**ABSTRACT**

Heat exchangers are devices in which heat is transferred from one fluid to another at different temperatures with wide applications in many field of engineering such as power generation, chemical processing, electronics cooling, automotive, refrigeration and air-conditioning. They are classified typically according to type operation, construction and flow arrangement into shell-and-tube, double-pipe, compact, cross-flow, etc. The heat transfer from bank of tubes depends on geometric arrangement, Reynolds number and the position of tube in the bank. However, the determination of the number of tube rows required to enhance heat transfer has been one of the major challenge in exchanger design. The aim of this study was to investigate the heat transfer and fluid flow characteristics associated with a staggered and in-line tube banks in cross-flow using experimental and numerical methods.

The cross-flow heat exchanger (Plint & Partner, Ltd, Workingham, England) was used for the experimentation. During this process, a complete set of test were taken with the heated element in each of the four ranks of tube for ten different throttle openings in the range of 10-100% to determined the Nusselt number and pressure drop across the bank.

Based on the experimental data, numerical simulation was carried out using FEMLAB 3.0. This was done by modeling the working sections of the cross-flow heat exchanger. Both the experimental and numerical results were compared.

The experimental results show that the heat transfer coefficient in terms of Nusselt number associate with tube was determined by its position in the bank of tubes. The heat transfer coefficient for the tube in the first row was approximately equal to that of a single tube in cross-flow whereas larger heat transfer coefficients were associated with tubes of the inner rows. The tubes of the first row act as turbulence grid, which increases the heat transfer coefficient for tubes in the subsequent downstream ranks. However, the heat transfer conditions stabilize such that little change occurs in the convection coefficient for tube beyond the forth rank. The pressure drop across the bank of tubes was observed to increase with increasing Reynolds number.

The numerical results reveal the important aspects of the local heat transfer and flow features of the tube banks. These include boundary layer developments between tubes, formation of vortices, local variations of the velocity and temperature within the banks. The boundary layers developments and vortices between tube surfaces were found to be dependent substantially on Reynolds number. The numerical heat transfer and pressure drop results deviated by approximately ± 30 % and ± 20 % respectively from experimental values in both tube banks. The present numerical investigations suggest a good estimate of the Nusselt number and pressure drop for the tube banks.

The heat transfer rate of staggered array was moderately higher than those of the in-line array. The maximum enhancement relative to the in-line array was 20% for the staggered array. However, a comparison of the two arrays reveals marked differences in terms of the pressure drop. It was seen that the pressure drop of the staggered array was 35.2% higher than the in-line.

It can be infer from this study that the maximum number of tube rows required to obtain high heat transfer may not be more than four or five. This will facilitate the design of a compact heat exchanger. Additional tube rows would result to infinitesimal increase in heat transfer, large and bulky exchanger and high cost of design. The pumping power which is a function of the pressure drop was dependent on the tube banks arrangement.