RESEARCH ARTICLE OPEN ACCESS

Numerical Investigation of Single Phase Fluid Flow and Heat Transfer In Rectangular Micro Channel Using Nanofluids as A Cooling Liquid

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ABSTRACT
In this paper The Thermal behaviour of Micro channel heat sink were investigated used Al_2o_3-water base nanoluid. The model have been solved by ANSYS fluent 14.5 solver. The Dimension of each rectangular channel is 215**µ**m width, 821**µ**m depth and 4.48cm length. The Reynolds number range from 200 to 400 for power input 100 w. The high thermal conductivity of nanoparticles is shown to enhance the single phase heat transfer coefficient, especially for laminar flow. Higher heat transfer coefficient were achieved mostly in entrances region of micro channels. The enhancement was weaker in fully developed region.

I. INTRODUCTION

Micro-channel heat sinks constitute an innovative cooling technology for the removal of a large amount of heat from a small area. These micro-channels have characteristic dimensions ranging from 10 to 1000 **µ**m, and serve as flow passages for the cooling liquid. Micro-channel heat sinks combine the attributes of very high surface area to volume ratio, large convective heat transfer coefficient, small mass and volume, and small coolant inventory. Nanoparticles are also suitable for use in micro systems because they are many orders of magnitude smaller than the micro systems. Nanofluids is a new kind of heat transfer medium contaning a nanoparticle (1-100nm) which are uniformly and stable distributed in a base fluid. thermal conductivity of naofluids depend on many factor such as particle volume fraction ,particle material, particle size , particle shape, base fluid material and temperature.

II. EXPERIMENTAL WORK

Jaeseon lee and mudawar (oct 2006) have done experimental work to explore the microchannelcooling benefits of water-based nanofluids containing small concentrations of Al2O3. Fig. 1 shows the flow loop that was constructed to supply deionized water to the heat sink at the desired .pressure, temperature, and flow rate. The water was pumped from a liquid reservoir and circulated through the flow loop by a gear pump. Upon exiting the pump, a portion of the flow, controlled by a by-pass valve, entered the test loop containing the heat sink, while the remaining portion returned to the reservoir though a by-pass loop. The test loop water first passed through a heat exchanger where the water was cooled to the desired

inlettemperature. The water then passed through a filter to prevent any solid particles from blocking the heat sinkmicro-channels. After exiting the filter, the water was routed to one of two rota metersfor volume flow rate measurement. The water then entered the micro-channel heat sink test module where the electric power supplied to the heat sink was removed by the water. Leaving the test module, the water returned to the reservoir where it mixed with the bypassed flow.

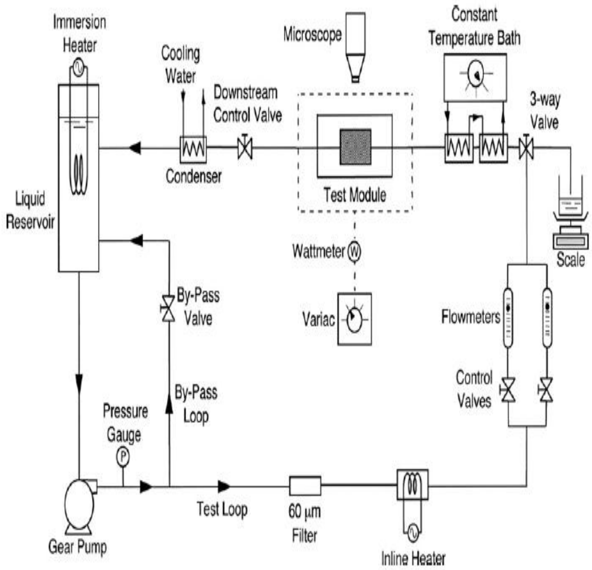

Figure 1

TEST MODULE

The test module consisted of a micro channel heat sink, housing, cover plate, and 12 cartridge heaters as illustrated in fig.2(a).A schematic of micro channel heat sink with key dimension is shown in fig.2(b). The Fluid is flowing through a rectangular micro channel embedded in a test module. There are 21 parallel rectangular micro-channels in the module. The dimension of each micro channel is 215 μ*m* width, 821 μ*m* depth and 4.48 cm length. The inlet velocity is *u (*m/s). The micro channel is made of oxygen free copper. The top surface of micro channel is subjected to adiabatic conditions. Operating conditions for the study are as follows: The operating range of Reynolds number based on the hydraulic diameter of the channel, Re =140 -941 *Dh* ,the power input range to the channel ,*Q* = 100 -300W, the inlet temperature of fluid to the channel, Tin= 30 0C, the range of inlet pressure, = 1.17 −1.36 bar, and the output pressur1.12 bar.

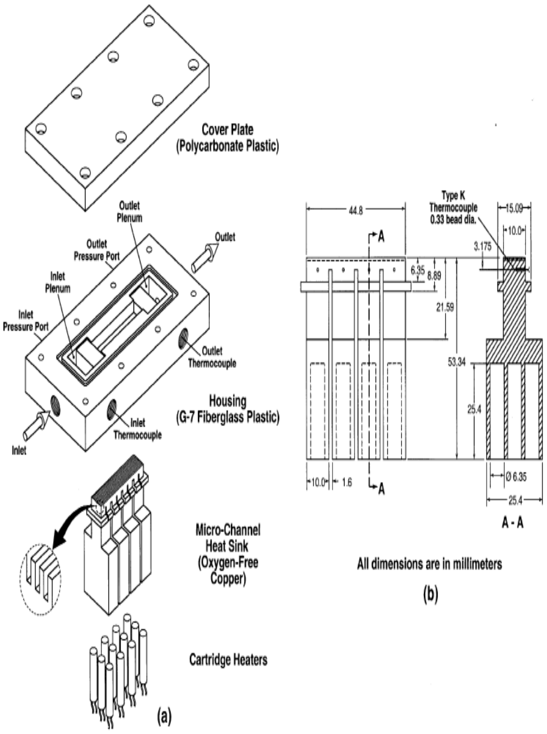

Figure 2(a) and 2(b)

EQUATION
Friction factor

=Pressure drop
The heat flux for unit cell is given equation

Where *N* is no. of micro channel.

$A_{bot=}$ × L   is the bottom area of unit cell micro channel
The heat flux to channel is given by

Single phase heat transfer coefficient along micro channel defined as

III. MODELING AND MASHING

In this section, the three dimensional fluid flow and heat transfer characteristics of the heat sink are analysed numerically. Fig. illustrate the computational domain for each rectangular micro channel. Dimension of each rectangular micro channel are given in table1. meshing of geometry is done in ANSYS work bench. Here we are selected automatic meshing method. so that software ANSYS choose best possible method according to its requirement for the refine of meshing is done obtained better result

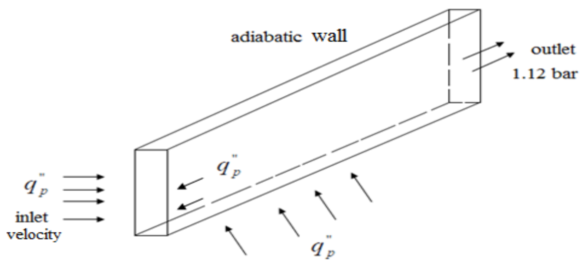

Figure 3

Table:1 dimension of each rectangular channel

W_W (μm)	W_{CH} (μm)	H_{CH} (μm)	L_{ch} (cm)
125	215	821	4.48

IV. BOUNDRY CONDITION

The boundary condition and initial condition related to the fluid dynamics and heat transfer in the CFD code were defined as follows. The boundary condition mainly include the inlet velocity, outlet pressure heated wall, insulated wall right wall and left wall.

V. RESULTS

Comparison of the present computed pressure drops and friction factors for water and its 1% nanoparticle concentration at different Re range from 200 to 400 with experimental results (Lee and Mudawar, 2007) are shown in Figure(4,5,6,7). These show that as Reynolds number increases pressure drop increases and friction factor decreases. Here one thing is noticeable that the pressure drop increases with increasing nanoparticle concentration at the same Reynolds number. So that 5% concentration of nanoparticle has a higher pressure drop and lower friction factor than water.

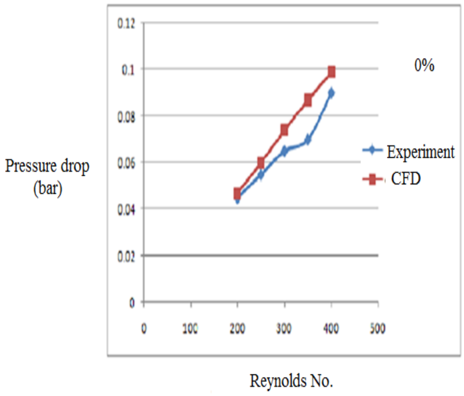

Figure 4 Variation of experimental andcomputational pressure drop for water

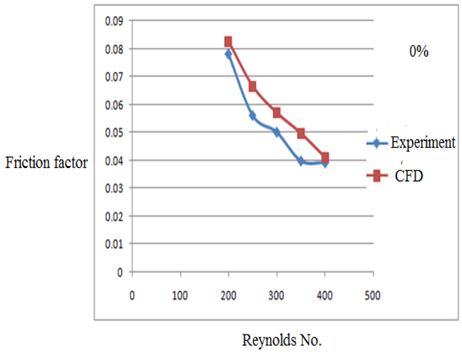

Figure 5 Variation of experimental andcomputational friction factor for water

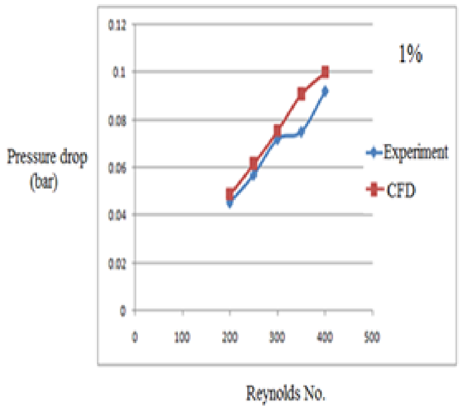

Figure 6 Variation of experimental andcomputational pressure drop for 1% alumina

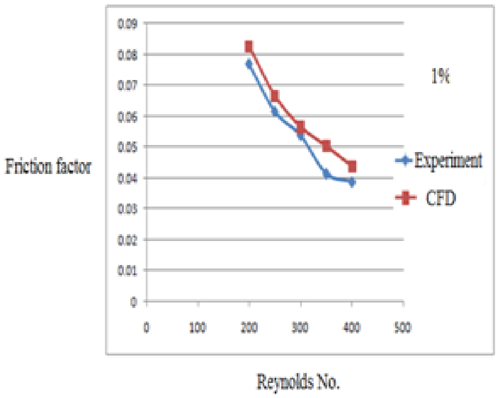

Figure 7 Variation of experimental and computational frictionfactor for 1% alumina

The variation of wall temperature along the micro channel for Re range from 200 to 400 and different concentration of nanoparticle as shown in figure.(8,9,10) Along the micro channel wall temperature is increase as fluid go from inlet to outlet for all Re range. As the concentration of nanoparticle increase the wall temperature is decrease. As the value of Re is increase from 200 to 400 the temperature at the outlet goes on decreasing.

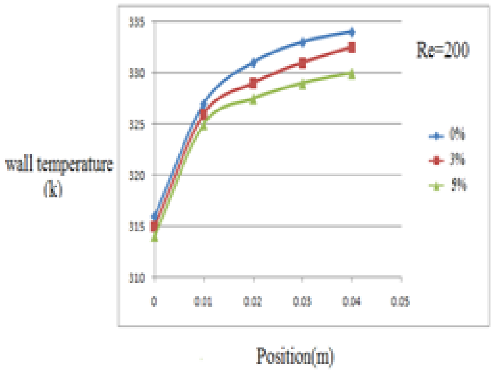

Figure 8 Variation of computational wall temperature for water, 3% and 5% alumina at Re=200

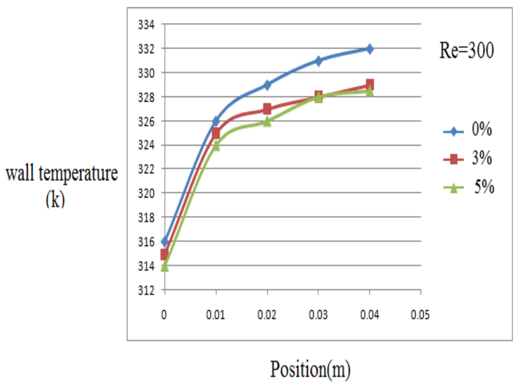

Figure 9 Variation of computational walltemperature for water, 3% and 5% alumina at Re=300

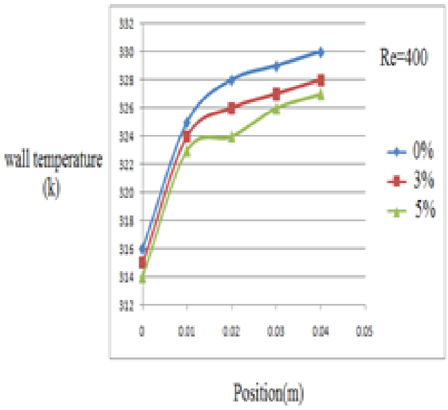

Figure 10 Variation of computational walltemperature for water, 3% and 5% alumina at Re=400

Along the length of rectangular micro channel The heat transfer coefficient decrease as fluid go from inlet to outlet for all Reynolds no. range from 200 to 400 are shown in table and also in figure.(11,12,13) Higher values of heat transfer coefficient are obtained at entry region of micro channel where as lower values are obtained at the exit region for all nanofluids. Higher value of heat transfer coefficient are obtained by increasing the Reynolds number. Heat transfer coefficient are also increase by increasing the nanoparticles concentration. so that The value of heat transfer coefficient of 5% nanoparticles concentration is higher than water.

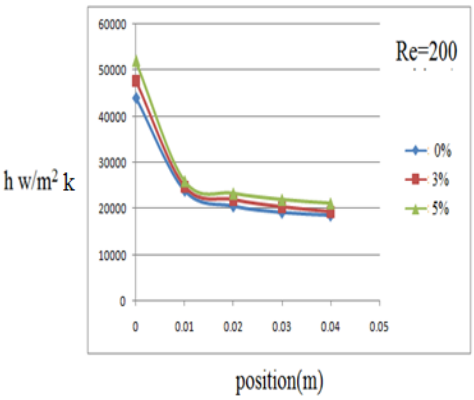

Figure 11 Variation of computational heat transfer coefficient for water, 3% and 5% alumina at Re=200

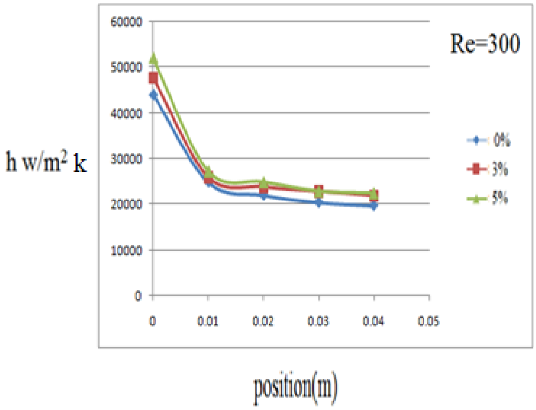

Figure 12 Variation of computational heat transfer coefficient for water, 3% and 5% alumina at Re=300

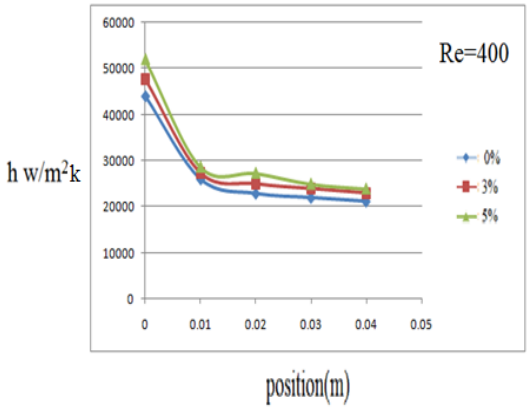

Figure 13 Variation of computational heat transfer coefficient for water, 3% and 5% alumina at Re=400

VI. CONCLUSION

The high thermal conductivity of nanoparticles relative to common pure fluids enhances the single-phase heat transfer coefficient for fully-developed laminar flow. Increasing nanoparticles concentration increases single- phase pressure drop compared to pure fluids at the same Reynolds number.Increasing nanoparticle concentration decreasing wall temperature compared to pure fluids at the same Reynolds number. Higher single-phase heat transfer coefficients are achieved in the entrance region of micro-channels with increased nanoparticle concentration.

NOMENCLATURE

f_{sp}= friction factor
D_h= hydraulic diameter(**μ**m)
L=Length of channel(cm)
$\boldsymbol{\rho}_f$= density of fluid(kg/m^3)
u=velocity of fluid(m/s)
q_{eff}= heat flux to unit cell(w/m^2.k)
N= Number of channel

A_{bot}= area of bottom wall(**µ**m)
W_{cell}= width of cell(**µ**m)
$W_{ch=}$width of the channel(**µ**m)
H_{ch}= height of channel(**µ**m)

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