Hydrodynamic Characteristics of Flow around Tube Bank with Integral Wake Splitter

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Abstract.
This paper reports the effects of a longitudinal plate attached at the backward stagnation point of a bank of tubes on the local static pressure distribution. The longitudinal plate is termed as an integral wake splitter. Investigations on hydrodynamic characteristics of tube banks with integral wake splitter were carried out in cross flow of air in a rectangular duct at a Reynolds number of 15950. The integral wake splitter length-to-tube-diameter ratios studied were 0.5, 1.0, 1.5 and 2.0. The tube bank consisting of 12 rows and 3 tubes per row in equilateral triangular arrangement with a transverse pitch to diameter ratio, \( a = 2 \). The results obtained were compared to the experimental data of Seri et al. (2014). It is observed that the addition of the integral wake splitter reduces the overall pressure drop.

Introduction
Cross-flow heat exchangers are commonly used in many systems such as air conditioning coils, economizers of steam boilers and waste heat recovery systems. When the flow direction is at right angles to the tube axis, it is termed cross-flow and it generates a secondary flow. The most common tube used is circular in shape. The flow phenomenon is complex and has been subject of much research. Its hydrodynamics dictates the thermal performance of the system.

Altering the hydrodynamics in an effort to improve the overall performance has also received much attention in research. Some researchers investigated additional features to the heat exchanger in order to improve the heat transfer performance [1 - 3]. Others modified the shape of the traditional circular tube to enhance the overall heat exchanger performance [4 - 7].

In an attempt to improve the performance of the cross-flow heat exchanger, the present study investigates the effect of longitudinal plate attached at the back end of the tubes of a bank on the hydrodynamics of the system.

Experimental Setup
The experimental work was conducted in an open circuit wind tunnel illustrated in Fig. 1. A centrifugal blower forced the air flow to test section through a bellows, diffuser, settling chamber and contraction nozzle. The bellows isolated the test section from vibration produced by the blower. The settling chamber damped flow disturbances and provided uniform flow at the contraction
nozzle inlet. The contraction nozzle directed the flow and increased the mean flow velocity in the test section. The 3-dimensional view of the contraction nozzle is shown in Fig. 2.

Cylindrical tubes arranged in the test section were made from copper. Local static pressure measurements were taken at the mid-span of each tube through 0.5mm diameter holes. The static pressure holes were drilled at several angles, \( \theta \), shown in Fig. 3.

The measurement schematic is shown in Fig. 4. For each angle \( \theta \), pressure different between \( p_0 \) and total pressure at the free stream was measured. Local pressure coefficients around the tubes were then calculated based on (1), where \( p_0 \) is the local static pressure at the forward stagnation point of each tube.

Fig. 5 shows the test configuration. The tubes were arranged in staggered arrangement with the pitch between the tubes equals to twice the tube diameter. Splitter plate lengths tested in the present work are 0.5D, 1D, 1.5D and 2D.
\[ C_p = \frac{2(p_0 - p)}{\rho V^2} \]  

(1)

**Results and Discussion**

Fig. 6 illustrates the local distribution of pressure coefficient around tubes with integral wake splitter of lengths 0.5D, 1D, 1.5D, and 2D for Reynolds number equal to 15950. The free stream velocity is taken to be the reference velocity for Reynolds number. In terms of pressure recovery, all cases show a similar trend. Wake splitter lengths of L/D = 0.5 and 1 give similar \( C_p \) distribution, except a minor cross-over of the 2nd and the 3rd row \( C_p \) for L/D = 1. \( C_p \) drops steeply for tubes at 2nd at 3rd rows for all wake splitter length.

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**Fig. 6. Local distribution of pressure coefficient around tubes for various wake splitter length at Re = 15950**

**Fig. 7. Local distribution of pressure coefficient around tubes in the (a) 1st row, (b) 2nd row, (c) 3rd row and (d) 4th row for Re = 15950**
Fig. 7 compares the present experimental result to that of Seri et al. [8], at $Re = 15950$, so as to see the effects of integral wake splitter towards the local pressure coefficient around the tubes. The effect of the wake splitter can hardly be seen for the 1st row. However, for the 2nd row, tube bank with integral wake splitter exhibits higher minimum pressure. It can be clearly seen that better pressure recovery can be achieved with splitter plate of $L/D = 0.5$ and $L/D = 1$. At the 3rd row, the splitter plate of $L/D = 2$ gives lesser pressure loss compared to the others. All plate lengths studied are observed to be able to reduce pressure loss at the 4th row.

Conclusions

The effect of attaching integral wake splitter plate, with length of 0.5, 1, 1.5 and 2 times the tube diameter, to tube bank in a cross-flow of air at Reynolds number of 15950 has been investigated. It is observed that having integral wake splitter in an attempt to reduce pressure loss as compared to plain tube bank becomes more pronounced downstream. At the 4th row, all splitter plate length is able to reduce pressure loss. It can be concluded that by attaching longitudinal plate at the rear stagnation point of a tube bank improves the performance of a cross-flow heat exchanger by reducing the required pumping power.

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