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Experimental and Numerical Investigations of Forced Convection in Tube-Type Heat Exchanger

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Abstract:- Experimental and numerical studies of forced convectionheat transfer in tube-type heat exchanger consisting four columns of five cylindrical tubes arranged so that every second column is displaced (i.estaggered configuration) were carried out. Experiments were conductedtodeterminethe effects of flow pattern on heat transfer and pressure dropwithin the heat exchanger and the heat transfer dependence on position. In the analytical approach, the dimensionless representationsof the rates of forced convection (i.eNusselt number) and pressure loss(i.e drag coefficient) were obtained. The numerical simulation is carried out using **FEMLAB 3.0** and the results compared favourably with the experimental. The flow visualization featuressuch as boundary layer developments between tubes, formation of vortices, local variations of the velocity and temperature distribution within the heat transfer device were revealed by numerical solution. The resultsshowed that the average Nusselt number increases with increasing Reynolds number and the heated element position in the bank. The drag coefficient decrease with increasing Reynolds numbers.

Keywords:- Tube-type heat exchangers, staggered tube bank, forced convection.

I. INTRODUCTION

The process of forced convection heat transfer to or fromtube bankwas the subject of many theoretical and experimental studies because of their relevance in many engineering applications. This process is significant in the design of heat transfer process devices suchas boiler for steam generation and cooling coil of air conditioning system.

The increasing interest in developing compact, and high efficient heat exchanger motivated researchers to study heat transfer from tube bankof circular cross section (Keys and London, 1998).

The studied tube-type heat exchanger is astaggered arrangement of four columns of five parallel cylinders. The configuration is determined by tube diameter and longitudinal and transverse pitches which are distances between tube centres. In this heat transfer device, fluid flow perpendicular to the tube bank thus simulating a typical cross flow heat exchanger, used in many industrial applications such as boilers, automotive, air conditioner, etc.

The fluid flow conditions within the bank are dominated by turbulence because most heat exchangers operate at high Reynolds numbers (Re) and inducedvortex sheddingwhich enhanced the heat transfer process.The turbulence intensity and its generation are governed by the bank geometry and Re.It was observed that with shorter transverse pitches, the velocity fluctuations become more intensive. The turbulence level of the main flow can influence fluid flow only over the first and second rows (Mehrabian, 2007). A tube bank acts as a turbulent grid and establishes a particular level of turbulence.The heat transfer conditions stabilize, such that little change occurs in the convection coefficient for tube beyond the fifth row tube (Yoo et al, 2007).

For optimal design of heat transfer process device andthe determination of its operational performance parameters, the drag, and heat transfer associated with fluid flow over the tube surfaces have to be known.Because a sudden changes in these quantities can lead to hysteresisand poor device functionality (Yukio et al, 2010).

Although reasonable number of researchers had conducted experiments and numerical analyses on fluid flow and heat transfer at the tube bank, but different correlation equations have been proposed to predict the heat transfer or the Nusselt number. The results obtained depend on the geometric configuration, number of tube rows,and the Reynolds number. For example,(Žukauskas,1987) obtained acorrelation given as

$$Nu = C\,\mathrm{Re}^{m}\,\mathrm{Pr}^{n}\left(\frac{\mathrm{Pr}}{Pw}\right)^{0.25} \qquad 1$$

wherePr_w and Pr represent the Prandtl numbers evaluated at the wall temperature and the bulk mean temperature, respectively.Re denotes the Reynolds number evaluated at the bulk mean temperature, and it is based on the average velocity through the least cross section formed by the tube array. The constants C, m, and n vary depending on the Reynolds number and tube bundle geometry and it can be found in many heat transfer textbooks.