Performance Enhancement of Tube Bank Heat Exchanger using Passive Techniques: A Review

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Abstract— In this paper, the passive flow control of fluid in the downstream direction of the circular tube and in tube banks by means of changing the shape of tube to oval shape . Heat transfer and pressure drop depend on complex flow pattern of fluid in tube banks, whereas pressure drop linked directly with the fluid pumping capacity. A primary focus is to review experimental, analytical and numerical works that had been carried out to study the effect of longitudinal and transverse tube spacing, Reynolds number, stagnation point and surface roughness on wake size and vortex shedding.

Keywords— Heat transfer, circular cylinder, oval tube, splitter plate, tube banks, cross flow, drag, bluff body, vortex shedding, .

INTRODUCTION

A heat exchanger is a device built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix. Tube bank is the cross flow tubular heat exchanger and consists of multiple rows of tubes. One fluid passing through the tubes and other is passing across the tubes as shown in Figure 1. Tube banks arrangement include the in-line and the staggered arrangements. Cross flow tubular heat exchanger are found in diverse equipment as economizer, waste heat recovery, evaporator of an air conditioning system to name but few.

Heat Exchanger involve several important design consideration which include thermal performance, pressure drops across the exchanger, fluid flow capacity, physical size and heat transfer requirement. Out of this following consideration, determination of pressure drop in a heat exchanger is essential for many applications because the fluid needs to be pumped through the heat exchanger. The fluid pumping power is proportional to the exchanger pressure drop. In tube banks, the heat transfer and pressure drop characteristic depend upon the flow pattern of fluid. The fluid flow converges as the minimum area occurs between the tubes in transverse row or in a diagonal row which makes the flow pattern very complex

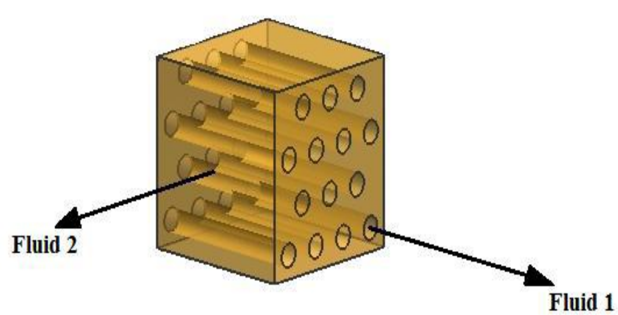

Figure 1.Cross Flow Tube Banks

Passive control is one of the flow control techniques for reducing the aerodynamic drag exerted on a bluff body. It controls the vortex shedding by modifying the shape of the bluff body or by attaching additional devices in the flow stream.

PASSIVE HEAT TRANSFER AUGMENTATION TECHNIQUES

A Dewan1, P Mahanta1 (2004), this paper presented is a review on progress with the passive augmentation techniques in the recent past and will be useful to designers implementing passive augmentation techniques in heat exchange. Twisted tapes, wire coils, ribs, fins, dimples, etc., are the most commonly used passive heat transfer augmentation tools.

A twisted tape insert mixes the bulk flow well and therefore performs better in a laminar flow than any other insert because in a laminar flow the thermal resistance is not limited to a thin region. However, twisted tape performance also depends on the fluid properties such as the Prandtl number. Twisted tape in turbulent flow is effective up to a certain Reynolds number range but not over a wide Reynolds number range. Compared with wire coil, twisted tape is not effective in turbulent flow because it blocks the flow and therefore the pressure drop is large. Hence, the thermo-hydraulic performance of a twisted tape is not good compared with wire coil in turbulent flow.

Wire coil in laminar flow enhances the heat transfer rate significantly. However, the performance depends on the Prandtl number. If the Prandtl number is high, the performance of the wire coil is good because, for a high Prandtl number, the thickness of the thermal boundary layer is small compared with the hydrodynamic boundary layer and the wire coil breaks this boundary layer easily. Therefore, both heat transfer and pressure drop are large. Wire coil enhances the heat transfer in turbulent flow efficiently. It performs better in turbulent flow than in laminar flow. The thermo-hydraulic performance of wire coil is good compared with twisted tape in turbulent flow.

There are several passive techniques other than twisted tape and wire coil to enhance the heat transfer in a flow, such as ribs, fins, dimples, etc. These techniques are generally more efficient in turbulent flow than in laminar flow.

EFFECT OF SPRINGS AND ANNULAR INSERTS IN CONCENTRIC TUBE HEAT EXCHANGER

Kumbhar D.G.(2010) in this paper emphasis is given to works dealing with twisted tape inserts because according to the recent studies, these are known to be economic heat transfer enhancement tool. A twisted tape insert mixes the bulk flow well and therefore performs better in laminar flow, because in laminar flow the thermal resistant is not limited to a thin region. The result also shows twisted tape insert is more effective, if no pressure drop penalty is considered.
Twisted tape in turbulent flow is effective up to a certain Reynolds number range. It is also concluded that twisted tape insert is not effective in turbulent flow, because it blocks the flow and therefore pressure drop increases. Hence the thermo hydraulic performance of a twisted tape is not good in turbulent flow. These conclusions are very useful for the application of heat transfer enhancement in heat exchanger networks.

S.S.Joshi (2013), the aim of this investigation is to study use of inserts as passive heat transfer augmentation technique to enhance the effectiveness of concentric tube heat exchanger. Tube in tube heat exchanger is retrofitted with screwed protrusions in annular portion and different springs are used as inserts in inner tube. The experimentation is carried out at different flow rate of either fluid for three different arrangements of spring inserts.
(i).The springs of different diameters and their fixing arrangement causes more turbulence which causes more heat transfer to occur. Hence the effectiveness of heat exchanger is increased.
(ii). For spring type-III (Diameter nearly equal to the diameter of inner tube which is fixed (adhered) to the inner tube surface heat transfer is maximum but at the same time friction factor is also increases. The heat transfer and friction gradually decreases for spring type-I (2 mm less than the diameter of inner tube fixed at both ends) and spring type-II (2 mm less than the diameter of inner tube Fixed (adhered) to the inner tube surface) respectively. Hence he concluded that as diameter of spring decreases, the heat transfer and friction factor decreases. Also when the spring is fixed to inner surface of tube, maximum value of effectiveness is achieved. (iii)The heat transfer in the heat exchanger could be enhancement by using inserts and springs of different diameters and their fixing arrangement. Use of annular insert causes slight increase in heat transfer coefficient and effectiveness of heat exchanger.

(iii) The heat transfer in the heat exchanger could be enhancement by using inserts and springs of different diameters and their fixing arrangement. Use of annular insert causes slight increase in heat transfer coefficient and effectiveness of heat exchanger.

EFFECT OF SPLITTER PLATE ON FLOW AND HEAT TRANSFER BEHAVIOR AROUND CIRCULAR CYLINDER.

J.Y. Hwang et al. (2003) numerically studied flow induced forces on a circular cylinder using detached splitter plate for laminar flow. A splitter plate with the same length as the cylinder diameter was placed horizontally in the wake region. Suppressing the vortex shedding, the plate significantly reduced drag force and lift fluctuation, there existed an optimal location of the plate for maximum reduction. However, they sharply increase as the plate was placed further downstream of the optimal location.

H. Akilli et al. (2008) investigated experimentally passive control of vortex shedding by splitter plates having L/D ratio (0.2 to 2.4) attached on the cylinder base in shallow water flow at Re = 6300. In this study, the length of the splitter plate was varied from in order to see the effect of the splitter plate length on the flow characteristics. Instantaneous and time-averaged flow data clearly indicated that the length of the splitter plate has a substantial effect on the flow characteristics. They found the flow characteristics in the wake region of the circular cylinder sharply changed up to the splitter plate length of L/D=1.0 and above this plate length, small changes occurred in the flow characteristics.

HEAT TRANSFER FROM TUBE BANKS

W.A. Khan et al. (2006) studied heat transfer from tube banks using analytical approach. It was concluded that the average heat transfer coefficients for tube banks depend on the longitudinal, transverse pitches, Reynolds number and Prandtl number. Compact banks (in-line or staggered) indicate higher heat transfer rates than widely spaced ones and the staggered arrangement gives higher heat transfer rates than the in-line arrangement. This was also supported by the further work of **W. A. Khan (2007)**, where an optimal model of tube banks heat exchanger was developed using entropy generation minimization method. It was also demonstrated that the staggered arrangement gives a better performance for lower approach velocities and longer tubes, whereas the inline arrangement performs better for higher approach velocities and larger dimensionless pitch ratios.

S. G. Chakrabarty (2012) conducted experimentation on passive flow control of fluid in the downstream direction of the circular tube and in tube banks by means of splitter plate The angle (θ) is measured from the front stagnation point. Behavior of Nusselt number for different passive control method is shown. The heat transfer coefficient decreases gradually from front stagnation point towards the separation point. The heat transfer coefficient has the minimum value near the separation point. After the separation point the heat transfer coefficient increases because of the considerable turbulence exists over the rear side of the tube where eddies of the wake sweep the surface in case of circular tube without splitter plate. For comparison of Nusselt number distribution on the circular tube with the Nusselt number distribution on the splitter plate and V-shaped profile, Graph 3.2 and 3.4 shows the variation of Nusselt number along length of the splitter plate (from L=0 to L=0.05m) and V-shaped profile (L=D). Splitter plate is attached in a longitudinal slot into circular tube at θ=180°. Therefore Nusselt number on circular tube at θ=180° and splitter plate length (L) = 0 is assume to be same.

James E. O'Brien (2000) This paper presents the results of an experimental study of forced convection heat transfer in a narrow rectangular duct fitted with either a circular tube or an elliptical tube in crossflow. The duct was designed to simulate a single passage in a fin-tube heat exchanger. Heat transfer measurements were obtained using a transient technique in which a heated airflow is suddenly introduced to the test section.

An experimental study of local heat transfer in a narrow rectangular duct fitted with either a circular tube or an elliptical tube in cross-flow has been performed. The duct was designed to simulate a single passage in a fin-tube heat exchanger with a duct height of 1.106 cm and a duct width-to height ratio, W/H, of 11.25. The test section length yielded L/H = 27.5 with a flow development length of L/H = 30. The test cylinder was sized to provide a diameter-to-duct height ratio, D/H of 5. The elliptical tube had an aspect ratio of 3:1 and a/H equal to 4.33. Heat transfer measurements were obtained using a transient technique in which a heated airflow was suddenly introduced to the ambient-temperature test section. High-resolution local test-surface temperature distributions were obtained at several times after initiation of the transient using an imaging infrared camera. Corresponding local fin-surface heat transfer coefficient distributions were calculated from a locally applied one-dimensional semi-infinite inverse heat conduction model. Heat transfer results were obtained over an airflow rate ranging from 1.56 x 10-3 to 15.6 x 10-3 kg/s. These flow rates correspond to a duct-height Reynolds number range of 630 – 6300.

CONCLUSION

This paper describes the influence of various type of passive techniques used to enhances the performance of tube bank heat exchanger. The performance parameters such as the flow behavior and heat transfer characteristic which increase the heat transfer rate. Among the various passive techniques the oval shape tube bank found more effective as compare with the circular tube bank because of their smaller face area. Oval shape tube heat exchangers are more compact in size than circular tube heat exchangers. So it means that more tube can be adjusted into a specified volume, which indicates higher heat transfer rate. By employing oval shape tubes instead of circular tube in tube banks reduces the size wake and turbulence generation. It modifies the boundary layer over the tubes. By creating a streamlined extension of the circular tube, it reduces the wake size which added to their better combined thermal-hydraulic performance, which indicates that encouraging characteristics for using oval shape tube in heat exchanger.

REFERENCES:

[1] A Dewan1, P Mahanta1, K Sumithra Raju1 and P Suresh Kumar2 "Review of passive heat transfer augmentation techniques" Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy 2004 218: 509.

[2] Kumbhar D.G.1, Dr. Sane N.K.2 "Heat Transfer Enhancement in a Circular Tube Twisted with Swirl Generator: A Review" Proc. of the 3'd International Conference on Advances in Mechanical Engineering, January 4-6, 2010.

[3] S.S Joshi et.al / (IJAEST) international journal of advanced engineering sciences and technologies Vol No. 12, Issue No. 2, 041 – 048.

[4] Jong-Yeon Hwang, Kyung-Soo Yang and Seung-Han Sun, "Reduction of flow-induced forces on a circular cylinder using a detached splitter plate", Physics Of Fluids, Volume 15, Number 8, August 2003.

[5] Huseyin Akilli, Cuma Karakus, Atakan Akar, Besir SahinN and Filiz Tumen, "Control of Vortex Shedding of Circular Cylinder in Shallow Water Flow Using an Attached Splitter Plate", Journal of Fluids Engineering, April 2008.

[6] W.A. Khan, J.R. Culham and M.M. Yovanovich, "Convection heat transfer from tube banks in crossflow: Analytical approach", Int. Journal of Heat and Mass Transfer, 49 (2006), 4831-4838.

[7] W.A. Khan, J.R. Culham and M.M. Yovanovich, "Optimal Design of Tube Banks in Crossflow Using Entropy Generation Minimization Method", Journal Of Thermophysics and Heat Transfer, Vol. 21, No. 2, April-June 2007.

[8] S.G. Chakrabarty and Dr. U. S. Wankhede "Flow and heat transfer behaviour across circular cylinder and tube banks with and without splitter plate" International Journal of Modern Engineering Research , ISSN: 2249-6645 Vol.2, Issue.4, July 16. 2012 pp-1529-1533.

[9] James E. O'Brien, Manohar S. Sohal Proceedings of NHTC'00 34th National Heat Transfer Conference Pittsburgh, Pennsylvania, August 20 – 22, 2000