Abstract

A matrix heat exchanger (MHE), invented by McMahon, Bowen and Bleyle Jr. in 1949, consists of a set of highly conducting (copper or aluminium) perforated plates or wire screens, stacked alternately with an equal number of insulating spacers (stainless steel or plastics). The stack of plates and spacers is bonded together, using a suitable joining technique, to form a monolithic matrix with leak free passages for the fluids exchanging heat between one another. The unique construction of the matrix heat exchanger satisfies the diverse requirements of high effectiveness, high compactness, low axial conduction and uniform flow distribution in one unit.

While early investigators considered an MHE to be a continuous heat exchanger with the perforated plates serving as efficient fins, Sarangi and Barclay, in 1984, showed that the conventional analysis is inadequate to predict the performance of a high-N_{tu} heat exchanger with a discrete structure and a finite number of lateral heat transfer paths. During the last one decade much work has been done, both experimental and analytical, towards improved understanding of the performance of a matrix heat exchanger. This thesis is another step in that direction. A numerical model of the MHE with circular cross section has been developed. This model takes into account the discrete nature of the MHE, the radial resistance of the plates and axial conduction through the separating wall.

Heat transfer and flow friction characteristics of perforated plates are the most important factors in matrix heat exchanger design. They are functions of the plate geometry, plate thickness, porosity, and of perforation size, shape and arrangement. There is no satisfactory technique for predicting the heat transfer coefficients on matrix heat exchanger surfaces as a function of geometrical and process parameters. Therefore, it is necessary to experimentally determine heat transfer coefficients in the exchanger core under realistic operating conditions. The single-blow transient test technique provides a useful method for this purpose. A single-blow test apparatus has been used to measure heat transfer coefficients on small stacks of plate-spacer pairs. Results of the single-blow tests have been studied using an analytical model developed for the purpose.

The second major objective of this thesis is the development of all-metal matrix heat exchangers for low power cryogenic applications. Several methods, both mechanical and chemical, have been used for fabrication of copper perforated plates and stainless steel spacers. Stacks of plate-spacer pairs have been joined using diffusion bonding and vacuum brazing techniques to build a few prototype heat exchangers. A vacuum brazing furnace has been built in house for this purpose. The design and construction details of the furnace have been presented in the thesis.

Prototype heat exchangers, constructed using Institute and outside facilities, have been studied for heat transfer and pressure drop performance using a test apparatus built in the laboratory. The results have been compared with those of the numerical model.

Key Words: Cryogenics, Heat transfer, Heat exchanger, Matrix heat exchanger, Perforated plate, Heat exchanger performance, Single-blow test, Photochemical milling, Diffusion bonding, Vacuum brazing, Vacuum Furnace