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ScienceDirect

Energy Procedia 85 (2016) 244 – 251

Energy Procedia

Sustainable Solutions for Energy and Environment, EENVIRO - YRC 2015, 18-20 November 2015, Bucharest, Romania

Plate heat exchangers - flow analysis through mini channels

Oana Giurgiu[a*], Angela Pleșa[a], Lavinia Socaciu[a]

[a]Technical University of Cluj Napoca, Muncii Bulevard, no.103-105, Postcod: 400641, Cluj-Napoca, România

Abstract

The study presents a Computational Fluid Dynamics (CFD) numerical study for two different models of mini channels, included in plate heat exchangers structure. The influence of geometric characteristics of the two studied plates on the intensification process of heat transfer was studied comparatively. For this purpose, it was examined the distribution of velocity, temperatures fields and distribution of convection coefficient along the active mini channel. The analyzed mini channels had the inclination angles of 30° respectively 60° and the Reynold flow number was 3500. Also a session of experimental measurements have been carried out on the two types of analyzed plates for the heat exchangers, confirming the results obtained through numerical simulation that the plate heat exchanger model using mini channels with inclination angle of β = 60° provides best heat transfer.

Peer-review under responsibility of the organizing committee EENVIRO 2015

Keywords: CFD Analysis; heat transfer; inclination angle; plate heat exchangers

1. Introduction

Heat exchangers were studied intensively in the last years [1-3] in order to increase the reliability and the performance of these devices. The efforts have focused in the increase of the heat flux in this type of devices. This direction led to the apparition of smaller channel dimensions. The small channels are classified by dimensions as follows [4]: less than 0.1 µm they are called nano-channels, from 0.1 µm to 10 µm they are known as transitional channels, from 10 µm to 200 µm as micro-channels, from 200 µm to 3 mm as mini channels, and > 3 mm are called conventional channels.

It is quite obvious that over the past few decades and with the refinement of mini and micro fabrication techniques, the use of mini channels has become promising for a variety of industrial applications, [5]. Mini

* Corresponding author.
E-mail address: oana.giurgiu@termo.utcluj.ro.

Peer-review under responsibility of the organizing committee EENVIRO 2015
doi:10.1016/j.egypro.2015.12.236

channels continue to play an integral part in thermal management (microchip cooling, micro reactors) and energy systems (fuel cells, micro combustion) applications [6].

Mini channel cooling is a popular solution to high heat rejection requirements of today's high power electronic devices. These systems are capable of discarding large heat loads while being relatively small in size.

The traditional heat transfer performance can be improved by the use of the mini channel structure. The mini channel geometry and size have significant impact on the performance of heat exchanger. Therefore, there will be great significance to explore the optimal structure of the mini channel through the mini channel heat exchanger design [7].

The aim of the present work was to examine the influence of the geometrical parameters of the heat exchanger plates on overall heat transfer coefficient and the heat flux. For this purpose were studied two types of heat exchangers with different geometry of the mini channel formed between two adjacent plates. The two models were analyzed numerically using fluent software and in laboratory using an existing experimental setup for the plate heat exchangers.

Nomenclature

L	length of the mini channel [mm]
l	width of the mini channel [mm]
H_0	height of the mini channel [mm]
p	waiving step [mm]
β	inclination angle [$^\circ$]
t_{11}, t_{12}	inlet respectively exit temperature of the hot agent [$^\circ$C]
t_{21}, t_{22}	inlet respectively exit temperature of the cold agent [$^\circ$C]
t_p	wall temperature [$^\circ$C]
$\dot{V}_1$	volume flow rate of hot agent [m^3/h]
$\dot{V}_2$	volume flow rate of cold agent [m^3/h]
η	thermal efficiency [%]
$\dot{Q}_1$	heat flux given by the hot agent [W]
$\dot{Q}_2$	heat flux accepted by the cold agent [W]
k	overall heat transfer coefficient [W/m^2K]
Re	Reynolds number

2. Numerical Analysis

The numerical study consists in fluid flow and thermal CFD numerical simulation of the heat transfer for two different types of mini channels. Having in mind the purpose of this study was to find the way in which the geometry of the plates is influencing the heat transfer between the plate and the fluid, and not the heat transfer from the hot agent to the cold one we made some assumption. It was considered that the cold fluid flows through the mini channel. Also the plate have a constant temperature, that of the hot fluid.

The Re number for the studied flows based on stream wise mean velocity and equivalent diameter of the flow cross section was 3500.

CFD analysis for each studied model was conducted on a small part of the heat transfer area of both mini channels. From previous studies, we concluded that the work fluid should be distributed evenly over the entire area studied. For this, were introduced two moderation areas (1 and 3 in Figure 1), one at the entrance and one at the exit of the plate, [8, 9].

In this way the phenomenon of pushing the fluid in the inlet and outlet areas is avoided. Based on this observation the geometric models under study were modeled, as shown in Figure 1.

2.1. Geometrical description

The mini channels were obtained by over layering corrugated plates, stacked together in order to form the flow channel. Plate dimensions are: length of the plate L = 40 mm, width l = 20 mm, waiving step p = 10 mm, height