ABSTRACT

Perforated plate heat exchangers (PPHEs) are made of alternately arranged high thermal conductivity (copper or aluminum) perforated plates and low thermal conductivity insulating spacers. The plates and spacers are bonded together to form a single unit. Although, since 1950, there have been significant developments on this type of heat exchanger, there are still some scopes for further improvements in the areas of thermal design, heat transfer and fluid friction correlations, and manufacturing of PPHEs. Some studies carried out in these directions are presented in this thesis.

Existing numerical models for prediction of thermal performance of a PPHE are in general limited by two major assumptions: effect of boundary wall that separates the fluids from the ambient is ignored and heat conduction in the perforated region of the plates is one dimensional. Because of the first assumption, axial conduction loss through the boundary wall is ignored. The second assumption makes the models unsuitable for complex geometries such as “finger” or inter-wound spiral geometry. Since the plates are very thin and made of high thermal conductivity material two dimensional heat conduction analysis in lateral direction is sufficient for the plates. In the walls (both inner and boundary walls) we need to consider heat exchange between the walls and plates as well as heat flow in axial direction. These two requirements make the problem a three-dimensional one globally. In this thesis a Fluent based three dimensional numerical model has been presented.

Heat transfer and flow friction characteristics of perforated plates depend on many controlling parameters. Most of the correlations in literature do not include all the controlling variables. Besides, separate correlations need be developed for inline and shifted holes arrangements. Another Fluent based numerical model has been developed for heat transfer and flow friction studies on perforated plates. Using the model a large number of data is generated under varying parametric conditions. The data is used not only for understanding the behavior of the controlling parameters but also for developing generalized correlations for heat transfer and flow friction.

Fabrication of PPHEs needs perfection in diffusion bonding. Copper (Cu) and stainless steel (SS) being the most commonly used materials in PPHEs, some sample

studies on diffusion bonding between Cu and SS have been conducted. In this study, effects of various parameters such as nickel interlayer thickness, diffusion bonding temperature and duration of bonding etc. on the bond quality and joint strength have been observed. From the study, operating conditions for obtaining good bonding are determined. In the other part of the study, a stepwise procedure for making PPHEs by diffusion bonding has been established. Several heat exchangers have been fabricated and pressure tested for leak tightness.

A test setup has been developed for testing fabricated prototype heat exchangers at cryogenic temperatures. Experimentally observed data are compared with the model predicted data. Frictional pressure drop studies on the heat exchangers have been conducted by using a separate table top experimental setup. Friction factor data obtained through the experiments have been compared with the data from the correlations developed in the thesis.

Key words: Perforated plate heat exchanger, 3D modeling, heat transfer and flow friction characteristics, diffusion bonding, fabrication and testing of PPHEs