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Heat transfer improvement of water/single-wall carbon nanotubes (SWCNT) nanofluid in a novel design of a truncated double-layered microchannel heat sink

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ABSTRACT

In the present study, laminar flow and heat transfer of nanofluid water/single-wall carbon nanotubes have been investigated in a novel design of double layered microchannel heat sink (MCHS). Present investigation has studied the dimensionless values of truncated lengths (λ) of 0, 0.4, 0.8 and 1. Studied Reynolds numbers were 500, 1000 and 2000. The effect of volume fraction of nanoparticles in the Newtonian suspension of water based nanofluid was studied for values of 0, 0.04 and 0.08. The results showed that the thermal resistance and ratio of maximum and minimum temperature difference for bottom wall of microchannel as well as the ratio of thermal resistance decrease by increasing the nanoparticles volume fraction and decrement of λ. The Performance evaluation criteria (PEC) factor on the bottom of channel increases in all ratios of λ by augmenting volume fraction of nanoparticles.

1. Introduction

From 1960s, downsizing was an important tendency in science and technology. Micro-Electro-Mechanical Systems (MEMS) generate notable heat during their operations, while custom coolants do not have sufficient cooling ability for thermal removal of the high-tech industries. Furthermore, by adding solid micro-sized particles to these coolants, they cannot be used in applicable cooling systems. Because they are too enormous size for flowing in the narrow channels and demanded cooling of MEMS systems. Since the nanoparticles can flow in microchannels without sedimentation, they can be considered as proper cooling fluids. They can improve cooling systems of MEMS in high heat flux conditions. Nanofluids can be used for improvement of thermal management systems in engineering applications. Nowadays, many industries need heat transfer optimizations. For instance, transportation industry has a critical demand for improvement of cooling fluids operation in transportation facilities. Nanofluids can provide the possibility of efficient heat transfer in engines, pumps, radiators and other small components. Lighter transport services can traverse more distance by less amount of fuel. Efficient transport services decrease the expenses due to lower energy consumption. Also, low fuel consumption will lead to less demand of fuel and will reduce the environmental pollution. Therefore, nanofluids can have vital roles in transportation systems.

In 1981, the first microchannel heat sink (MCHS) presented with silicon surface and parallel micro scale channels. In two recent decades, due to the capacity of transferring high heat flux from a small surface, microchannel heat sinks have been investigated. In recent decades, noticeable progresses for producing micro instruments in the electronics industry have been achieved [1]. Nowadays, the considerable progress of micro-building techniques has made the microchannels to be able to have various practicable functions on several areas. Because of importance of heat transfer issue in microchannels, numerous investigations about heat transfer issue in microchannels and other geometries have been studied by researchers [2–5]. Akbari et al. [6] numerically studied the effects of ribs on laminar flow and heat transfer

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Nomenclature

A	bottom area of the DL-MCHS (m^2)
A_c	cross-sectional area of channel (m^2)
c_p	specific heat (J/kg K)
D_h	hydraulic diameter (m)
f	friction factor
H_c	channel height (m)
K	thermal conductivity of the coolant (W/m K)
L	truncation length of the top channel (m)
L_x	width of the DL-MCHS (m)
L_y	height of the DL-MCHS (m)
L_z	length of the DL-MCHS (m)
P	pressure (Pa)
PEC	performance evaluation criteria
q''	heat flux on the bottom wall (W/m^2)
R	overall thermal resistance of the DL-MCHS (K/W)
T	temperature (K)
$T_{b,max}$	maximum temperature observed on the bottom wall (K)
$T_{b,min}$	minimum temperature observed on the bottom wall (K)
T_{max}	maximum temperature observed in the heat sink (K)
T_{min}	minimum temperature observed in the heat sink (K)
u, v, w	velocity components in x-, y-, z-directions (m/s)
W_c	channel width (m)
W_r	vertical rib width (m)
x, y, z	coordinates (m)

Greek symbols

β	channel-to-pitch width ratio
Δ	variation
δ_b	thickness of bottom wall (m)
δ_L	thickness of top wall (m)
δ_1, δ_2	thickness of intermediate wall (m)
λ	dimensionless truncation length
λ_R	thermal resistance ratio of new design-to-original design
$\lambda_{\Delta T}$	temperature difference ratio on the bottom wall of new design-to-original design
μ	coolant viscosity (Pa s)
θ	dimensionless temperature
ρ	density (kg/m^3)

Subscripts

ave	Average
f	fluid phase
in	Inlet
nf	Nanofluid
out	Outlet
s	solid phase
1	bottom channel
2	top channel

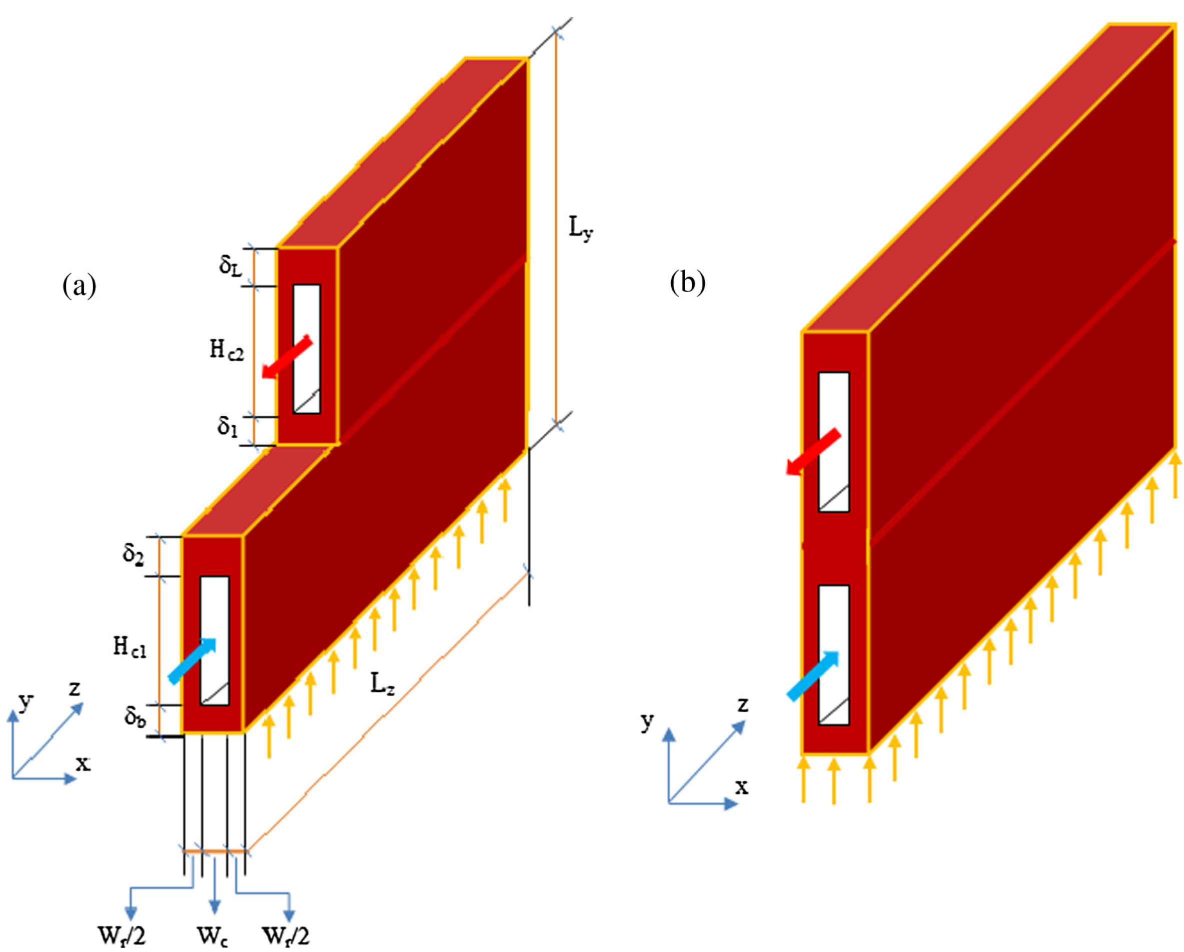

Fig. 1. Schematics of studied problem.