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Review

Single-phase heat transfer enhancement in micro/minichannels using nanofluids: Theory and applications

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HIGHLIGHTS

- Review recent experimental and numerical studies on heat transfer in micro/minichannels and nanofluids.
- Display the new applications of using nanofluids and micro/minichannels to enhance thermal performance.
- Explain the factors affecting the thermal conductivity enhancement ratio of nanofluids.
- The challenges of using the mini/microchannels and nanofluids.

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ABSTRACT

New cooling techniques are being explored for the dissipation of heat fluxes. Many recent studies on heat transfer in micro/minichannels (M/MCs) with nanofluids have focused on combining the advantages of both, for the purpose of obtaining higher single-phase enhancement of heat transfer. Developing of many applications such as cooling electronic device, solar cell, and automotive technology is highly demanded now a day to obtain high efficiency and reduce the operating cost. This review article summarizes recent studies, with a focus on two main topics: The first part contains the main concepts such as scaling effects of M/MCs, physical properties and convective heat transfer. The second part displays the main recent applications of M/MCs with nanofluids with the challenges to be widely used. The purpose of this article to provide exhaustive and comprehensive review of updated works published in this new area, with general conclusions.

Contents

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Nomenclature

c_p	specific heat (J kg^{-1} K^{-1})
k	thermal conductivity (W m^{-1} K^{-1})
k_{pe}	modified thermal conductivity
$k_{nanolayer}$	nanolayer thermal conductivity
n	the shape factor
z	Boltzmann constant
Re	Reynolds number
f_e	function of volume ratio and particle vol.%
U, u	velocity (m s^{-1})

Greek letters

ρ	density (kg m^{-3})
φ	volume fraction
μ	dynamic viscosity (N s m^{-2})
β	layer thickness/particle radius
α	the weight factor

Subscripts

nf	nanofluids
bf	base fluid
p	nanoparticles
eff	effective
statice	statice
brownian	Brownian motion
T	thermophoresis

Abbreviations

M/MC	Micro/minichannel
MC	Microchannel
MiC	Minichannel
HTC	heat transfer coefficient
EDL	Electrical Double Layer
MEPCM	microencapsulated phase change material
CNT	carbon nanotube
PV/T	photovoltaic/thermal
PV	photovoltaic
EG	ethylene glycol

1. Introduction

Novel technologies have allowed several applications such as electronic devices to become more compact and very highly efficient, although this requires high heat flux removal. Decreasing the hydraulic diameter and increasing the surface area per unit flow volume are very effective ways of removing excess heat. This enhances heat transfer coefficient (HTC) in a microstructure, since the surface area is increased. Thus, smaller channels are more desirable for heat removal [1].

Several studies have further analyzed the effect of nanofluids on heat transfer rate and thermal performance of many recent applications. Several parameters comprising particle physical properties (material, size and shape), temperature dependent, additives, base fluid, and acidity affect heat transfer enhancement have been investigated extensively. However, increase in pumping power, the stability of fluid settling and possibility of clogging, as well as damaging the flow loop parts by corrosion and high cost caused by these ultra-fine particles have constrained the practical applicability of the technology.

Recent studies have attempted to combine the advantages of nanofluid and microchannels to obtain a higher heat transfer coefficient. Many excellent review articles have taken into consideration the M/MCs design and applications [2–10], the nanofluids properties and enhancement of heat transfer coefficient [11–17], the applications of nanofluids [18–22] and some of them combine the convective heat transfer of M/MC with nanofluids [23,24]. However, the theory of nanofluids and M/MCs has not effectively incorporated into real applications, thus more research effort is needed towards this direction. This paper comprehensively reviews current researches within the scope of M/MCs and nanofluids, specifically theories, parameters effects, challenges, and future works. This review will be relevant to real applications of heat transfer and energy collection.