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A numerical investigation of fluid flow maldistribution in inlet header configuration of plate fin heat exchanger

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Abstract

The common assumption made for the design of heat exchangers is that the fluid flow in the header and core part is uniform. It is found that the flow maldistribution is very significant in the direction normal to the flow direction in inlet header of the plate fin heat exchanger. In the present work numerical analysis of a plate fin heat exchanger accounting for the effect of fluid flow maldistribution in inlet header configuration of the heat exchanger is investigated. Various inlet configuration has been studied for various Reynolds Number. A modified header configuration with double baffle plate having two arrangements are proposed and simulated. The two dimensional parameters are used to evaluate the flow non-uniformity in header, gross flow maldistribution parameter (S_g), velocity ratio (θ). A validation of numerical work is done by comparing results of numerical analysis for conventional header with the experimental results from the literature. A series of velocity vectors and streamline graphs at different cross-section. The numerical results indicate that the flow maldistribution is serious in conventional header, while in the improved configuration less maldistribution occurs. The flow maldistribution parameter (S_g) and velocity ratio (θ) is less in improved configuration as compared with conventional header. The improved header can effectively enhance the efficiency of plate fin heat exchanger and uniformity of flow distribution.

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Keywords: flow maldistribution, plate fin heat exchanger, velocity ratio, inet header.

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1. Introduction

Plate-fin heat exchangers are employed in a wide variety of energy conversion applications such as power plants, petrochemical plants, radiators of transport vehicles to name a few and they exchange heat energy among two-fluids with different supply temperatures. A large extent of energy transfer takes place in these types of heat exchangers which are used in different applications. The heat exchangers used in these applications consume significant portion of energy, so improvement in the efficiency of plate and fin heat exchangers will save significant amount of energy. A major advantage of the plate fin heat exchanger over a conventional heat exchanger is that the fluids are exposed to a much larger surface area because the fluids spread out over the plates. In the design of the plate fin heat exchanger, it is generally assumed that the fluid flow distribution is uniformly distributed among all the parallel fin passages through the heat exchanger core. But in actual practices, it is impossible to distribute the fluid flow uniformly because of flow maldistribution. Flow maldistribution is a non-uniform distribution of mass flow rate in a heat exchanger core. Flow maldistribution depends on several factors such as heat exchanger's geometrical configuration (i.e. mechanical design, channel and header geometry and dimensions, manufacturing tolerances or imperfections), operating conditions (flow velocity changes along the headers, fluid viscosity, and multiphase flow). Flow maldistribution is a very important factor and it affects the performance of heat exchanger to large extent [1-2]. Jian Wen and Yanzhong Li [3] analysed the fluid flow maldistribution for the conventional header used in industry. According to him, a baffle with small holes of three different kinds of diameters was recommended to be installed in the header to control the flow maldistribution in the heat exchanger. The numerical result obtained effectively improved the performance of the heat exchanger. Zhang and Li Yanzhong [4] proposed a two modified headers with a two stage distributing structure to reduce the flow non-uniformity. They proved that the fluid flow distribution in plate-fin heat exchangers was more uniform if the ratios of outlet and inlet equivalent diameters for both headers are equal. Ranganayakulu and K. N. Seetharamu [5] studied a cross flow plate-fin compact heat exchanger, accounting for the combined effects of two-dimensional longitudinal heat conduction through the exchanger wall and non-uniform inlet fluid flow and temperature distribution was being carried out by using a finite element method. Jiao et al. [6] experimentally investigated the header configuration on flow maldistribution in plate fin heat exchanger. Their study suggests that the performance of flow distribution in plate fin heat exchanger has effectively improved by optimum design of the header configuration. Zhang and Yanzhong Li [7] studied analytically two stage flow distribution in header with inlet equivalent diameters in plate fin heat exchanger. It was verified that the fluid flow distribution in plate-fin heat exchangers was more uniform if the ratios of outlet and inlet equivalent diameters for both headers were equal. L. Sheik Ismail et al.[8] performed CFD analyses for three different types of heat exchanger with fin geometries in order to study the effect of flow maldistribution on the performance of heat exchanger. Modified header was proposed for improving the flow maldistribution for three heat exchangers. Three offset strip fins and 16 wavy fin used in for thermal simulation and j and f vs. Re design data are generated using CFD analysis only for turbulent flow region. M. A. Habib et al. [9] did CFD investigation on the flow maldistribution in air-cooled heat exchangers. The effects of the number of nozzles, nozzle location, nozzle geometry, nozzle diameter, and inlet flow velocity and the incorporation of a second header on the flow maldistribution inside the tubes of an air-cooled heat exchanger. The results indicate that incorporating a second header, a significant reduction in the flow maldistribution. In present work a modified header with different arrangement of baffle plate is proposed. The flow characteristics in the modified header are studied numerically.

Nomenclature

S_g	gross flow maldistribution parameter
θ	velocity ratio
N	channel number
V_{max}	maximum Velocity
V_{min}	minimum Velocity
V_i	local Passage velocity
V_{avg}	average Passage velocity