. Zdravkovich, [1997] “Flow around circular cylinders”, Oxford University Press, New York.
[15]. M. Breuer, J. Bernsdorf, T. Zeiser, & F. Durst, [2000] “Accurate computations of the laminar flow past a square cylinder based on two different methods: lattice-Boltzmann and finite volume,” Int. J. Heat Fluid Flow, vol. 2.
[16]. S. Z. Shuja, B. S. Yilbas, & M. O. Iqbal, [2000] “Heat transfer characteristics of flow past a rectangular protruding body,” Number. ransfer, Part A, vol. 37.